DOCUMENT OF THE INTER-AMERICAN DEVELOPMENT BANK

BELIZE

CLIMATE VULNERABILITY REDUCTION PROGRAM (BL-L1028)

ECONOMIC ANALYSIS ANNEX

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Acronyms used in the document

ECLAC	Economic Commission for Latin America and the Caribbean
ESCI	Emerging and Sustainable Cities Initiative
GDP	Gross Domestic Product
GOB	Government of Belize
ICZM	Integrated Coastal Zone Management
IDB	Inter-American Development Bank
IHC	*Instituto de Hidráulica Ambiental de la Universidad de Cantabria* – IHCantabria
Interim Report	Feasibility and Preliminary Designs of Small Scale, Nature Based Coastal Protection Works in Caye Caulker and Goff Caye, Belize CSD/RND - Climate Vulnerability Reduction Loan Program (BL-L1028) Preliminary Design Phase, Interim Report. Prepared for the Inter-American Development Bank
IRR	Internal Return Rate
NEMO	National Emergency Management Organization
NPV	Net Present Value
Program	Climate Vulnerability Reduction Loan Program
ROI	Return of Investment
SLR	Sea Level Rise
WTTC	World Travel & Tourism Council

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A. Introduction

Belize is highly vulnerable to hurricanes and tropical storms due to its location in the Caribbean basin and its topography. On August 3-4, 2016, the country was hit by Hurricane Earl. With maximum wind speeds of 75 mph, the storm made landfall in Belize City as a Category 1 hurricane and then moved westward across the country. Most areas affected received 8-12 inches of rain over a period of 5 to 8 hours. The wind and rain caused extensive damage to housing and infrastructure in Belize City, as well as to the country's two main industries: agriculture and tourism.

Belize's National Emergency Management Organization (NEMO) was responsible for the immediate emergency response—in coordination with government authorities—including the conduct of preliminary damage and needs assessments for the most urgent supplies and recovery work. However, to assess and plan for medium to long term reconstruction efforts, there is a need for a nationally coordinated effort—in collaboration with relevant international agencies—to design a comprehensive strategy for climate and disaster risk resilient and sustainable reconstruction. Belize's capacity to carry out this work is limited.

In this context, the Government of Belize (GOB) requested support from the IDB and the Economic Commission for Latin America and the Caribbean (ECLAC) to assess the impact of hurricane Earl in its national territory. Additionally, the GOB requested recommendations for a reconstruction plan to improve future risk-resilient investments in the country. The ECLAC report estimated the monetary effects (damage, loss and additional costs) and macroeconomic impact of the hurricane.

Subsequently, based on the effects of the disaster, and in keeping with the GOB's resources and priorities, the GOB stated its interest in the Inter-American Development Bank (IDB)'s Climate Vulnerability Reduction Loan Program (henceforth, the Program or BL-L1028) with the overall aim of: (i) Reducing the main climate-related vulnerabilities of the productive sector which includes the tourism and agriculture segments of the economy, especially in the areas affected by hurricane Earl—as identified in ECLAC's damage assessment report; and (ii) installing flood control measures in Belize City that build from (a) the Bank-financed Flood Mitigation Infrastructure Program[1] and (b) risk assessment studies recently completed under the Emerging and Sustainable Cities Initiative for Belize City[2].

The IDB and the GOB agreed with a strategy to reduce disaster and climate-related vulnerabilities in the productive sector and to improve flood control in Belize City that comprises two main components:

[1] According with IDB (2011), the objective of the Loan 2566/OC-BL to Belize Flood Mitigation Infrastructure Program for Belize City *"... is to support the Government of Belize in the rehabilitation, improvement and protection of the Belize City's drainage and urban road networks aiming at reducing Belize City's vulnerability to flooding events while increasing long term capacity to provide adequate maintenance to streets, drains and Canals*".

[2] According with IDB (2015), "*The main objective of this Technical Cooperation (TC) is to improve the sustainability and urban environment of Belize City, through the implementation of the methodology of the Emerging and Sustainable Cities Initiative (ESCI) regular program*".

Component 1. Improving Climate and Disaster Risk Reduction Governance. This includes: (i) implementation of climate-resilient flood-control measures to protect public and private infrastructure in tourist areas of Orange St. of Belize City, such as canals, levees and sluices; and (ii) shoreline stabilization measures on public land in coastal tourist areas, among them small-scale structural and non-structural coastal protection works, including enhancement of natural infrastructure for the purposes of risk reduction.

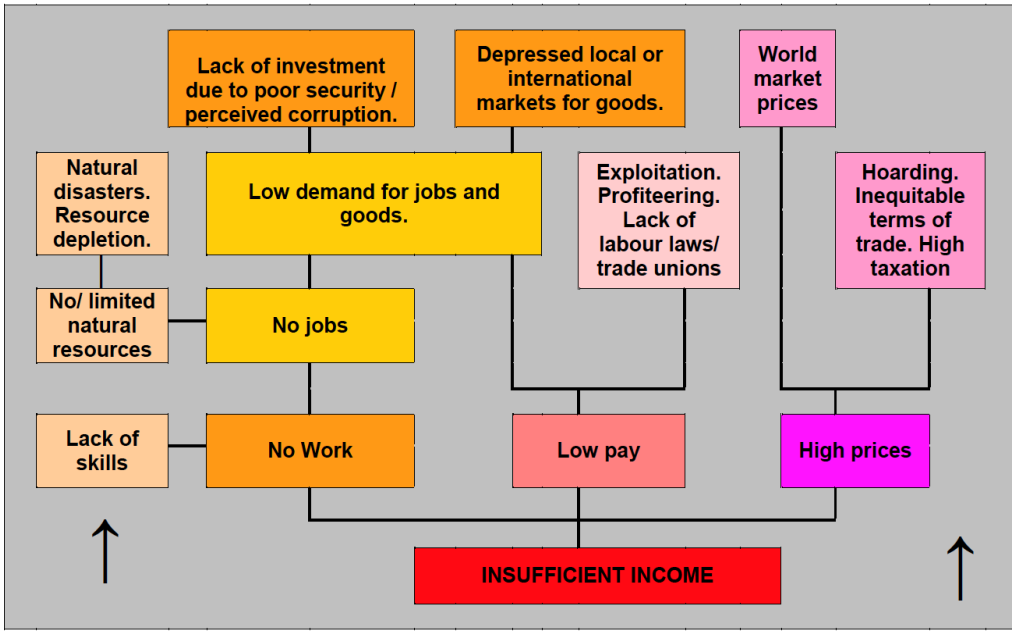
Component 2. Governance for disaster risk management and climate change adaptation. This includes: (i) risk-identification improvements by making risk information accessible to decision-makers, technicians, the private sector and the general population, and capacity increases to produce and analyze risk information; (ii) risk-reduction improvements by supporting the design of tourism and land use building codes, including nature-based solutions; and (iii) disaster-risk financial-protection improvements by supporting the design of a climate risk financing strategy, for the tourism and agriculture sectors.

With regard to interventions in the tourist sector, it is important to mention that the National Development Framework for Belize 2010 – 2030, Horizon 2030 (year of publication) recognizes that tourism and agriculture are Belize's main economic drivers, and consequently it includes as a proposed goal for 2030 to "*ensure a sustainable and profitable tourism sector*" (page 26). In the same sense, "*Belize 2016-2019, Growth and Sustainable Development Strategy*" (2016) establishes that tourism, agriculture, and agro-processing are critical economic drivers.

The mentioned documents are aligned with the National Sustainable Tourism Master Plan (2011), highlighting that "*Caye Caulker continues to offer a low-key charm along with attractive beaches and a cultural offering*" (page 8).

It is important to mention that according to the World Travel & Tourism Council (WTTC) (2017) tourism contributed to 14.1% of the country's gross domestic product (GDP) in 2016. Its total contribution (taking into account the activities of the restaurant and leisure industries directly supported by tourists) was 38.1% of GDP. In addition, in 2016 tourism accounted for 12.6% of Belize's total employment.

In addition, BL-L1028´s components are aligned with efforts to mitigate the impact of natural disasters [sic]. Disasters have been identified by the GoB and the Caribbean Development Bank (2009) as one of the economic causes of poverty, as shown in the figure below:



Economic Causes of Poverty.

Source: GoB and the Caribbean Development Bank (2009)

According to the Government of Belize and the Caribbean Development Bank (2009, page 214) "*In summary, the major change that has occurred since 2002 is that poverty has increased and, simultaneously, become more evenly distributed across the country. Patterns of poverty in terms of groups more or less likely to be affected have changed little. The causes remain much the same: a difficult macro-economic situation caused by the recession, and natural disasters, along with social factors related to family and household relationships which are both destructive in themselves and can create a cycle of inter-generational poverty*".

