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REPORT

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Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis

D6a: Identification and justification of DRM and ACC measures for Ghana - Sector GH9-a New Ningo - Lekpoguno

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Colophon

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LIST OF ACRONYMS AND ABBREVIATIONS

CBA / *ACB*	Cost Benefit Analysis / *Analyse Couts Bénéfices*
CCA / *ACC*	Climate Change Adaptation / *Adaptation au Changement Climatique*
CI / *IC*	Coastal Index / *Indicateur Côtier*
CLC	Corine Land Cover / *Couverture Occupation des Sols Corine*
COCED	Cost Of Coastal zone Environmental Degradation / *Couts de la Dégradation de l'Environnement Côtier*
CRAF	Coastal Risk Assessment Framework / *Plan d'Evaluation des Risques Côtiers*
DRR / *RRC*	Disaster Risk Reduction / *Réduction des Risques des Catastrophes*
ESL	Extreme Sea Level / *niveau marin extrême*
EVI / *IVE*	Economic Vulnerabity Index / *Index de Vulnérabilité Economique*
EWS	Early Warning System / *Système d'Alerte Précoce*
GDP / *PIB*	Gross Domestic Product / *Produit Intérieur Brut*
IPCC / *GIEC*	Intergovernmental Panel on Climate Change / *Groupe d'experts intergouvernemental sur l'évolution du climat*
IRR / *TRI*	Internal Rate of Return / *Taux de Rendement Interne*
IUCN / *UICN*	the International Union for Conservation of Nature / *Union Internationale pour la Conservation de la Nature*
NDF / *FND*	the Nordic Development Fund / *Fonds de Développement Nordique*
NPV / *VPN*	Net Present Value / *Valeur Présente Nette*
RCP	Representative Concentration Pathways
RSLR	Relative Sea Level Rise / *élévation relative du niveau marin*
SVI / *IVS*	Social Vulnerability Indicator / *Indicateur de Vulnérabilité Sociale*
TA / *AT*	Technical Assistance / *Assistance Technique*
ToR / *TdR*	Terms of Reference / *Termes de Reference*
WACA	West Africa Coastal Areas management program / *Programme de Gestion des Zones Cotieres d'Afrique de l'Ouest*
WAEMU	West African Economic and Monetary Union / *Union Economique et Monétaire d'Afrique de l'Ouest*

1. INTRODUCTION

1.1 THE ASSIGNMENT

The West African coastal area hosts big infrastructure, major industries, tourism, agriculture and fishing activities as well as human settlements and its forerunners (e.g. communication routes) that drive economic growth and provide the livelihoods of many people. It is one of the most rapidly urbanising areas in the world and in many of the West African countries the economic activities that form the backbone of national economies are located within the coastal zone; however population pressures and increasing exploitation of coastal resources have led to rapid coastal environmental degradation. Coastal ecosystems in West Africa now face a range of challenges, including: coastal erosion, overexploitation of natural resources (such as fisheries and sand/gravel mining), marine and coastal pollution, rapid urbanization and unsustainable land use, and overall poor environmental governance (The World Bank, 2016).

To address these challenges, the World Bank is developing a *Programmatic Technical Assistance* (TA) for a *West Africa Coastal Areas Management Program* (WACA). The project '*WACA Erosion and Adaptation'* is part of the WACA Programmatic TA and aims to promote sound coastal management practices for a selected group of countries. In the countries covered by the present assignment, that is Benin, Côte d'Ivoire, Ghana and Togo, the project is financed by the Nordic Development Fund (NDF), which has entrusted the World Bank with its implementation.

As part of the project '*WACA Erosion and Adaptation'*, the main objectives of the consultancy services for the *'Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis*' are:

- To conduct a multi hazard and climate risk assessment of the coastal zone's vulnerability to climate change and climate variability in Benin, Cote d'Ivoire, Ghana and Togo, with a special focus on 4 selected sites;
- To assess the Cost Of Coastal zone Environmental Degradation (COCED);
- To evaluate the most efficient options to protect the populations, the natural assets, the capital assets, the cultural assets and the activities of the selected pilot zones.

The following deliverables are expected:

- D0: Inception Report;
- D1[a,b,c,d]: Reports on the qualitative review of natural hazards and risk mapping, for each country;
- D2: Report on the definition of the pilot sites for each of the four countries and the detailed methodology;
- D3[a,b,c,d]: Reports for the quantitative risk assessment of coastal erosion and flooding for each pilot site;
- D4[a,b,c,d]: Reports for the COCED analysis for each of the countries;

- D5: An Executive Comparative Report on the coastal zones management and the COCED results;
- **D6[a,b,c,d]: Reports on the identification and justification of Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) measures for each pilot site [present deliverable];**
- D7[a,b,c,d]: Reports on the Cost Benefit Analysis of the selected DRR and CCA options;
- D8: An Executive Comparative Report on the selected DRR and CCA options;
- D9[a,b,c,d]: PowerPoint presentations for the meeting with each communities council;
- D10: Policy note COCED, policy measures and recommendations;
- D11: Final project report.

1.2 SCOPE OF THE REPORT

This document presents the Report Identification and justification of DRM and ACC measures for Ghana of the consultancy services for the ‘Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis’.

The scope of this Report on DRR and CCA measures is to identify possible soft to hard adaptation options to reduce, prevent and mitigate risks and environmental degradation, through protection measures (construction of dykes, beach nourishment…), retreat, coastal ecosystems reinforcement for current and future climate variability. It is also within the present report to make a justified selection of DRR and CCA measures that are focused on ecosystems so as to ensure that future development, the quality of the commons, the shoreline recession, protection against floods and strategies for the development of wetlands are perfectly balanced.

The report partly fulfils the objectives of Task 4 ‘Economic modelling and analysis of environmental remediation and adaptation options in selected pilot areas’. The analysis presented herein builds on and assimilates the findings in previous phases of this study, for which cross-references are established where appropriate.

1.3 STRUCTURE OF THE REPORT

The report is structured as follows:

- The executive summary, which provides a synopsis of the key issues covered in the report;
- Section 1 presents a brief introduction to the assignment as well as the scope and structure of the report;
- Section 2 provides a summary of the more salient pilot site characteristics and existing measures (multi-sector plans) to the scope of the present report;
- Section 3 describes the identification and justification of DRR and CCA measures proposed for the pilot site in analysis;

- Section 4 discusses the results of the Coastal Index calculations, and compares this ranking with the listed hotspots in previous studies;
- Section 5 discusses the results of the quantitative analysis of the proposed DRR and CCA measures proposed, which is the base for the informative comparison between them presented therein;
- Section 6 presents the main conclusions of the report;
- Section 7 contains the reference list.

2. THE PILOT SITE

2.1 REMINDER OF SITE CHARACTERISTICS

In this paragraph a summary of the most salient characteristics of the pilot site in analysis is given. For more detailed information reference is made to Deliverable 3 of the consultancy services for the ‘Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis’ (IMDC, 2017a).