This ex-ante economic evaluation was carried out to assess the economic viability of BL-L1028. In particular, through a cost-benefit analysis, we assess the viability of a flood-mitigation infrastructure (pumped flood reduction scheme) in the Orange St. area of Belize City and the viability of shore-stabilization measures in Caye Caulker (nature-based and hybrid coastal-protection interventions to enhance natural tourism) and Goff's Caye (soft coastal-protection strategies to build more climate-resilient tourism amenities), considering a social discount rate of 12%. The analysis estimates benefits with and without BL-L1028.

With regard to the interventions in the Orange St. area of Belize City, The Program will generate the following benefits: (i) avoided direct and indirect damages; (ii) avoided costs in terms of refugees and fatalities; (iii) increase in property values. However, the Program will generate operational and maintenance costs.

With regard to the interventions in Caye Caulker, the Program will generate the following benefits: (i) avoided flood losses, (ii) avoided loss of urban area due to coastal retreat; (iii) avoided reduction in tourist expenditures due to land erosion; (iv) fewer displaced people and fatalities; (v) increase in property values. However, the Program will generate operational and maintenance costs.

Regarding interventions in Goff's Caye, the Program will generate the following benefits: (i) avoided loss of island surface; (ii) increase in annual tourist expenses. However, the Program will generate operational and maintenance costs.

Overall, the Net Present Value (NPV) of BL-L1028 is greater than US$5,605,267. The Internal Rate of Return (IRR) is robust at 17.0%. For proposed investments in the Orange St area of Belize City, the NPV of BL-L1028 is greater than US$3,385,106. The IRR is robust at 17.7%. For the proposed investments in Caye Caulker, the NPV of BL-L1028 is greater than US$1,560,299. The IRR is robust at 33.2%. For proposed investments in Goff's Caye, the NPV of BL-L1028 is greater than US$659,862 The IRR is robust at 15.5%. Sensitivity analyses were also conducted and, under the most conservative assumptions, the NPV of benefits for the Orange St. area of Belize City is US$177,515 with an IRR of 12.3%, the NPV of benefits for Caye Caulker is US$711,623 with an IRR of 24,9%, the NPV of benefits for Goff's Caye is US$55,780 with an IRR of 12.4%, reflecting that BL-L1028 is a viable investment from an economic standpoint.

It is important to mention that benefit estimates for Component 1 are conservative, given that the analysis does not include social benefits, such as salaries generated for employing local labor from the intervention area, or health benefits, which result from reduced pollution in the area.

Regarding Component 2, given the difficulty to estimate benefits related to improved institutional disaster risk management capacity, only its costs are considered in the analysis. This is a conservative approach given that such benefits are clearly non-zero. Considering Component 2, NPV of BL-L1028 is greater than US$5,177,178. The IRR is 16.3%. Incorporating the cost of Component 2 into the estimation of net benefits does not affect the program's economic viability.

The document is organized in three sections. Section A lays out the motivation for considering flood control investments in Belize. Section B presents the cost-benefit analysis for interventions in Orange St of Belize City, Caye Caulker and Goff´s Caye. For each intervention, the problematics without project and the proposed solution are discussed, as well as the theoretical foundations and assumptions employed to estimate benefits and assess net returns, which are subjected to a sensitivity analyses. Finally, Section C offers conclusions.

B. Ex ante economic analysis for proposed interventions

Ex-ante economic analysis for interventions in the Orange St. area of Belize City

Introduction

Problem

According to IDB (2016, page 1 of executive summary) "*Belize City is exposed to three major types of flood hazards, namely: (1) pluvial flooding (intense rainfall) related to very high intensity, short duration rainfall events over Belize City; (2) fluvial flooding (river overtopping) related to prolonged rainfall across the Belize River catchment; and (3) coastal flooding (storm surge) related to tropical storms and hurricane winds as well as low pressure arriving at the coast*", in a context of increases in the mean sea level caused by climate change and built-up in areas prone to pluvial and coastal flooding.

Proposed solution

After the devastating effects of Hurricane Earl, and in line with Article 7 of the Paris Agreement, by which signatory countries "*establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2*", the GOB stated its interest in BL-L1028, which would provide climate-resilient flood-control measures in the Orange St. area of Belize City to protect public and private infrastructures, building from (a) the Bank-financed Flood Mitigation Infrastructure Program[3] and (b) risk assessment studies recently completed under the Emerging and Sustainable Cities Initiative for Belize City[4].

IHCantabria (IHC) was hired to carry out pre-feasibility studies for prioritization and design of flood control works in Belize City, taking into account the city's elevation, which may be affected by expected sea level rise (SLR) due to climate change. According to IHC (2017, page 3), "*It was decided to prioritize a pumping station and associated works in downtown Belize as a pilot project, with the idea of testing at a critical zone, Downtown Belize, the new polder-like strategy, including the possibility to expand it to other areas in the future, in case that the experience is positive. The location chosen for the pumping station drainage area has been Belize between Collet and East Canal (approx. from Orange St. to Dean St.) because it is one of the most affected areas in the city (>1 m water depths every 5-10 years)*"[5].

[3] According to IDB (2011), the objective of the Loan 2566/OC-BL to Belize Flood Mitigation Infrastructure Program for Belize City *"... is to support the Government of Belize in the rehabilitation, improvement and protection of the Belize City's drainage and urban road networks aiming at reducing Belize City's vulnerability to flooding events while increasing long term capacity to provide adequate maintenance to streets, drains and Canals*".

[4] According with IDB (2015, page 1), "*The main objective of this Technical Cooperation (TC) is to improve the sustainability and urban environment of Belize City, through the implementation of the methodology of the Emerging and Sustainable Cities Initiative (ESCI) regular program*".

[5] According with IHC (2017, page 18), "*The project area is defined as all the urban sectors that drain towards the East or Collet canals, including the blocks situated outside the perimeter defined by both canals*".

According to IHC (2017, page 23), "*The proposed system's backbone is a pumping station that will drain the rainfall accumulated in each rainfall spell within the project area towards the sea. It will connect the low areas through a network of canals, being the main ones the Collet Canal and East Canal. The pumping facility, located on the coastline at the southern outlet of Collet Canal, including helicoidal (screw) pumps to raise the water to the sea. For the system to be effective, it will also be necessary to isolate it from the surrounding water (Haulover Creek, West Canal and the sea, up to a certain level) so that no water enters from the outside*". The proposed system is depicted in the figure below:

Pumped Flood Reduction System.

Source: IHC (2017)

According to IHC (2017), the abovementioned scheme will be able to mitigate completely risk for floods with a return period of 10 years, as well as to reduce the impact of 20-year

floods. The Program will not be able to mitigate 50-, 100, and 500-year events, mainly associated with hurricanes.

The proposed interventions account for US$ 6,853,460, to be executed in a 2-year period, and with an expected yearly maintenance and operative cost around US$ 34,267.

Benefits, assumptions, net returns and sensitivity analysis

Benefits

The Program will generate the following benefits:

- **Avoided direct and indirect damages**. Direct damages correspond to damages to buildings, its contents and its utilities services network. This category encompasses all damages to the physical elements of the buildings. Indirect damages includes, among others, traffic disruption, business operation interruption, school closings, people prevented from working and medical care costs, and are equivalent to 100% of direct damages[6].

- **Avoided cost in terms of refugees and fatalities.** Reducing the impact from floods will reduce the required resources for refugees and also fatalities. Information from M&K (2016) supplemented by studies from ESCI (2016) and expert criteria are used to estimate the cost of refugees and fatalities.

- **Increase of property values**. Several studies have attributed the current housing conditions in downtown Belize City (low construction standards, badly maintained, with poor access and without basic services or street lighting) to neighborhood exposure to floods (Ministry of Housing and Urban Development 2013, Central Building Authority 2012). Floods have been identified as a critical hindering factor for future development. If flood risk is reduced in downtown Belize City, given its stock of historical and heritage sites as well as proximity to the sea and connectivity to the rest of the city and the cayes, urban renovation will be catalyzed, having a direct observable impact on tourist revitalization, property values and the development of infrastructure with a typology adapted to floods (Downtown Rejuvenation Project 2013). This urban renovation will be further enhanced by the expected reduction in the pollution of the Collet and East Canals, which will foster the emergence of recreational spaces with high urban value (IDB and Belize City Council 2016).

  Eves and Wilkinson (2014) suggest that floods (and other disasters) have an impact on the property market, particularly on buyer, renter and vendor behavior. By

[6] Wisner (2003) and other authors provide evidence that for events of low return periods the relation between direct damages and indirect damage is approximately 1..

comparing sales listings and median house prices in flood-affected and flood-free suburbs after a disaster took place, the authors find that sales listings fell immediately after the flood in the affected areas, but there was no corresponding fall or increase in sales listings in the flood-free suburbs.

Certainly, as information about hazard event propagates and risk perception is updated, demand for properties which are at the greatest risk will fall leading not only to possible outmigration, but also price decrease. In fact, research on the effects of floods on property values show that hazardousness is a factor in housing value differentials. Bin and Polasky (2004) find that houses located within a floodplain have a 24% lower market value than equivalent houses located outside the floodplain. Furthermore, the price discount from locating within a floodplain is significantly larger after floods occur than before. Bin and Kruse (2006) indicate that on average property values are approximately 10% lower if located within a flood zone.