The pilot site area is vulnerable to both coastal flooding and erosion in differing degrees of risk over its extension. The long-term evolution of the coastline, evaluated as an average retreat rate per year based on literature (see, e.g., Boateng, 2012), indicates a retreat of about 9 m/year from Old-Ningo to Afitsedor Lagoon and 3 m/year from Afitsedor Lagoon to Lekpoguno. With respect to coastal flooding, the flood model results suggest that because the pilot site area largely lays at low elevations, coastal flooding is mostly dominated by the water level with respect to hinterland elevation, rather than wave overtopping flow dominated. The nature of the assets exposed vary between residential areas, rural and agriculture areas, infrastructure (the littoral road), and Songor protected area at the eastern limit of the pilot site area.

2.2 INVENTORY OF EXISTING MEASURES (MULTI-SECTOR PLANS)

In this paragraph an inventory of existing DRR and CCA measures (incl. multi-sector plans) is given. Reference is made to Deliverable 3 of the consultancy services for the ‘Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis’ (IMDC, 2017a) for more detailed information.

The present situation along the Ghanaian coastline is one of spatial variability that appears to reflect a complex interplay between geographical and geological conditions and natural hydrodynamic and geomorphic drivers of coastline change, as well as varied engineering interventions and infrastructure, including the international ports of Tema and Takoradi, the construction of the Akosombo dam in 1964 and standalone coastal protection works. The existence of illegal sand mining activities has been reported (see, e.g., Jonah et al., 2015) and is further contributing to the destruction and degradation of the Ghanaian coast.

Ghana does not have any national or sub-national coastal zone management plans available. It is perceived that coastal protection measures along the Ghanaian coast are proposed based on urgency.

At strategic level, Ghana established a National Climate Change Policy (NCCP) Action Programme for Implementation, which supports the policy actions in the Indicative Nationally Determined Contributions (INDC) submitted to the U.N. Framework Convention on Climate Change (UNFCCC). The NCCP Action Programme for Implementation includes the details of initiatives and programmes to achieve the objectives of each Policy Focus Area. The following step will be to produce operational plans by implementing units such as district assemblies, traditional authorities and non-governmental organizations on the programmes and actions identified by stakeholders.

3. DRR AND CCA MEASURES

DRR and CCA measures to manage, protect and conserve environmental, social and economic coastal resources and enhance the resilience of coastal communities to coastal hazards are based on either:

- Coastal protection, by implementing either ‘hard’ or ‘soft’ structural options, applied alone or in combination;
- Preservation/enhancement of natural coastal processes and protection and restoration of coastal habitats and services, among others coastal setbacks for human settlements and activities and the creation and maintenance of “green infrastructure”, which may be supplemented by coastal protection measures such as beach nourishment and dune building to minimise negative impacts and/or compensate for any residual effects.

Over time, one measure or strategy (combination of measures) can be replaced or complemented by another.

3.1 GOALS

The goals of the DRR and CCA measures are to preserve and rehabilitate the natural coastal resources essential for livelihoods and social welfare and supporting the sustainable development of key growth sectors such as fisheries, tourism, industry, etc. thereby increasing the resilience of coastal assets against climate and other natural hazards.

In these instances, the screening/identification of options to remediate for environmental degradation and to reduce the vulnerability and risk to threats from climate change and variability in the pilot site in analysis takes the following items into account:

- The type of the hinterland, rural or developed, and plausible scenarios of future development;
- The protection status along the pilot site, based on model results.

These are considered in conjugation with the consultancy services for the ‘Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis’ specific focus on ecosystems so as to ensure that future development, the quality of the commons, the shoreline recession, protection against floods and strategies for the development of wetlands are perfectly balanced.

3.2 ADAPTATION OPTIONS

The adaptation options discussed hereafter are: (1) hold the existing line of defence; (2) (planned) retreat; (3) accommodation; and (4) do nothing. For each of them different approaches can be followed, these are explained in the following paragraphs. Reference is made to Deliverable 2 of the consultancy services for the ‘Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis’ and references cited therein for information on other management strategies and adaptation technologies (IMDC, 2016).

3.2.1 Hold the line

The adaptation option "hold the existing defence line", generally involves implementing adaptation options drawn from an array of 'hard' (examples of hard defences include groynes and seawalls) and 'soft' (examples of soft defence include artificial beach nourishment and dune building) structural options, applied alone or in combination. This option is the traditional approach to coastal adaptation. It aims at protecting the coast against coastline retreat and flooding, in turn protecting the coast and hinterland status quo in terms of possible impact on housing, infrastructure and activities, often at the expense of losing the beach and the dynamic coastal landscape. An example of a hold the existing defence line is given in Figure 3-1.

Figure 3-1: Hold the existing defence line, seawall - Takoradi, Ghana

Beach nourishment and dune building refers to the maintenance of beaches and dunes along an eroding and/or low-lying coastline by means of the artificial supply of sediments to a beach and/or dune. It reduces the detrimental impacts of coastal erosion by providing additional sediment which satisfies erosional forces. Because it generally involves raising the crest levels of the beach and/or dune, this is also an effective defence against coastal flooding. It should be noted, and always well communicated to stakeholders that artificial nourishment will not make the beach and dunes stable. Shoreline erosion will continue to occur, but the widened and deepened beach will provide a buffer to protect coastal infrastructure and other assets from the effects of coastal erosion and storm damage (Linham and Nicholls, 2010).

Artificial beach nourishment and dune building are flexible – not permanent and reversible – adaptation options, which can be implemented without compromising future adaptation options or strategies. They have the potential to preserve and enhance coastal ecosystems and promote recreation and tourism through beach widening, while providing an increased capacity for coping with coastal erosion and flooding. In addition, as a result of sediment redistribution within the sediment cell, is likely to positively impact adjacent area to the pilot site that were not directly nourished.

The technology and methods involved in beach nourishment and dune building are well established and many contractors experienced in beach nourishment are available worldwide to undertake such projects (Linham and Nicholls, 2010). One of the main barriers for the implementation of this option is the availability (quantity) and suitability (quality) of sediments at optimal distances between borrow and target sites. Other relevant factors, which may also affect unit costs, include project size, availability (and size) of dredgers locally (large mobilisation distances can substantially increase costs), number of journeys required, material losses, degree of site exposure, tidal range, potential adverse consequences for the environment (including direct burial of animals and organisms residing on the beach, lethal or damaging doses of water turbidity – cloudiness caused by agitation of sediments – and altered sediment compositions which may affect the types of animals which inhabit the area), third party requirements.

Beach nourishment and dune building can be complemented with hard structural options such as groynes (as a nourishment stabilisation measure – see Figure 3-2) and seawalls (as a last line of defence). However, this option will result in the loss of the flexibility advantage associated to beach nourishment and dune building as standalone measures.