Daniel et al. (2009) also study whether floods have an impact on residential property values, finding that floods had negative effects on prices of the houses that were affected; specifically a decrease of about 9 per cent. Using hedonic property models in a difference-in-differences framework, Atreya and Ferreira (2015) show that the price discount for properties in inundated areas is 20-34% larger than in comparable properties out of floodplain.

Jin et al. (2010) investigate the effects of flood mitigation structures on home values in coastal areas and find that the average marginal increase in property values near the protective infrastructure is 10 percent. It is expected that to the extent that the flood mitigation measures implemented as a result of BL-L1028 reduce flood risk, price differentials between flood-prone and non-flood areas should be reduced.

In addition, the Program will generate operational and maintenance costs. The pumped flood reduction scheme would require operative and maintenance costs throughout the life cycle of the project (50 years). These costs were estimated based on the preliminary designs of the flood control works.

The impact of climate change is incorporated by assuming, based on the IHC (2017) feasibility study, a 10% increase in the magnitude of flood damages from year 26 onwards. This is derived from scaling up storm probability, which is assumed to be equally distributed to all storm damage outcomes.

Assumptions

The assumptions used in the economic analysis were elaborated with support from IHC. Expert criteria were complemented with information from the literature and other countries, which was adapted to Belize using the process of benefit transfer (Rosenberger and Loomis 2004).

Variable	Assumption	Justification about the assumption
Building stock value	US$ 152,172,000	M&K (2016) generated a geo-referenced database of exposed assets in GIS format for Belize City. Exposed assets of the area that will be affected by the pumped flood reduction scheme were selected for the analysis.
Total surface	70 ha	
Number of buildings by category in the intervention area	Category B (middle quality building): 315 Category C (low quality building): 1,326	
Land to building value ratio[7]	1	Expert criteria after visits to the intervention area.
Cost of buildings	B: US$ 150,000 C: US$ 60,000	Buildings were classified according to its building quality. The cost of buildings was determined by estimating its reposition cost, using M&K (2016) and expert criteria after field visits to the intervention area.
Property value increase	15%	The property value increase is based on evidence found in the literature for similar interventions. A mid-range estimate is considered.
Damage function		IHC (2017) generated flood damage functions modifying CAPRA damages functions according with the quality buildings observed in Belize. Damages functions for different return periods were generated.
Indirect damages	100% of direct damages	Wisner (2003) and other authors provide evidence that for events of low return periods the relation between direct damages and indirect damage is approximately 1
Equivalent cost per resettled person	15	According with IHC(2017).
Equivalent cost per fatality	461,261	Miller (2000) estimated the statistical value for the world average life between US$ 630,000 and US$ 900,000 of 1995, with the point estimate being 650,000. By adjusting this estimate by inflation and considering the per capita income of Belize, the statistical value of a life for Belize ranges between US$ 447,068 and US$ 638,669, with the point estimate of US$ 461,261.
Effect of climate change from year 26 to year 50	10% increase in damages, both with and without BL-L1028	IHC (2017), using information from IPCC.
Discount rate	12%	As required by IDB.

[7] Relation between the size of the building and the land parcel on which it sits.

Summary of economic benefits

In the situation without Program, flooding damages will continue. In the situation with Program, 2-, 5- and 10-year flood damages will be avoided due to the pumped flood reduction scheme. In addition, urban improvements that will increase property values will take place.

Economic Return

The implementation of the interventions in the Orange St. area of Belize City will entail both increases in costs for implementation and maintenance and increases in benefits, which exceed such costs. Thus, the Program will generate a NPV of US$ 3,385,106, with an IRR of 17.7%.

The return of investment (ROI) is 1.5 which includes a 12% discount rate.

Summary of Results	
Total discounted cost	6,740,169
Tota disconted benefits	10,125,275
Net Present Value	3,385,106
Internal return rate (IRR)	17.7%

Source: IHC (2017)

The detailed cash flow is presented next:

Year	Disc. Cost	Disc. Benefits
0	3,426,730	0
1	3,059,580	0
2	27,318	1,058,419
3	24,391	948,624
4	21,777	850,206
5	19,444	761,988
6	17,361	682,914
7	15,501	612,037
8	13,840	548,508
9	12,357	491,567
10	11,033	440,530
11	9,851	394,787
12	8,796	353,790
13	7,853	317,045
14	7,012	284,113
15	6,261	254,598
16	5,590	228,146
17	4,991	204,440
18	4,456	183,195
19	3,979	164,155
20	3,552	147,092
21	3,172	131,801
22	2,832	118,099
23	2,529	105,819
24	2,258	94,815
25	2,016	84,955
26	1,800	76,118

27	1,607	67,963
28	1,435	60,681
29	1,281	54,180
30	1,144	48,375
31	1,021	43,192
32	912	38,564
33	814	34,432
34	727	30,743
35	649	27,449
36	579	24,508
37	517	21,882
38	462	19,538
39	412	17,444
40	368	15,575
41	329	13,907
42	294	12,417
43	262	11,086
44	234	9,898
45	209	8,838
46	187	7,891
47	167	7,045
48	149	6,291
49	133	5,617

Source: IHC (2017)

Sensitivity analysis

In this section, we conduct sensitivity analysis to the following assumption: a more modest increase in property values and a lower ratio of indirect to direct damages.

It is important to mention that variables related with displaced people and fatalities do not have a significant impact on net benefits, given their probability of occurrence. For this reason, they are not included in the sensitivity analysis.

	Base Scenario	**Property value increase (9%)**	**Indirect damages/direct damages (0.3)**
Net Present Value	3,385,106	177,515	2,668,697
Internal return rate (IRR)	17.7%	12.3%	16.5%

The detailed cash flows are presented below:

- Property value increase from 15% to 9%

As previously mentioned, urban improvements will increase property values. A conservative increase of 15% is used for the base scenario. Even if the price increase were more modest (9% is the lower-bound estimate found in our literature review), the program would remain economically viable.

Year	Disc. Cost	Disc. Benefits
0	3,426,730	0
1	3,059,580	0
2	27,318	723,122
3	24,391	648,109
4	21,777	580,869
5	19,444	520,597
6	17,361	466,573
7	15,501	418,149
8	13,840	374,746
9	12,357	335,843
10	11,033	300,975
11	9,851	269,723
12	8,796	241,712
13	7,853	216,608
14	7,012	194,108
15	6,261	173,944
16	5,590	155,872
17	4,991	139,675
18	4,456	125,160
19	3,979	112,152
20	3,552	100,495
21	3,172	90,048
22	2,832	80,686
23	2,529	72,297
24	2,258	64,779
25	2,016	58,042
26	1,800	52,005

27	1,607	46,433
28	1,435	41,458
29	1,281	37,016
30	1,144	33,050
31	1,021	29,509
32	912	26,347
33	814	23,524
34	727	21,004
35	649	18,753
36	579	16,744
37	517	14,950
38	462	13,348
39	412	11,918
40	368	10,641
41	329	9,501
42	294	8,483
43	262	7,574
44	234	6,763
45	209	6,038
46	187	5,391
47	167	4,814
48	149	4,298
49	133	3,837

Source: IHC (2017)

- Ratio of indirect damages to direct damages decrease from 1 to 0.3

Wisner (2003) established that for events of low return period the relation between direct damages and indirect damage is close to 1. Recent empirical evidence based on a similar intervention in Bolivia (IDB's BO-L1188 project) shows that this ratio is approximately 0.7.

An even more conservative scenario is considered, where this ratio equals 0.3. Even under this conservative scenario, the program remains economically viable.