Figure 3-2: Groynes as stabilisation measure for beach nourishment and dune building - Ada, Ghana

Pursuing a protect option based on ‘hard’ structural options like seawalls and groynes has a few important advantages such as the high degree of protection over a long period of time (provided that they are adequately maintained and appropriately designed). It should be noted here that the positive impacts of the protection with ‘hard’ structural options are generally localised and unwanted negative impacts to downdrift areas (problem transfer or acceleration) is likely.

A widely recognised issue with coastal protection options is the increased sense of security, which may result in unwise development in areas at risk if not carefully regulated. It should be noted here, and well communicated to stakeholders, that any adaptation option is not an endpoint but rather an ongoing process, implying that a constant prioritisation of risks and opportunities and a review of the effectiveness of DRR and CCA measures in place is required and the lessons should be fed back to improve maintenance and future interventions.

3.2.2 Retreat

Within the (planned) retreat option are measures aiming at protecting, preserving or restoring the shore and the dynamic of the coast and the natural appearance of the landscape, as well as protecting against coastline retreat to the extent possible. It generally involves the abandon (with or without actual removal) of infrastructure in currently developed areas, resettlement of inhabitants and requires that new development be set back from the shore, as appropriate. Within this adaptation strategy are the managed realignment (understood herein as a deliberate process of altering defenses to allow flooding of a presently defended area) – see Figure 3-3, and the coastal setbacks (understood herein as a prescribed distance to a coastal feature such as the line of permanent vegetation, within which all or certain types of development are prohibited).

Figure 3-3: Schematic of the concept behind the managed realignment option (Linham and Nicholls, 2010)

For the pilot site in analysis only the coastal setback option, materialized as either a horizontal (or lateral) or a vertical (or elevation) setback (see Figure 3-4), is taken forward. In general terms, a coastal setback may dictate a minimum distance from the shoreline for new buildings or infrastructure facilities, or may state a minimum elevation above sea level for development (Linham and Nicholls, 2010). The reason why both types of setbacks are being considered in this analysis relates to the fact that the pilot site is exposed to hazardous from coastal flooding (by placing buildings or activities above a certain flooding level) and the erosion (by allowing room for the average high water mark to naturally move inland).

Setback distances can be determined either as (Linham and Nicholls, 2010): (1) a fixed setback which prohibits development for a fixed distance landward of a reference feature; or (2) a floating setback which uses dynamic, natural phenomenon to determine setback lines and can change according to an area's topography or measurements of shoreline movement. For the pilot site in analysis the setbacks are established as distinct coastal exclusion zones based on historic erosion rates and extreme water levels, as well as model results. The vulnerability of those within the coastal exclusion zones should be periodically re-assessed and revised (if necessary).

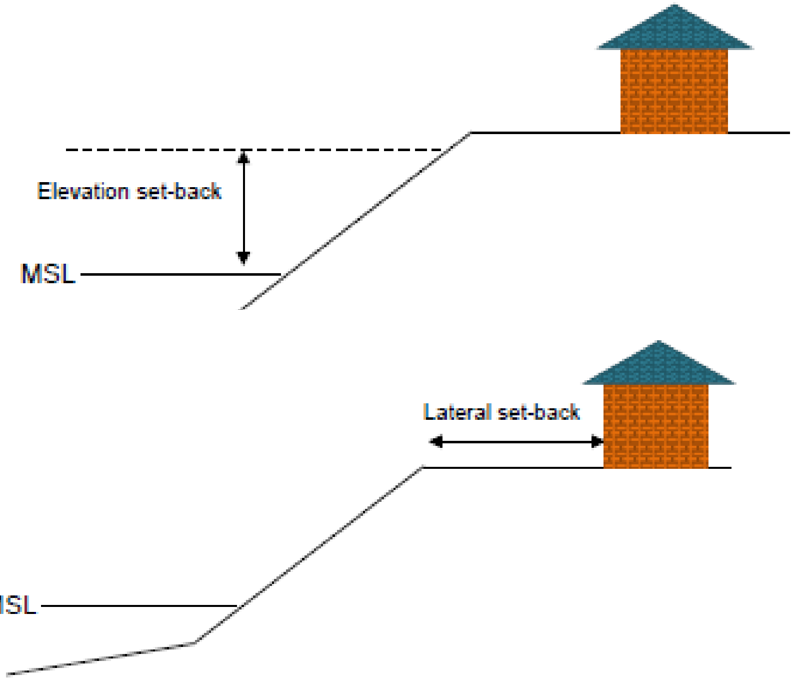

Figure 3-4: Schematic of the concept behind the coastal setback option (Linham and Nicholls, 2010)

Coastal setbacks can be enforced with immediate effect (meaning, all infrastructure is removed within the buffer zone at once) – see , or delayed in time effect (meaning, structures would be allowed to remain, but if significantly damaged or destroyed by a storm, they would usually be required to be reconstructed in line with the new setback line).

The main barriers for implementation, which also affects option unit costs are the land payments and compensation requirements. Public opposition is also likely to be a very significant barrier for implementation, thus the measure requires adequate communication in the consultation with stakeholders.

The retro-active application of coastal setbacks is unlikely in a number of cases (Linham and Nicholls, 2010): (1) coastal cities and urbanisations, (2) industrial areas and uses associated with maritime activities and, (3) traditional developments integrated with the coastal landscape. The effectiveness of coastal setbacks lies in the potential to tie the policy in with existing land use and building regulations, moreover it strongly depends on the effective implementation of coastal regulations, so to ensure that developments within exclusion zones proceed over time regardless of any pressure. In addition, problems may arise as a result of setback review, if for instance it results in the reclassification of newly (or to be) developed coastal areas as no-build zones (which may imply compensation for lost development potential) or where existing structures are now in place (which may imply more compensation than initially thought to those experiencing the physical loss of property).

Coastal setbacks can be implemented along with coastal protection, namely artificial beach nourishment and dune building. This provides the double benefit of maintaining natural protective features, as well as providing a buffer zone against coastal flooding and erosion.

In Figure 3-5 a practical example of the application of the coastal setback adaptation option, enforced with immediate effect is given.

Figure 3-5: Retreat, existing situation before (top panel) and after (bottom panel) coastal setback - Abidjan, Ivory Coast

3.2.3 Accommodation

This option include site adaptation strategies to adapt buildings or a piece of infrastructure so that they are more resilience to extremes of climate, namely dry and wet floodproofing, elevate on fill or mound, elevate on piles, site protection, building system protection floating structures and amphibious structures (Figure 3-6). It applies to new construction or retrofitting of existing building, although it should be considered that costs of retrofitting buildings to higher standards are typically significant and may present many technical and urbanistic challenges.

Accommodation options also include (and very often require) preparing for extreme events through developing early warning systems and plans for evacuation, emergency response and recovery, as it focus on preventing the damage and not on preventing the hazard.

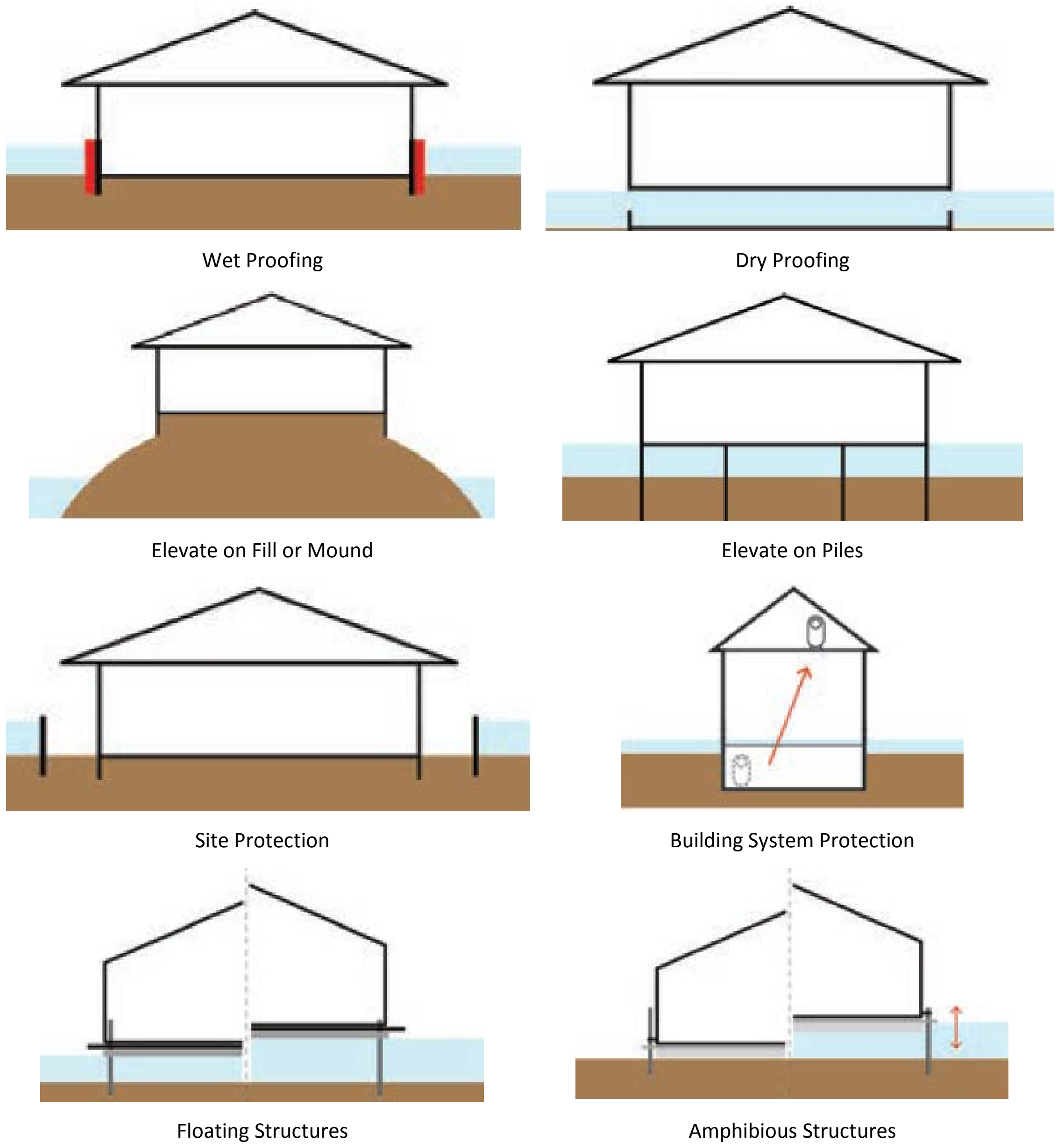

Figure 3-6: Site adaptation strategies (adapted NYC Planning, 2013)

3.2.4 Do nothing

The “do nothing” is understood herein as the strategy where no active intervention (not even maintenance) is taken.

In the context of the present study, the scenario relative to a do nothing strategy corresponds to the actual situation (baseline scenario). The particular interest of this scenario lies on the reference it provides so as to compare and contrast the costs and benefits of the adaptation options under appraisal. It is expected that climate change and extremes of climate will likely further exacerbate those presently exposed, generally jeopardising natural coastal resources essential for livelihoods and social welfare and supporting the sustainable development of key growth sectors such as fisheries, tourism, industry, etc.

In general terms, this strategy is mostly appropriated in areas where there is no people, and so nothing of "value" (to the government) to protect; otherwise, the consequences of ignoring the effects of flooding and coastal erosion or dealing with them as they come may generate a strong negative public sentiment, but more importantly cause significant human suffering and economic losses to national economies. The do nothing option differs from the (planned) retreat in two main important aspects: (1) deals with the consequences of the effects of flooding and erosion ex-post, which means that effort (investment policy) is not placed in lessening vulnerability of people and property and promoting wise management of land and the environment but rather in disaster relief; (2) does not contribute (or this is very limited) to raise political and public awareness and preparedness to the vulnerability in coastal areas.

3.3 APPLICATION TO THE PILOT SITE / SELECTION OF MEASURES ADAPTED TO THE PILOT SITE

As described in section 3 of the present report, there are many possible options for promoting coastal resilience and adaptation at the pilot site. The first step toward selecting measures adapted to the pilot site is to identify objectives for coastal resilience on variable temporal scales and at the spatial scale of the pilot site, and examine the ability of a strategy to address existing coastal hazards and the opportunities related to the safeguarding and valorisation of the environment and of the social and economic structure. Regional opportunities for larger-scale reach strategies should also be taken into consideration.

Opportunities for valorisation of the pilot site mainly concern agriculture and tourism activities. The major natural hazards encountered are coastal erosion and flooding (IMDC, 2017a).

To conduct an initial screening analysis to identify which management strategies may be appropriate, the following alternatives, incorporating different DRR and CCA measures applied as standalone measures or in combination, are under appraisal (Table 3-1):

- Do nothing, where no active intervention (not even maintenance) is taken, which is used as the baseline scenario, for comparison of the other alternatives);
- First alternative: hold the existing line of defense, this is the protection scenario where it is assumed that only a residual risk of flooding and coastal erosion remains;
- Second alternative: (planned) retreat, in this scenario DRR and CCA measures will not change the hazard intensity but rather the exposure by means of a change in land use;
- Selected adaptation option (e.g. coming from the multi-sectoral investment plans, current policies etc.), this is likely to entail the implementation of complementary protection and retreat options, which will be justified based on the assessment of the costs and benefits.

Because there is much uncertainty in examining both how climate hazards may evolve from now through 2100 and how the elements of vulnerability may change, also a "multi-layered approach" to resilience could be chosen, which comprises strategies in combination and on-going processes of assessing risks, developing and evaluating alternatives, and implementing flexible and adaptive strategies. Because the context is highly uncertain and unpredictable interventions require flexibility through a process of continual adjusting, learning and innovation.