Year	Disc. Cost	Disc. Benefits
0	3,426,730	0
1	3,059,580	0
2	27,318	983,531
3	24,391	881,504
4	21,777	790,050
5	19,444	708,074
6	17,361	634,594
7	15,501	568,732
8	13,840	509,699
9	12,357	456,786
10	11,033	409,361
11	9,851	366,854
12	8,796	328,757
13	7,853	294,612
14	7,012	264,010
15	6,261	236,584
16	5,590	212,004
17	4,991	189,975
18	4,456	170,233
19	3,979	152,540
20	3,552	136,685
21	3,172	122,476
22	2,832	109,743
23	2,529	98,332
24	2,258	88,107
25	2,016	78,944
26	1,800	70,733

27	1,607	63,154
28	1,435	56,388
29	1,281	50,346
30	1,144	44,952
31	1,021	40,136
32	912	35,835
33	814	31,996
34	727	28,568
35	649	25,507
36	579	22,774
37	517	20,334
38	462	18,155
39	412	16,210
40	368	14,473
41	329	12,923
42	294	11,538
43	262	10,302
44	234	9,198
45	209	8,213
46	187	7,333
47	167	6,547
48	149	5,846
49	133	5,219

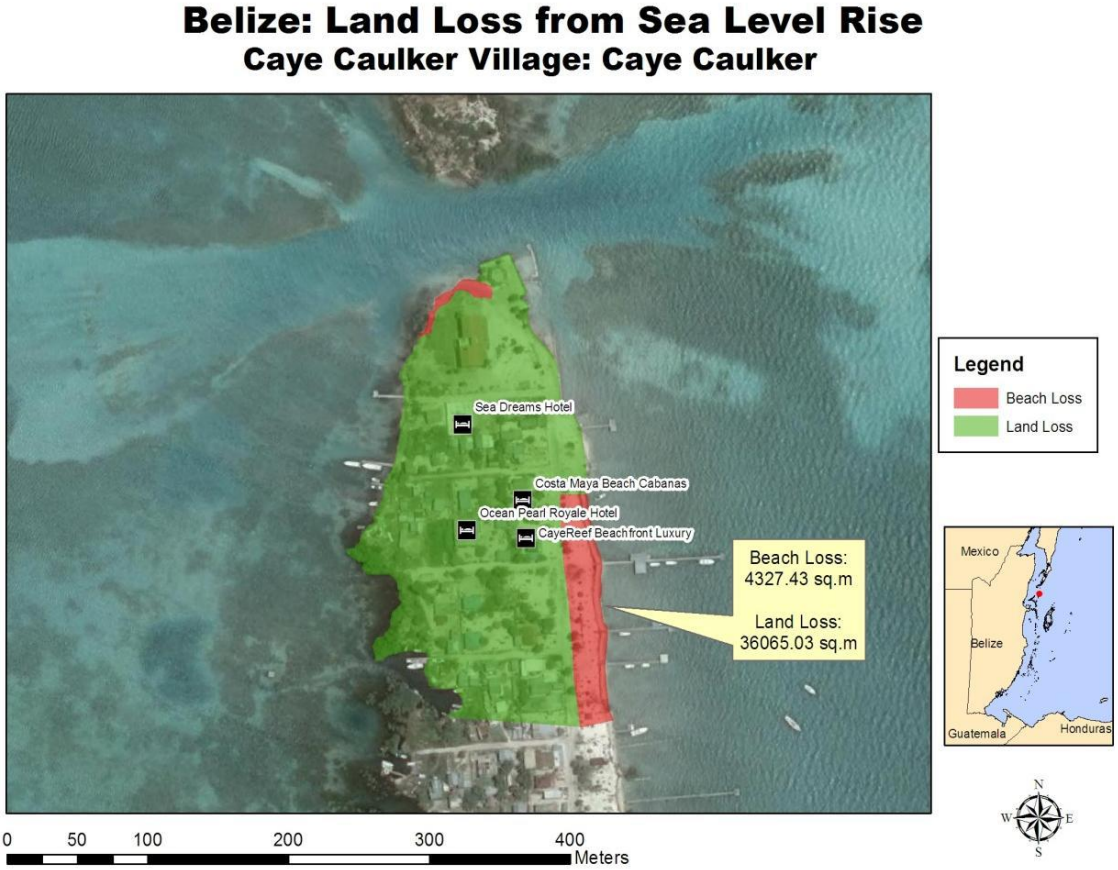
Source: IHC (2017)

2. Ex-ante economic analysis for interventions in Caye Caulker

Introduction

Problem

According to the Interim Report (2017), the low elevation of Caye Caulker makes it vulnerable to natural and climate-change-induced SLR. With regard to beach area losses due to SLR, CARIBSAVE (2012) estimated that (i) in a 0.5m SLR scenario, Caye Caulker would lose 17% of its beach area; (ii) in a 1m SLR scenario, Caye Caulker would lose 96% of its beach area; and (iii) in a t 2m SLR scenario, Caye Caulker would completely lose its beach area, as shown in the figure below. It is important to mention that previous interventions made by the GOB for climate change adaptation have not proven sustainable.



Source: CARIBSAVE (2012)

According to the Interim Report (2017, page 18), the "*Feasibility and Preliminary Designs of Small Scale, Nature Based Coastal Protection Works in Caye Caulker and Goff's Caye, Belize*" mentions that in Caye Caulker the government has "*undertaken beach nourishment in Palapa Gardens 3 times in the last 5 years […]Regardless, the sand was placed and spread to extend the beach past the mangroves. It has been reported that the sand has been eroding slowly, and it is suspected that the longshore transport at Palapa Gardens is from South to North. The placed sand is likely being eroded and transported to the North, and eventually being lost to the Split system*". This suggests that Caye Caulker requires another alternative for shoreline stabilization.

Proposed solution

Component 1 of BL-L1028 includes shoreline stabilization measures on public land in coastal tourist areas, including small-scale structural and non-structural coastal protection works, such as enhancement of natural infrastructure for the purposes of risk reduction.

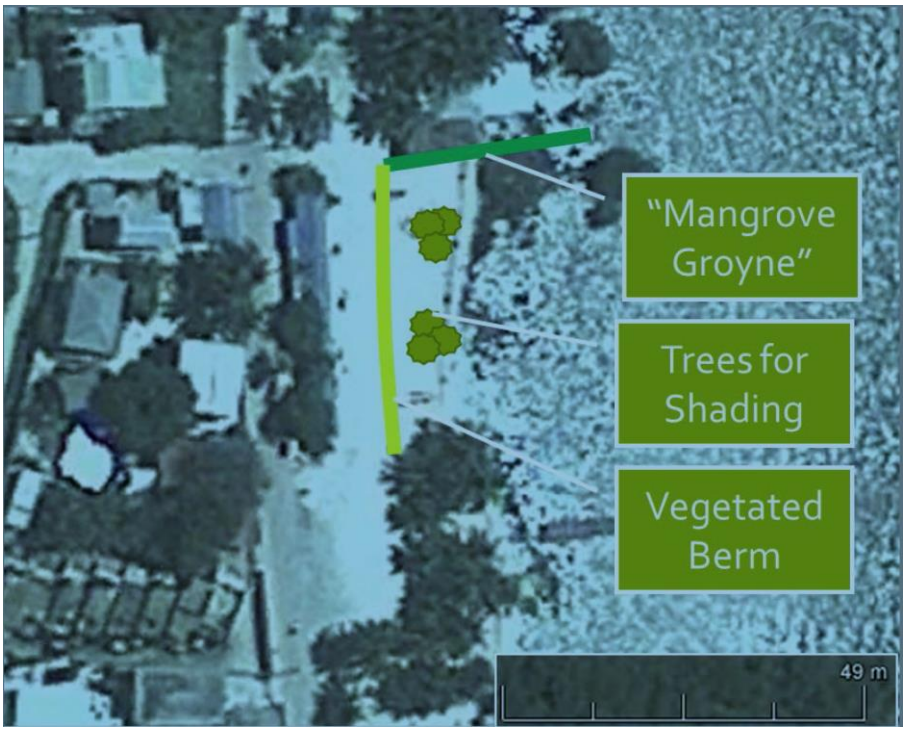
The selection of the intervention site considered the relative vulnerability of tourist areas to the potential impact by climate change. According to a report by Caribsave (2014, page 5), *"… the highest potential impact to the tourism areas will be to the popular destination of Ambergris Caye, Central Region, Caye Caulker, Turneffe Atoll, Lighthouse Reef Atoll and South Central Region. Considering this, there is a great need to prioritize these areas for adaptation interventions*".

As a result, and given the importance of Caye Caulker as a tourist destination for Belize, the Interim Report (2017, page 17) highlighted the importance of:

• "*[Reducing] the erosion of the placed beach fill and consequently [increasing] the longevity between beach nourishment required at Palapa Gardens,*
• *[Reducing] vulnerability of the infrastructure behind the Palapa Gardens area, and*
• *[Enhancing] the tourism product through beautification of the beach area*".

To attain these goals, BL-L1028 will have the following components. These are shown in the figure below:

COMPONENT	OBJECTIVE
Caye Caulker Coastal Protection Interventions	**To establish nature-based and hybrid coastal-protection interventions, enhancing Caye Caulker's natural tourism products**
Installation of mangrove groin	To protect recently nourished Palapas Beach from erosion caused by longshore drift, which is amplified by the Split. To protect property along Palapas Beach from erosion.
Vegetated berm	To protect property along Palapas Beach from storm surge.
Planting of appropriate vegetation	To add further stability to beach.



Components of Intervention

Source: Interim Report of the "Feasibility and Preliminary Designs of Small Scale, Nature Based Coastal

The proposed interventions account for US$ 396,000, to be executed in one year, and with an expected yearly maintenance and operative cost around US$ 3,960.

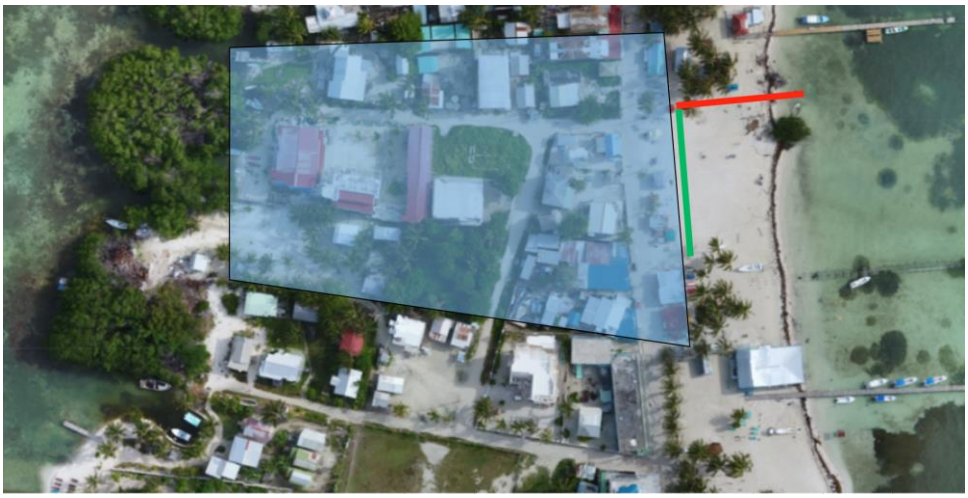
Benefits, assumptions, net returns and sensitivity analysis

Benefits

In the situation without Program, flooding damages will continue, and they will intensify as a result of SLR. In the situation with Program, 2-year flood damages will be avoided. 5-year flood damages are mitigated in the absence of climate change. For other return periods, damages are reduced.

The Program will generate the following benefits:

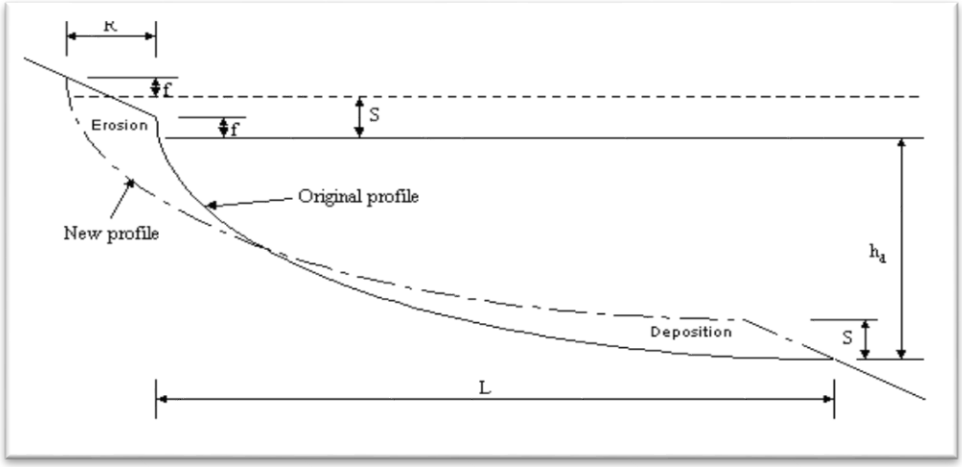
> **Avoided flood losses.** The proposed interventions will generate a protected area (shown in picture below), that will be less affected by coastal floods, in terms of avoiding direct and indirect damages. Direct damages correspond to damages to buildings, its contents and its utilities services network. This category encompasses all damages to the physical elements of the buildings. Direct damages are estimated using flood damage functions for each of the different quality building types of Caye Caulker, using modified CAPRA damage functions, considering various levels of SLR for the different return periods under analysis. Indirect damages are estimated by using a coefficient of 100% over direct damages (Wisner, 2003).



- **Avoided loss of urban area due to coastal retreat.** As a consequence of the Program, land erosion will reduced. Bruun's rule is used to assess loss of urban area due to erosion. This information is used to estimate annualized erosion losses[8].

- **Avoided reduction in tourist expenditures due to land erosion.** Land erosion is likely to cause a decline in tourism (and hence in tourism-related expenses) in Caye Caulker. Average tourist expenditures are estimated using the number of tourists in the protected area, daily expenses per tourist and the occupancy rate. In addition,

[8] Bruun's Rule is a two-dimensional model of shoreline response to rising sea level.
According to Otvos (1982) "…*the Bruun Rule applies to low coastal and adjacent nearshore zones, composed of unconsolidated sediments... Assuming an equilibrium profile as sea level rises, material eroded from the beach foreshore and backshore is deposited on the shoreface down to a limiting depth: there is a parallel shoreward beach profile displacement during the erosion of the upper beach zone; the material eroded equals the volume of material deposited on the nearshore bottom; the rise of the nearshore bottom level due to the deposition equals the sea level rise. This maintains a constant water depth in that area and elevates the nearshore profile proportionally to the rising sea level*". R = SL/(hd+f), Where S is the amount of sea level rise, L is the active length of the profile, hd is the closure depth, and f is the freeboard. R is typically of the order 50-100 times the magnitude of S.



"Shoreline retreat" (based on Brunn's rule) is estimated based on an analysis by CARIBSAVE (2012).

Even though there are not specific studies for Belize regarding the impact of quality of beaches on tourist expenditures, there are estimates from studies for the Caribbean region that may be used as proxies. In addition, there is evidence in the literature on the impact of beach quality on tourism.

With regard to the impact of quality of beaches over expenses made by tourists, Schuhmann, et al. (2017), demonstrates the feasibility of investing in ICZM initiatives oriented towards tourism development in Barbados. One of the findings is that *"…visitors will pay US$800 less per week for stays where beaches are very narrow and more than US$1,000 less for stays where reef quality is low*" (page 35).

In terms of the relationship between quality of beaches and tourism, Banerjee, et al. (2016) find that "*For all tourist respondents, a sandy beach was the most important characteristic informing their choice of beach to visit*" (page 21). This is in line with Coral et al. (2016), who argue that "*Continuous coastal degradation and beach reduction make them less attractive as tourist destinations*" (page 52).

- **Decrease in refugees and fatalities**. Reducing the impact from floods will reduce the required resources for refugees and also fatalities. Information from M&K (2016) supplemented by studies from ESCI (2016) and expert criteria are used to estimate the cost of refugees and fatalities.

- **Increase of property values**. According to the economic literature discussed in the previous section, flood risk mitigation will cause increases in property values. In addition, flood risk mitigation will generate a more protected and beautified beach, triggering investment and further increases in real estate prices.

On the other side, the Program will generate operational and maintenance costs. The establishment of a nature-based and hybrid coastal-protection interventions that also act to enhance the natural tourism products of Caye Caulker would require operative and maintenance cost throughout the life cycle of the project (20 years).

The impact of climate change is incorporated by assuming, based on the IHC (2017) feasibility study, a 10% increase in the magnitude of flood damages from year 26 onwards. This is derived from scaling up storm probability, which is assumed to be equally distributed to all storm damage outcomes, and SLR.

Assumptions

The assumptions used in the economic analysis were elaborated with support from IHC. Expert criteria were complemented with information from the literature and other countries, which was adapted to Belize using the process of benefit transfer (Rosenberger and Loomis 2004).

Variable	Assumption	Justification about the assumption
Total surface	1.25 has	Estimated from Google Earth.
Building stock value	US$ 2,160,000	The building stock value was determined by estimating the number of buildings in the area and their reposition cost, using M&K (2016) and expert criteria after field visits to the intervention area.
Land to build value ratio[9]	1	Expert criteria after visits to the intervention area.
Property value increase	15%	The property value increase is based on evidence found in the literature for similar interventions. A mid-range estimate is considered.
Number of buildings in the intervention area	36	Estimate from Google Earth and field visits to the intervention area.
Average tourist per building	4	Estimated by IHC (2017)
Increase in daily expense (US$)	10%	According to the Belize Tourism Board (2015), the average daily expenditure in US$ for Caye Caulker is US$ 116.99. Schuhmann, et al. (2017) find that tourist willingness to pay decreases when beaches are narrowed. This is in line with Banerjee et al. (2016), who evidence that a sandy beach is an important characteristic for choosing a beach. The analysis will consider that daily expense will increase by 10% as a result of the intervention.
Occupancy rate	50%	This figure corresponds to the hotel occupancy rate in Caye Caulker for 2015. It was taken from Belize Tourism Board. Belize, travel et Tourist Statistics, Digest 2015.
Shoreline retreat (based on Bruun's rule), equivalent to the relation between the maximum shoreline retreat (according to	14.6m	The value is estimated by IHC (2017), considering that retreat is equal to R = SL/(hd+f), Where S is the amount of sea level rise (0.3m), L is the active length of the profile (310.6m), hd is the closure Depth (5.4m), and f is the berm height (1m).