Table 3-1: Summary of adaptation options considered

Reference : Description *Adaptation Option*	**Geographic Impact**	**Time horizon for implementation [2]**	**Status**	**Qualitative Assessment [3]**			
				Social Impact (potential)	Economic Impact (potential)	Infrastructural Impact (potential)	Environmental Impact (potential)
Alternative 0 : reference scenario *Do nothing*	-	-	-				
Alternative 1 : protection scenario *Hold the existing line of defence*	SA	ST	-	ST	ST	ST	
Alternative 2a : coastal setback *(Planned) retreat*	SA	ST /LT	-				LTV
Alternative 2b : Adaptation of buildings *Accommodation*	SA	ST /LT	-	LTV	LTV	LTV	LTV
Alternative 3 : Commination of adaptation options *Hold the (existing defence) line in the short/medium term and (planned) retreat and accommodation in the long term*	SA	ST /LT	-	LTV	LTV	LTV	LTV

[1] Geographic impact:
ECA - Entire Coastal Area; SA - Specific Areas; I - International
[2] Time horizon for implementation:
U - Urgent (< 2 years); ST - Short term (< 5 years); LT - Long term (> 5 years)
[3] Impact:
ST - Short term (few decades); LTV – Long-term vision (> 50 years)

A “multi-layered approach” to resilience is typically built upon (Figure 3-7):

- Climate adaptation context, that is to examine relevant plans or projects that reflect the objectives for the area of study;
- Coastal climate risk profile, that is the interaction between coastal hazards and the populations, built environment, infrastructure, and natural resources that are vulnerable to the hazards;
- Adaptation pathways, that is flexible plans for how to combine a series of actions that can be taken in the short term (next 10 years), with periodic decision points over time, to address longer term objectives.

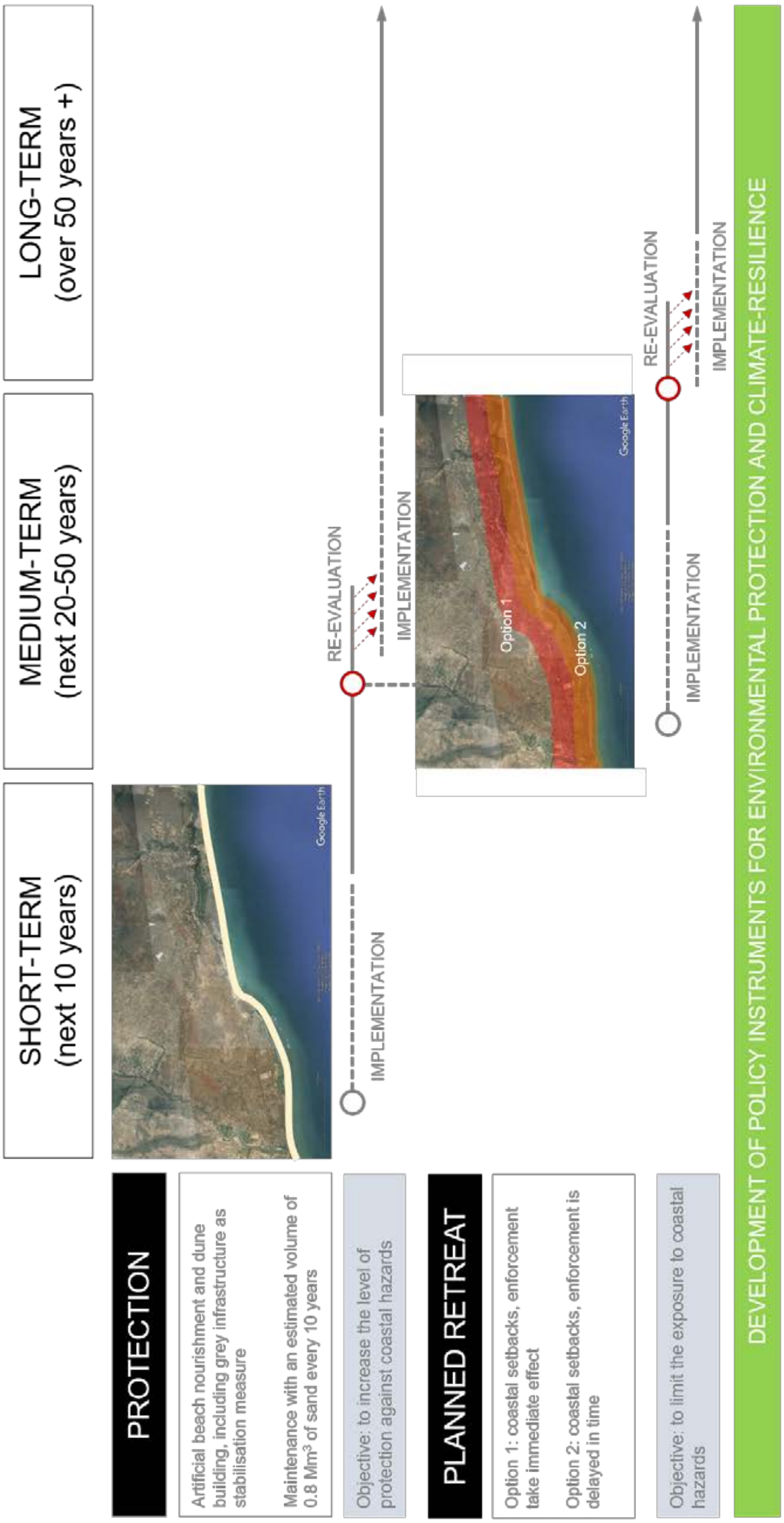

Figure 3-7: Illustrative example of a flexible adaptation pathway

4. QUANTITATIVE ANALYSIS

4.1 REMINDER OF MODELS IMPLEMENTED

The used models and the purpose is summarised hereafter. For more information on the models reference is made to Deliverable 3 of the consultancy services for the ‘Cost of Coastal Environmental Degradation, Multi Hazard Risk Assessment and Cost Benefit Analysis’ (IMDC, 2017a).

4.2 IMPLEMENTATION OF MEASURES

For the purpose of modelling efforts, there are two distinctive types of DRR and CCA measures:

- Measures that affect the intensity of coastal hazards: Alternative 1 and partially Alternative 3;
- Measures that prevent damage but do not have an impact on hazard intensity: Alternatives 2a and 2b.

Modelling efforts are required for both types of DRR and CCA measures but there is a difference in modelling objectives. Whilst for the first type of measures numerical modelling is used to evaluate whether the functional requirements for the flood and/or erosion control measures are fulfilled and to appraise where optimisations can be implemented; for the second type, numerical modelling is used to define the erosion and flooding buffer lines.

For the purposes of the present study, it is assumed that ongoing erosion and flooding control studies or projects are implemented in the short-term and that they are well-designed and maintained to be fully efficient over the next 50 years (relevant in Alternative 3 appraisal) or through 2100 (relevant in Alternative 1 appraisal).

5. RESULTS

The different alternatives are shown in the following figures. Figure 5-1 shows a map with the erosion and flood zones for the reference scenario (in 2100). No protection or development action is taken.