[9] Relation between the size of the building and the land parcel on which it sits.

sea level rise) and the protected width		
Damage function		IHC (2017) modified CAPRA flood damages functions according with the quality of buildings observed in Caye Caulker. Damage functions for different return periods were generated.
Average replacement cost	60,000	Replacement cost was estimated using M&K (2016) and expert criteria after visiting the intervention area.
Protected length (longshore measure)	100	Taken from preliminarily designs of interventions
Protected length (longshore measure)	125	
Indirect damages	100% of direct damages	Wisner (2003) and other authors provide evidence that for events of low return periods the relation between direct damages and indirect damage is approximately 1.
Equivalent cost per resettled person	15	According with IHC(2017).
Equivalent cost per fatality	461,261	Miller (2000) estimated the statistical value for the world average life between US$ 630,000 and US$ 900,000 of 1995, with the point estimate being 650,000. By adjusting this estimate by inflation and considering the per capita income of Belize, the statistical value of a life for Belize ranges between US$ 447,068 and US$ 638,669, with the point estimate of US$ 461,261.
Effect of climate change from year 26 to year 50	10% increase in damages, both with and without BL-L1028	IHC (2017), using information from IPCC.
Discount rate	12%	As required by IDB.

Economic Return

The implementation of the interventions in Caye Caulker will entail increases in both costs for implementation and maintenance and benefits, which exceed those costs. The Program will generate a NPV of US$ 1,560,299; with an IRR of 33.2%.

The ROI is 4.32, and includes a 12% discount rate.

Summary of Results	
Total discounted cost	469,325
Tota disconted benefits	2,029,624
Net Present Value	1,560,299
Internal return rate (IRR)	33.2%.

Source: IHC (2017)

The detailed cash flow is presented next:

Year	Disc. Cost	Disc. Benefits
0	396,000	0
1	3,536	0
2	3,157	96,129
3	2,819	99,984
4	2,517	101,908
5	2,247	102,273
6	2,006	101,390
7	1,791	99,521
8	1,599	96,890
9	1,428	93,679
10	1,275	90,045
11	1,138	86,114
12	1,016	81,991
13	908	77,763
14	810	73,501
15	723	69,258
16	646	65,082
17	577	61,005
18	515	57,054
19	460	53,250
20	411	49,606
21	37,020	46,132
22	327	42,832
23	292	39,711

24	261	36,766
25	233	33,996
26	208	31,398
27	186	28,034
28	166	25,031
29	148	22,349
30	132	19,954
31	118	17,816
32	105	15,907
33	94	14,203
34	84	12,681
35	75	11,323
36	67	10,109
37	60	9,026
38	53	8,059
39	48	7,196
40	43	6,425
41	3,838	5,736
42	34	5,122
43	30	4,573
44	27	4,083
45	24	3,646
46	22	3,255
47	19	2,906
48	17	2,595
49	15	2,317

Source: IHC (2017)

Sensitivity analysis

In this section, we conduct sensitivity analysis to the following assumptions: further decline in daily tourist expenses, and limited increase in property value.

It is important to mention that variables related with displaced people and fatalities do not have a significant impact on net benefits, given their probability of occurrence. For this reason, they are not included in the sensitivity analysis.

	Base Scenario	**Tourist daily expenses**	**Property value increase (9%)**
Net Present Value	1,560,299	711,623	1,521,895
Internal return rate (IRR)	33.2%	24.9%	32.5%

The detailed cash flows are presented below:

- Tourist daily expenses from US$ 129 to US$28.5

Banerjee (2016) estimates, for selected beaches in Barbados, the willingness to pay to maintain the beaches in their current condition. The study found that "*Tourists value the CIP interventions at Holetown and Rockley beach at BB$51 per visitor and BB$43 per visitor, respectively, while residents valued CIP interventions at Holetown Beach and Rockley Beach similarly at BB$57 per resident. Regression results show that beach width and a sandy beach are the most important beach characteristics to tourists, while residents have more complex motivations for valuing beach improvements*"[10] (page 32). We conduct a conservative exercise where the daily expense tourist value of CIP interventions was applied.

[10] 1BBD = 0.5 US$

Year	Disc. Cost	Disc. Benefits
0	396,000	0
1	3,536	0
2	3,157	77,326
3	2,819	74,800
4	2,517	71,928
5	2,247	68,813
6	2,006	65,539
7	1,791	62,177
8	1,599	58,783
9	1,428	55,403
10	1,275	52,072
11	1,138	48,819
12	1,016	45,665
13	908	42,627
14	810	39,716
15	723	36,939
16	646	34,301
17	577	31,804
18	515	29,449
19	460	27,233
20	411	25,154
21	37,020	23,208
22	327	21,390
23	292	19,695
24	261	18,118
25	233	16,653

26	208	15,294
27	186	13,655
28	166	12,192
29	148	10,886
30	132	9,719
31	118	8,678
32	105	7,748
33	94	6,918
34	84	6,177
35	75	5,515
36	67	4,924
37	60	4,397
38	53	3,925
39	48	3,505
40	43	3,129
41	3,838	2,794
42	34	2,495
43	30	2,227
44	27	1,989
45	24	1,776
46	22	1,585
47	19	1,416
48	17	1,264
49	15	1,128

Source: IHC (2017)

- Property value increase from 15% to 9%

As previously mentioned, urban improvements will increase property values. A conservative increase of 15% is used for the base scenario. Even if the price increase were more modest (9% is the lower-bound estimate found in our literature review), the program would remain economically viable.

Year	Disc. Cost	Disc. Benefits
0	396,000	0
1	3,536	0
2	3,157	91,997
3	2,819	96,294
4	2,517	98,614

5	2,247	99,331
6	2,006	98,763
7	1,791	97,176
8	1,599	94,796
9	1,428	91,810
10	1,275	88,376
11	1,138	84,623
12	1,016	80,660
13	908	76,575
14	810	72,440
15	723	68,311
16	646	64,236
17	577	60,250
18	515	56,380
19	460	52,648
20	411	49,069
21	37,020	45,652
22	327	42,404
23	292	39,328
24	261	36,424
25	233	33,691
26	208	31,126
27	186	27,791
28	166	24,813
29	148	22,155
30	132	19,781
31	118	17,662
32	105	15,769

33	94	14,080
34	84	12,571
35	75	11,224
36	67	10,022
37	60	8,948
38	53	7,989
39	48	7,133
40	43	6,369
41	3,838	5,687
42	34	5,077
43	30	4,533
44	27	4,048
45	24	3,614
46	22	3,227
47	19	2,881
48	17	2,572
49	15	2,297

Source: IHC (2017)

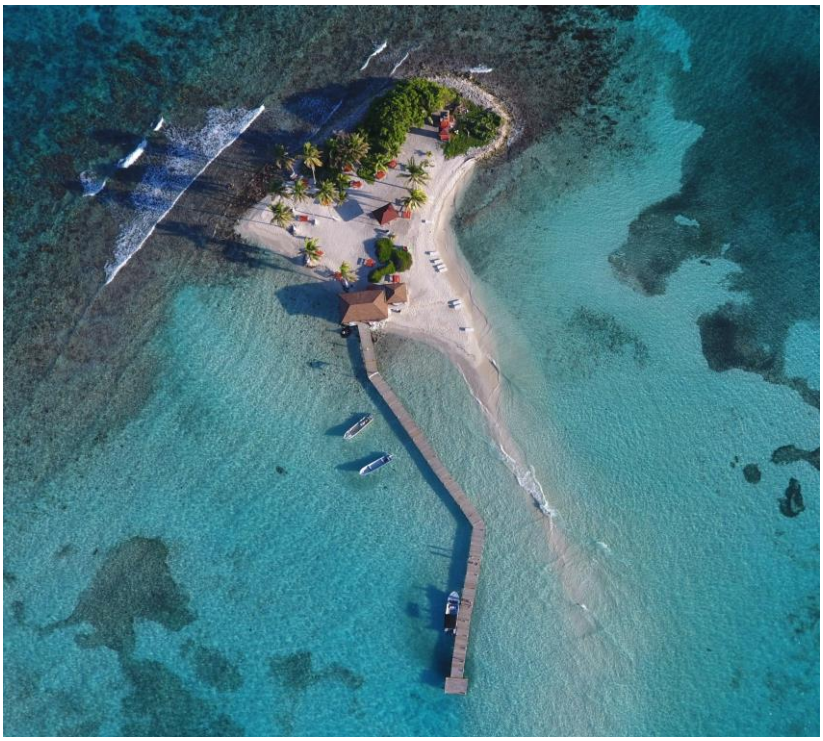
3. Ex-ante economic analysis for interventions in Goff's Caye

Introduction

Problem

According to the Interim Report (2017, page 9), *"…the case of Goff's Caye, easterly trade winds develop waves that erode sand from the nearshore waters and shoreline… With the main island only a few feet above sea level, the entire of Goff's Caye is considered to be extremely vulnerable to tropical storms. Reef degradation allows increased wave energy through the combined effects of a decrease in reef elevation above sea bed and a smoother reef structure that does less to dampen and dissipate wave energy*".

Proposed solution



Component 1 of BL-L1028 includes shoreline stabilization measures on public land in coastal tourism areas. Potential measures include small-scale structural and non-structural coastal protection works to enhance natural infrastructure for risk reduction. Goff's Caye was selected as part of BL-L1028's intervention sites given its contribution as a tourism engine in Belize[11]. As a result, the following components have been proposed:

COMPONENT	OBJECTIVE
Goff's Caye Coastal Protection Interventions	**To implement soft coastal protection strategies and build more climate-resilient tourism amenities in Goff's Caye**
Construction of a jetty	To replace the existing jetty that is unable to withstand extreme storm events. To maintain access to Goff's Caye.
Designation of mooring fields	To protect the ecosystem services of the reef surrounding Goff's Caye, which help buffer wave impacts and maintain biodiversity,

[11] According to "Belize Coastal Zone Management Plan" (2013, page 39) "*Integrated Major tourism activities in the coastal zone include diving and snorkeling with the most frequented sites being Hol Chan Marine Reserve, Blue Hole Natural Monument, and Goff's Caye Marine Managed Area*".

	which is a major attraction for scuba diving tourism.
Relocation of palapa to the north of the Caye on a stable substrate	To reduce coastal erosion caused by the amplification of wave action on palapa foundation. To reduce the vulnerability of the palapa to climate risks
Beautification of Goff's Caye, including revegetation, public facility upgrading, solar panel and signage installation	To enhance sustainable tourism amenities.

The proposed interventions account for US$ 961,400, to be executed in 1 year, and with an expected yearly maintenance and operative cost of approximately US$ 90,519.

Benefits, assumptions, net returns and sensitivity analysis

Benefits

In the situation Without Program, the average income will reduce, due reduction in tourist expenses. In the situation With Program, the average income will increase. Due to management of reef degradation, in case of sea level rise there will not be reduction on the island surface, that will maintain its carrying capacity, that complemented with tourist amenities activities will allow to increase occupancy rate and tourist daily expenses.

The Program will generate the following benefits:

- **Avoided loss of island surface.** The conservation of the coral reef and the active coastal zone management will allow reduction of coastal erosion and preservation of the available island surface. The impact of coral reef deterioration over the island surface is estimated taking into account the sea level increase, and its impact over the eroded land surface (estimated using Bruun´s rule).

- **Increase in yearly expense.** Yearly expenses will be affected by occupancy rate and by daily expenses per visitor. Regarding occupancy rate, expected benefits derive from the construction of the jetty, the designation of mooring fields, the relocation of the palapa and the beautification of the Caye,. Regarding the increase of daily expenses per visitor, the Palapa relocation and better tourist amenities will allow to increase daily expense per visitor, that will increase the yearly total expenses (estimated taking into account occupancy rate, visitors per day and daily expense).

On the other side, the Program will generate operational and maintenance costs. The management of reef degradation and tourist amenities would require operative and maintenance costs throughout the life cycle of the project (20 years).

The impact of climate change is incorporated by assuming, based on the IHC (2017) feasibility study, a 10% increase in the magnitude of flood damages from year 26 onwards. This is derived from scaling up storm probability, which is assumed to be equally distributed to all storm damage outcomes, and SLR.

Assumptions

The assumptions used in the economic analysis were elaborated with support from IHC. Expert criteria were complemented with information from the literature and other countries, which was adapted to Belize using the process of benefit transfer (Rosenberger and Loomis 2004).

Variable	Assumption	Justification about the assumption
Sea level rise	0.3	IHC (2017) and coastal zone management analyses in Belize.
Sea level increase (magnitude of increase)	0.07	
Current average visitors per day	80	Data provided by the Government of Belize.
Increases in occupancy rate	10%	Expected benefits derive from the construction of the jetty, the designation of mooring fields, the relocation of the palapa and the beautification of the Caye,. Occupancy rate increase based on IHC (2017) modeling.
Average daily expense per visitor	80	Data provided by the Government of Belize.
Increase in average daily expense per visitor	US$10	Increase of tourist amenities will increase daily expense per visitor. The amount of US$10 was estimated taking into account average current expense and conversations with people from travel agencies and public officers involved in Goff´s Caye.
Discount rate	12%	As required by IDB.

Economic Return

The implementation of the interventions in Goff's Caye will entail increases in both costs for implementation and maintenance and benefits, which exceed those costs. Thus, the Program will generate a NPV of US$ 659,862, with an IRR of 15.53%.

The ROI equals 1.38, which includes a 12% discount rate.

Summary of Results	
Total discounted cost	1,749,801
Tota disconted benefits	2,409,663
Net Present Value	659,862
Internal return rate (IRR)	15.53%

Source: IHC (2017)

The detailed cash flow is presented below:

Year	Disc. Cost	Disc. Benefits
0	905,190	0
1	80,821	0
2	72,161	53,390
3	64,430	71,504
4	57,526	85,124
5	51,363	95,004
6	45,860	101,790
7	40,946	106,032
8	36,559	108,195
9	32,642	108,679
10	29,145	107,816
11	26,022	105,891
12	23,234	103,140
13	20,745	99,764
14	18,522	95,927
15	16,537	91,767
16	14,766	87,397
17	13,184	82,910
18	11,771	78,381
19	10,510	73,871
20	93,838	69,428
21	8,378	65,088
22	7,481	60,882
23	6,679	56,830
24	5,964	52,947
25	5,325	49,244
26	4,754	45,727

27	4,245	40,827
28	3,790	36,453
29	3,384	32,547
30	3,021	29,060
31	2,698	25,946
32	2,409	23,166
33	2,151	20,684
34	1,920	18,468
35	1,714	16,489
36	1,531	14,723
37	1,367	13,145
38	1,220	11,737
39	1,090	10,479
40	9,728	9,357
41	869	8,354
42	776	7,459
43	692	6,660
44	618	5,946
45	552	5,309
46	493	4,740
47	440	4,232
48	393	3,779
49	351	3,374

Source: IHC (2017)

Sensitivity analysis

In this section, we conduct sensitivity analysis to the following assumptions: tourist daily expense and occupancy rate.

	Base Scenario	Tourist Daily Expense (US$85)	Occupancy Rate (85%)
Net Present Value	659,862	349,191	55,780
Internal return rate (IRR)	15.5%	14.0%	12.4%

The detailed cash flows are presented below:

Year	Disc. Cost	Disc. Benefits
0	905,190	0
1	80,821	0
2	72,161	53,390
3	64,430	71,504
4	57,526	85,124
5	51,363	95,004
6	45,860	101,790
7	40,946	106,032
8	36,559	108,195
9	32,642	108,679
10	29,145	107,816
11	26,022	105,891
12	23,234	103,140
13	20,745	99,764
14	18,522	95,927
15	16,537	91,767
16	14,766	87,397
17	13,184	82,910
18	11,771	78,381
19	10,510	73,871
20	93,838	69,428
21	8,378	65,088
22	7,481	60,882
23	6,679	56,830
24	5,964	52,947
25	5,325	49,244
26	4,754	45,727

27	4,245	40,827
28	3,790	36,453
29	3,384	32,547
30	3,021	29,060
31	2,698	25,946
32	2,409	23,166
33	2,151	20,684
34	1,920	18,468
35	1,714	16,489
36	1,531	14,723
37	1,367	13,145
38	1,220	11,737
39	1,090	10,479
40	9,728	9,357
41	869	8,354
42	776	7,459
43	692	6,660
44	618	5,946
45	552	5,309
46	493	4,740
47	440	4,232
48	393	3,779
49	351	3,374

- Tourist daily expense from US$90 to US$85

Increase of tourist amenities will increase daily expense per visitor. The amount of US$10 was estimated taking into account average current expense and conversations with people

from travel agencies. A more conservative scenario where tourist daily expenses grow more slowly is considered.

Year	Disc. Cost	Disc. Benefits
0	905,190	0
1	80,821	0
2	72,161	46,506
3	64,430	62,285
4	57,526	74,149
5	51,363	82,756
6	45,860	88,667
7	40,946	92,361
8	36,559	94,246
9	32,642	94,667
10	29,145	93,916
11	26,022	92,239
12	23,234	89,843
13	20,745	86,901
14	18,522	83,559
15	16,537	79,935
16	14,766	76,129
17	13,184	72,220
18	11,771	68,276
19	10,510	64,347
20	93,838	60,477
21	8,378	56,697
22	7,481	53,033
23	6,679	49,503
24	5,964	46,121
25	5,325	42,895
26	4,754	39,831

27	4,245	35,564
28	3,790	31,753
29	3,384	28,351
30	3,021	25,313
31	2,698	22,601
32	2,409	20,180
33	2,151	18,018
34	1,920	16,087
35	1,714	14,364
36	1,531	12,825
37	1,367	11,450
38	1,220	10,224
39	1,090	9,128
40	9,728	8,150
41	869	7,277
42	776	6,497
43	692	5,801
44	618	5,180
45	552	4,625
46	493	4,129
47	440	3,687
48	393	3,292
49	351	2,939

Source: IHC (2017)

- Occupancy rate from 90% to 85%

Expected benefits derive from the construction of the jetty, the designation of mooring fields, the relocation of the palapa and the beautification of the Caye The percentage of 10% was

established according with IHC (2017). A more conservative scenario where occupancy rates is 85% is now considered.