Figure 5-2 to Figure 5-5 shows the adaptation alternatives as described in Section 3.2. The advantages and disadvantages are included in the figure.

The impact of flooding and erosion on each of these alternatives is quantified on the basis of the results of the modelling (see Deliverable D3, IMDC, 2017a), and according to the methodology developed for COCED (see Deliverable D4, IMDC, 2017b) and will be described in the cost-benefit analysis of adaptation measures (see Deliverable D7, IMDC, 2017c).

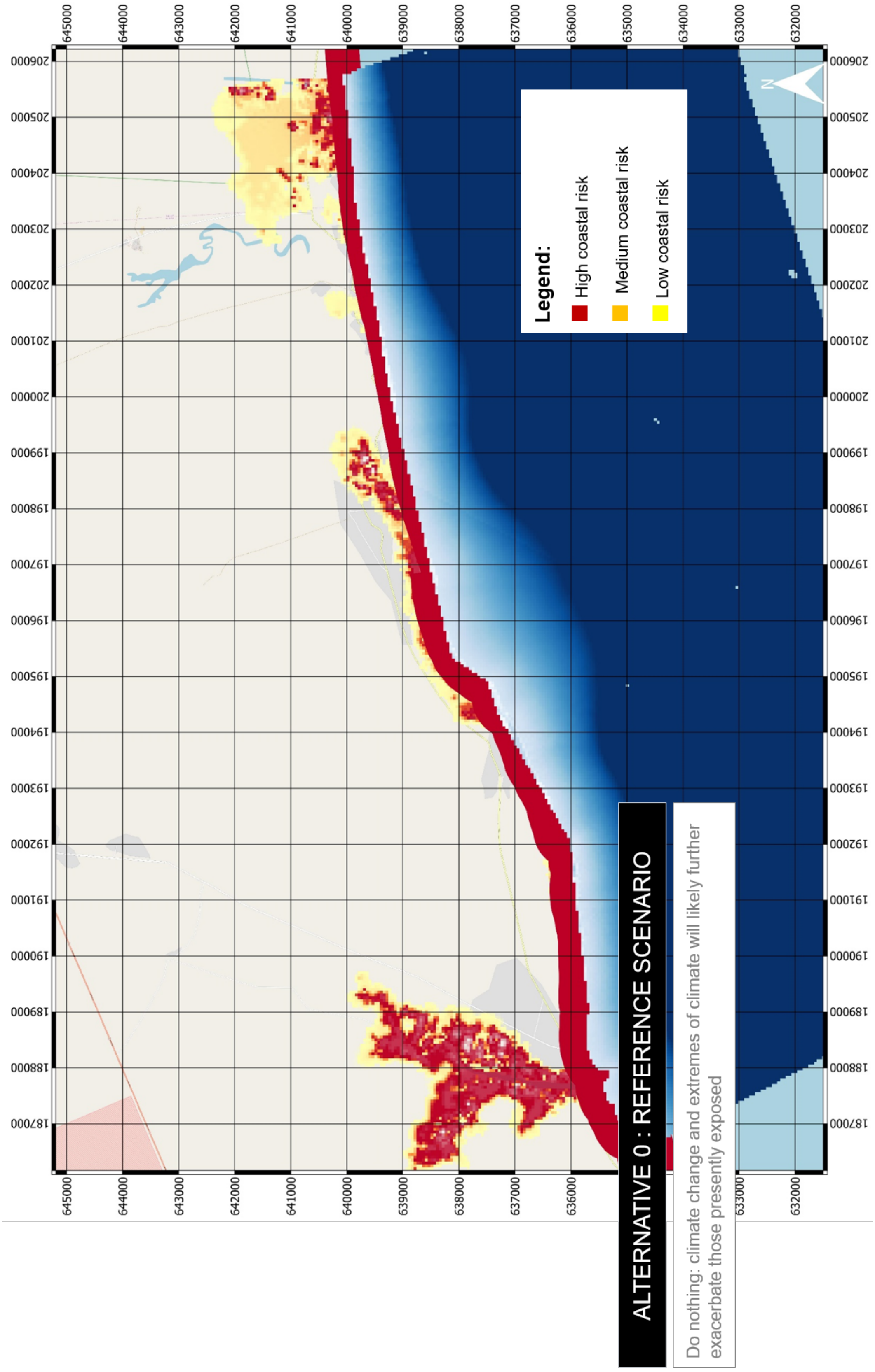

Figure 5-1: Coastal erosion and flooding risk map for the reference scenario (Alternative 0)