Year	Disc. Cost	Disc. Benefits
0	905,190	0
1	80,821	0
2	72,161	40,005
3	64,430	53,579
4	57,526	63,784
5	51,363	71,188
6	45,860	76,272
7	40,946	79,450
8	36,559	81,072
9	32,642	81,434
10	29,145	80,787
11	26,022	79,345
12	23,234	77,284
13	20,745	74,754
14	18,522	71,879
15	16,537	68,761
16	14,766	65,487
17	13,184	62,125
18	11,771	58,732
19	10,510	55,352
20	93,838	52,023
21	8,378	48,771
22	7,481	45,619
23	6,679	42,583
24	5,964	39,674
25	5,325	36,899
26	4,754	34,263

27	4,245	30,592
28	3,790	27,314
29	3,384	24,388
30	3,021	21,775
31	2,698	19,442
32	2,409	17,359
33	2,151	15,499
34	1,920	13,838
35	1,714	12,356
36	1,531	11,032
37	1,367	9,850
38	1,220	8,795
39	1,090	7,852
40	9,728	7,011
41	869	6,260
42	776	5,589
43	692	4,990
44	618	4,456
45	552	3,978
46	493	3,552
47	440	3,171
48	393	2,832
49	351	2,528

Source: IHC (2017)

4. Ex ante economic analysis for BL-L1028 as a whole

Regarding component 1, the ex-ante economic evaluation to assess the viability of flood mitigation infrastructure in the Orange St. area of Belize City and shore stabilization measures in Caye Caulker and Goff's Caye, considering a social discount rate of 12% evidences that the overall NPV of Component 1 of BL-L1028 is greater than US$5,605,267, with an IRR of 18.5%. A summary of the results considering all the proposed interventions is presented below:

	Belize City	Caye Caulker	Goff´s Caye	Total
IRR	17,7%	33.2%	15.5%	**18.5%**
NPV (US$)	3,385,106	1,560,299	659,862	**5,605,267**

Caye Caulker is the intervention that presented the higher IRR (33.2%), followed by Belize City (17.7%) and next by Goff's Caye (15.5%). This is line with GOB's priorities of supporting tourism as driver of the economy.

As mentioned, given the difficulty to assess the benefits of component 2 (risk-identification improvements by making risk information accessible to different actors; risk-reduction improvements by supporting the design of tourism and land use building codes; and a climate risk financing strategy, for the tourism and agriculture sectors), only the cost of Component 2 (USD 618,241) is considered in the analysis. This component has a maintenance cost of 1% per year resulting from the licenses and maintenance required by the information system. In addition, the training process will be held at least once per year. Regarding the financial strategy, once the country has the policy document and the 5-year operative plan, a system for managing information particularly for the agricultural sector will be required. In addition, specific guidelines will be required for advancing in the implementation of the financial strategy.

Overall, the Net Present Value (NPV) of BL-L1028 when both of its components are accounted for is greater than US$5,091,882. The Internal Rate of Return (IRR) is robust at 18.0%. Consequently, even when the costs (but not the benefits) of Component 2 are considered in the estimation of net benefits, the program remains a viable investment from an economic standpoint.

The detailed cash flow is included below:

	Disc. CF			
Year	**Belize City**	**Caye Caulker**	**Goff´s Caye**	**Component 2**
0	-3,426,730	-396,000	-905,190	0
1	-3,059,580	-3,536	-80,821	0
2	1,031,101	92,973	-18,772	0

3	924,233	97,165	7,074	-355,562
4	828,429	99,392	27,597	-75,437
5	742,544	100,026	43,641	-3,508
6	665,553	99,383	55,931	-3,132
7	596,536	97,730	65,085	-2,796
8	534,668	95,290	71,636	-2,497
9	479,210	92,251	76,036	-2,229
10	429,497	88,770	78,671	-1,990
11	384,936	84,975	79,869	-1,777
12	344,994	80,975	79,906	-1,587
13	309,192	76,856	79,019	-1,417
14	277,101	72,690	77,405	-1,265
15	248,337	68,535	75,229	-1,129
16	222,556	64,436	72,631	-1,008
17	199,449	60,428	69,726	-900
18	178,739	56,539	66,610	-804
19	160,176	52,790	63,361	-718
20	143,540	49,196	-24,410	-641
21	128,630	9,112	56,710	-572
22	115,267	42,505	53,401	-511
23	103,291	39,418	50,151	-45,619
24	92,558	36,505	46,984	-407
25	82,939	33,763	43,919	-364
26	74,319	31,190	40,972	-325
27	66,356	27,849	36,582	-290
28	59,246	24,865	32,663	-259
29	52,899	22,201	29,163	-231
30	47,231	19,822	26,039	-206
31	42,170	17,698	23,249	-184
32	37,652	15,802	20,758	-164
33	33,618	14,109	18,534	-147
34	30,016	12,597	16,548	-131
35	26,800	11,248	14,775	-117
36	23,929	10,042	13,192	-105
37	21,365	8,966	11,779	-93
38	19,076	8,006	10,517	-83
39	17,032	7,148	9,390	-74
40	15,207	6,382	-371	-66
41	13,578	1,899	7,486	-59
42	12,123	5,088	6,683	-53
43	10,824	4,543	5,967	-4,729

44	9,664	4,056	5,328	-42
45	8,629	3,621	4,757	-38
46	7,704	3,233	4,247	-34
47	6,879	2,887	3,792	-30
48	6,142	2,578	3,386	-27
49	5,484	2,301	3,023	-24
VPN	**5,605,267**			**5,091,882**
IRR	**18.5%**			**18.0%**

Source: IHC (2017)

C. Conclusions

An ex-ante economic evaluation to assess the economic viability of flood mitigation infrastructure (pumped flood reduction scheme) in the Orange St. area of Belize City and the viability of shore stabilization measures in Caye Caulker (nature based and hybrid coastal protection interventions that also act to enhance the natural tourism products) and Goff's Caye (soft coastal protection strategies and to build more climate-resilient tourism amenities), considering a social discount rate of 12%, evidenced that are viable investment from an economic standpoint.

Regarding interventions in the Orange St of Belize City, the analysis consist in comparing the differential in cost and benefits of the situation Without a Program, that corresponds to a situation without risk reduction works, against the situation With Program, that corresponds to a situation with the pumped flood reduction scheme. The Program will generate the following benefits: (i) Avoided direct and indirect damages; (ii) Avoided cost in terms of refugees and fatalities; (iii) Property value increase. On the other side, the Program will generate increase in the operational and maintenance cost.

Regarding interventions in Caye Caulker, the analysis consist in comparing the differential in cost and benefits of the situation Without a Program, that corresponds to a situation without coastal protection works, against the situation With Program, that corresponds to a situation with the establishment of a nature based and hybrid coastal protection interventions (will generate a protected area that will be less affected by coastal floods of different return period) that also act to enhance the natural tourism products of Caye Caulker. The Program will generate the following benefits: (i) Avoided flood losses, (ii) Avoided loss of urban area due to coastal retreat; (iii) Avoided losses from reduction of tourist expenses due to land erosion; (iv) Decrease in refugees and fatalities; (v) Property value increase. On the other side, the Program will generate increase in the operational and maintenance cost.

Regarding interventions in Goof´s Caye, the analysis consist in comparing the differential in cost and benefits of the situation Without a Program, that corresponds to a situation without management of reef degradation and tourist amenities, against the situation With Program, that corresponds to a situation with management of reef degradation (the coral reef and the active coastal zone management will allow reduction of coastal erosion and preservation of the available island surface) and tourist amenities. The Program will generate the following benefits: (i) Avoided loss of island surface; (ii) Increase in yearly expense. On the other side, the Program will generate increase in the operational and maintenance cost.

Overall, the Net Present Value (NPV) of BL-L1028 is greater than US$5,605,267. The Internal Rate of Return (IRR) is robust at 18.5%. For proposed investments in the Orange St area of Belize City, the NPV of BL-L1028 is greater than US$3,385,106. The IRR is robust at 17.7%. For the proposed investments in Caye Caulker, the NPV of BL-L1028 is greater than US$1,560,299. The IRR is robust at 33.2%. For proposed investments in Goff's Caye, the NPV of BL-L1028 is greater than US$659,862 The IRR is robust at 15.5%. Sensitivity analyses were also conducted and, under the most conservative assumptions, the NPV of benefits for the Orange St. area of Belize City is US$177,515 with an IRR of 12.3%, the NPV

of benefits for Caye Caulker is US$711,623 with an IRR of 24,9%, the NPV of benefits for Goff's Caye is US$55,780 with an IRR of 12.4%.

Furthermore, the NPV of BL-L1028 when both of its components are accounted for is greater than US$5,091,882. The Internal Rate of Return (IRR) is robust at 18.0%. Consequently, even when the costs (but not the benefits) of Component 2 are considered in the estimation of net benefits, the program remains a viable investment from an economic standpoint.

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