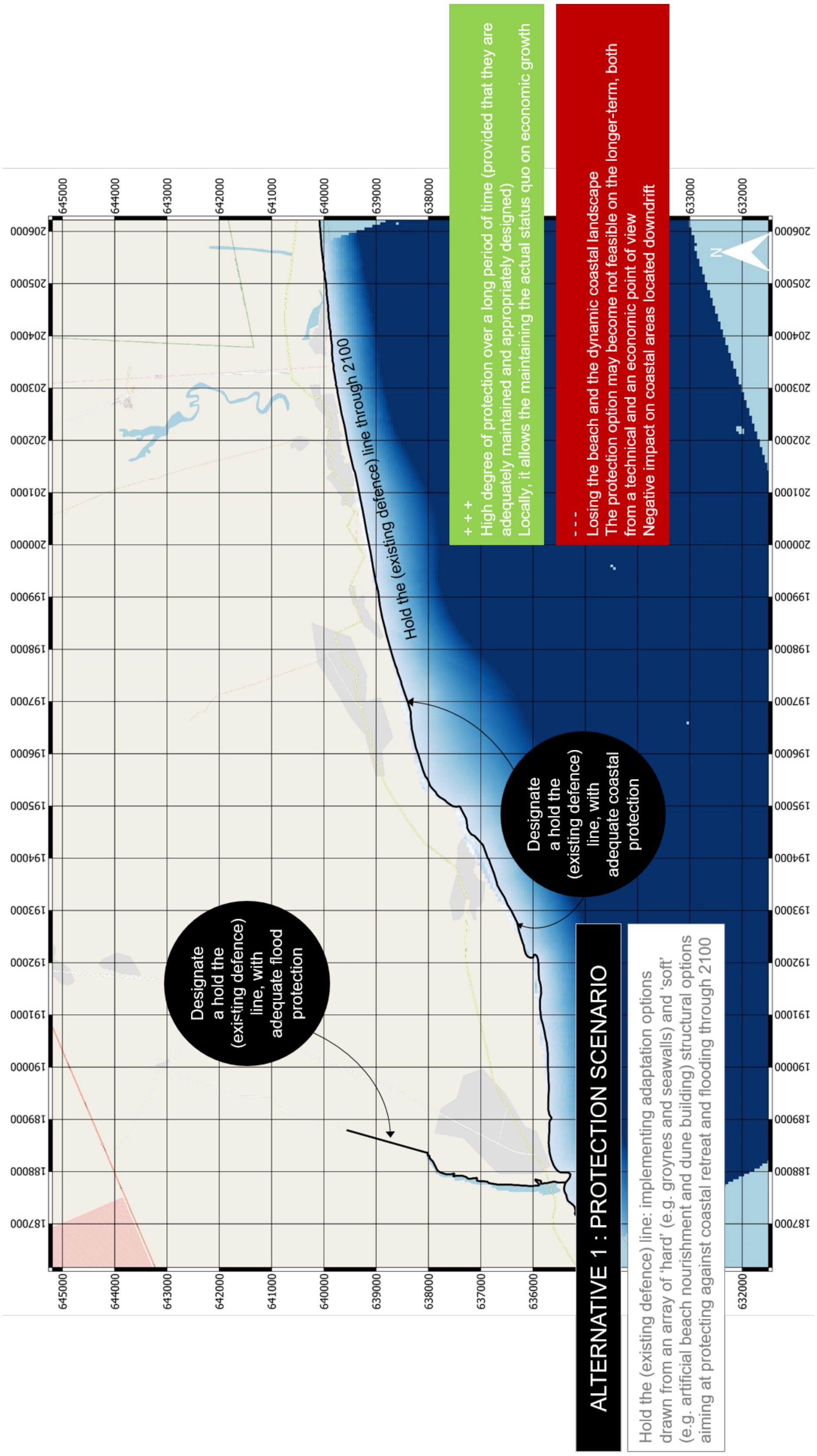

Figure 5-2: Alternative 1 - protection scenario

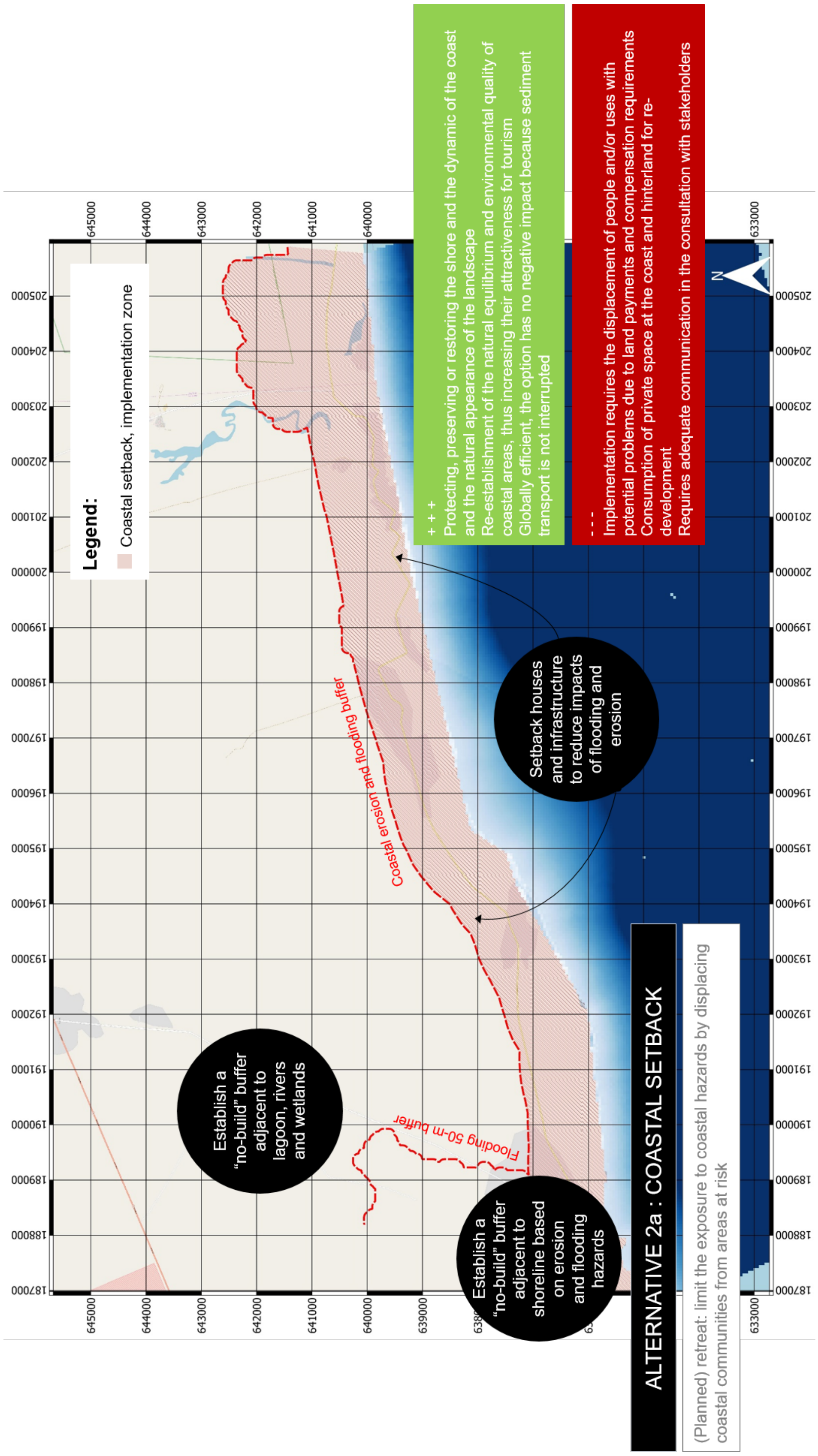

Figure 5-3: Alternative 2a - coastal setback

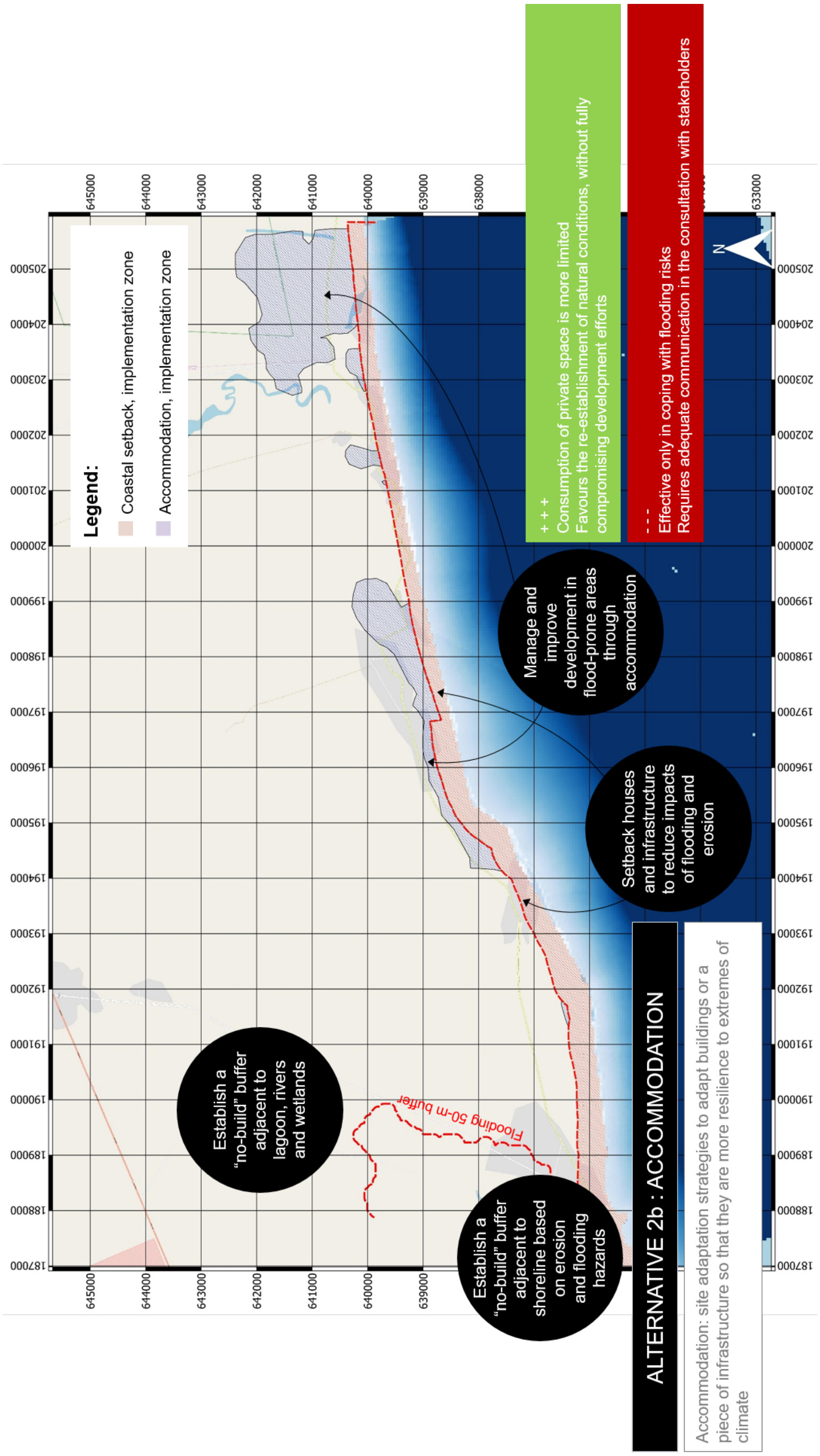

Figure 5-4: Alternative 2b – Accommodation: adaptation of buildings

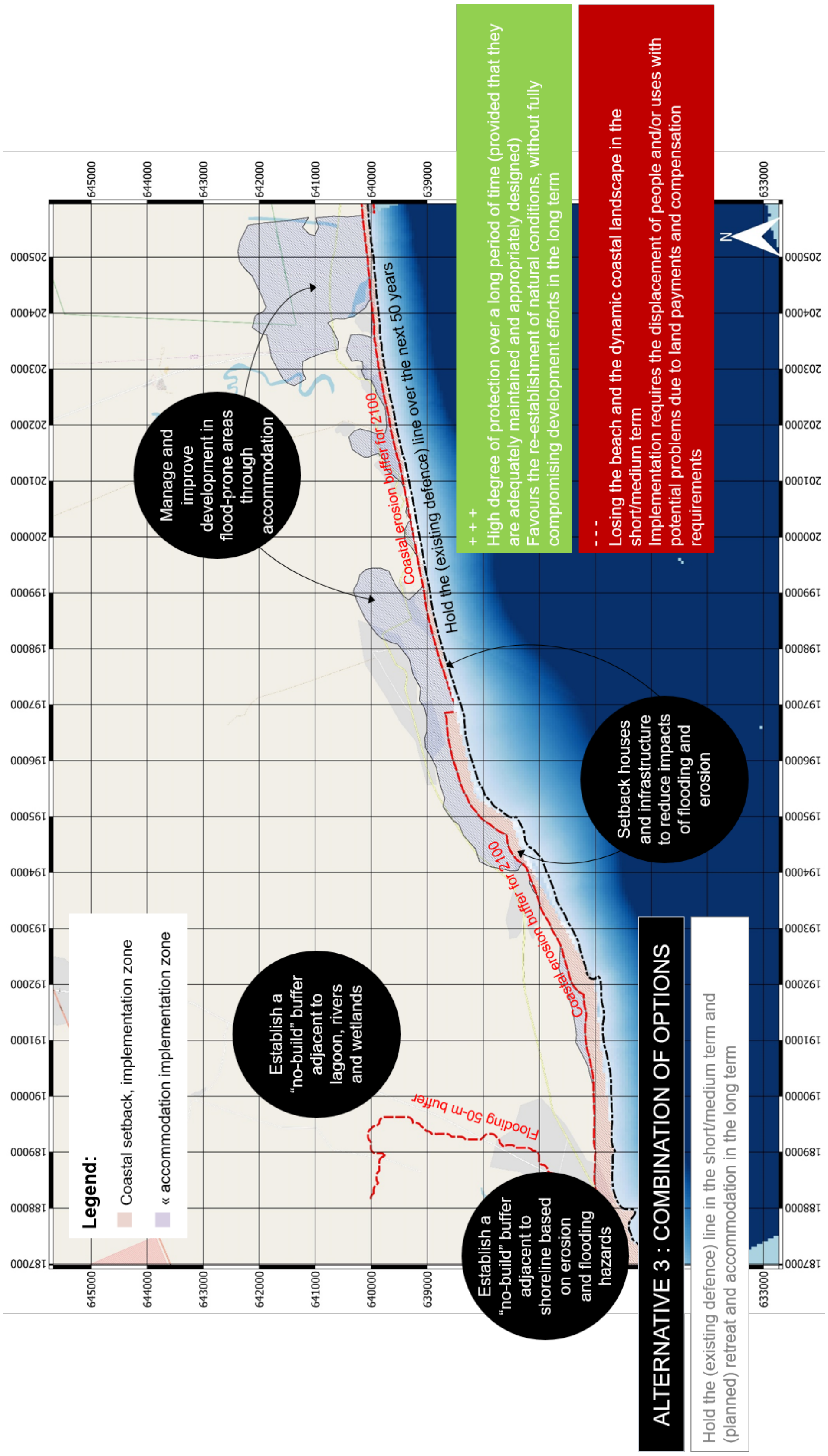

Figure 5-5: Alternative 3 - combination of adaptation options

6. CONCLUSIONS

Along the present report several adaptation options were presented. Alternatives have been created, so that different approaches can be explored and compared.

The following step is to examine which factors may drive the feasibility, costs and benefits of a given strategy (see Deliverable D7, IMDC, 2017c). Based on this examination, as well as the assessment of risk), it may be necessary to refine the selected adaptation option. The adaptation pathways approach, as described in section 3.2, will be relevant to choose the preferential alternative.

7. REFERENCES

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