RESPONDING TO CLIMATE CHANGE IN MOZAMBIQUE

Instituto Nacional de
Gestão de Calamidades

National Institute for Disaster Management (INGC)
PHASE II

THEME 2
COASTAL PLANNING AND ADAPTATION TO MITIGATE CLIMATE CHANGE IMPACTS

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EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

S.1 BACKGROUND

Mozambique is recognized as one of the countries in Africa that is most vulnerable to climate change. Hazards such as droughts and floods, variable rainfall and tropical cyclones already significantly affect the country.

The country's coastal zone is particularly vulnerable to the expected impacts of climate change. Contributing factors include:

- Vast low-lying coastal plains such as delta coasts;
- High population concentrations in close proximity to the sea;
- Poverty;
- Low capacity to defend infrastructure;
- Susceptibility to cyclone activity;
- Soft erodible coasts; and
- Inadequate and ageing coastal defences.

This situation is aggravated by direct exposure to high wave energy regimes in some parts, a potential increase in cyclone impacts, and impacted natural coastal defences such as dunes, mangroves and coral reefs. Large numbers of the local population also rely heavily on goods and services and economic benefits provided by the coastal zone.

In this regard, the National Institute for Disaster Management (INGC) initiated two studies to define and locally contextualise important drivers and impacts of climate change in the country. Phase I, completed in 2009, focused on determining the impacts of climate change on Mozambique at the macro level. The current project, Phase II, focuses on both the macro and the micro levels, with an emphasis on the implementation of adaptation measures and providing strategic and scientific evidence-based guidance for decision-making.

Led by the Mozambican government, the overall goal of the Phase II project is to help protect the country against the potential impacts of climate change, and to plan for and kick start prevention through the implementation of adaptation measures at national scale, on the basis of science and in support of sustainable development.

As such, a multi-disciplinary group of scientists from Mozambique and other institutions formulated 9 themes to encapsulate the research challenges faced, namely:

- *Theme 1*: Early Warning at a Different Scale
- *Theme 2*: Coastal planning and adaptation to mitigate climate change impacts
- *Theme 3*: Cities prepared for climate change
- *Theme 4*: Building resilience in partnership with the private sector
- *Theme 5*: Water – doing More with less
- *Theme 6*: Food – Meeting demands.
- *Theme 7*: Preparing People
- *Theme 8*: Extremes
- *Theme 9*: National Strategy: 'Climate Change and Disaster Risk Reduction"

While this study is primarily concerned with Theme 2, it is closely aligned with Themes 3 and 4, and addresses the following key questions:

- Where are the most vulnerable areas along the coast, at the local/micro level?
- What will these areas look like, with climate change, in future?
- Which key infrastructure and future investment plans are at risk in these areas?
- What recommendations are in order for planned investments along the coast, with emphasis on Beira and Maputo?
- What structural coastal protection measures are needed to compensate for the potential effects of climate change?
- What shoreline management plans are most appropriate for these areas?
- What should be the strategic framework on which all coastal structures and sea defences can be evaluated?
- What should go into a coastal zone information system?
- What input can be provided for in a coastal management policy?

The INGC also emphasised the need for a pro-active approach to protect lives and infrastructure, while at the same time finding sustainable solutions that are durable and low cost.

S.2 KEY CONSIDERATIONS AND FINDINGS

S.2.1 Drivers of change

In Theme 2 the physical factors that influence the risk to coastal infrastructure in current and future climate scenarios were identified. This included consideration of the current situation along with future sea-level rise scenarios of 0.5m, 1.0m or 2m by 2100. These are further considered both with and without taking cyclones into account and the consideration of possible increases in "storminess" being another component of climate change.

The primary hazards to physical (abiotic) coastal infrastructure related to sea storms and climate change are:

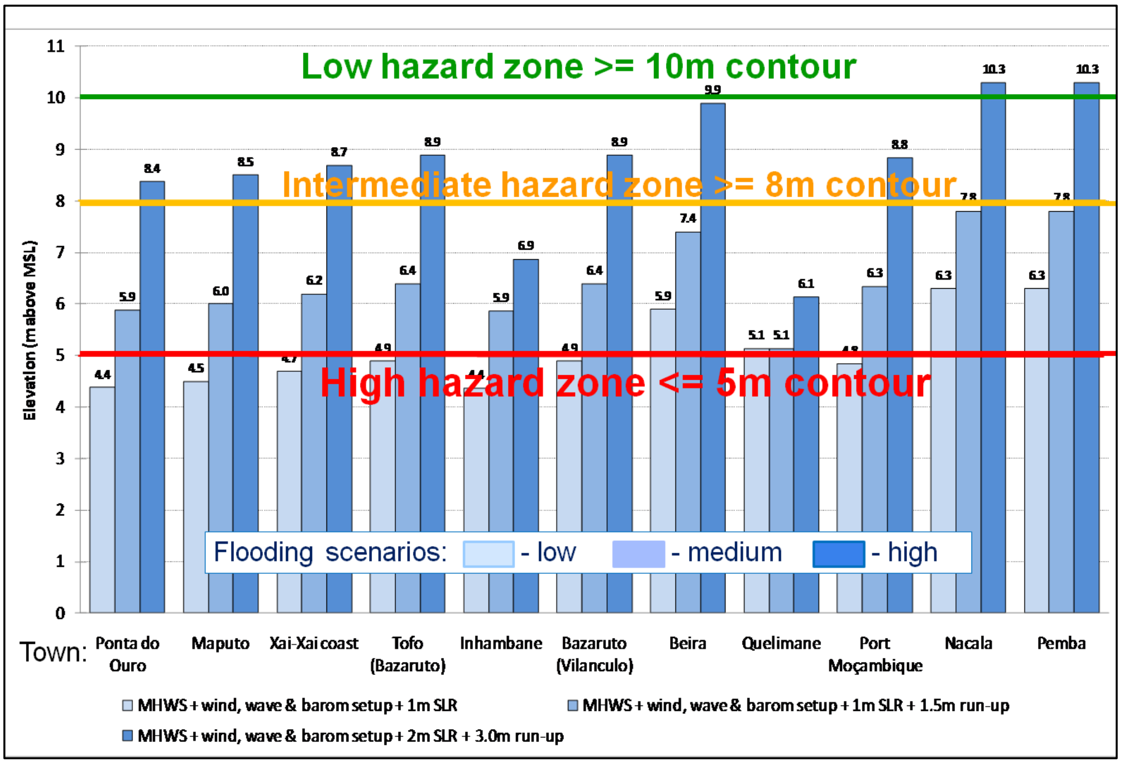
- Extreme inshore sea water levels resulting in flooding and inundation of low lying areas.
- Changes in cyclone characteristics, winds and local wave regime resulting in direct wave impacts.
- Coastal erosion and under-scouring of, for example, foundations and structures.
- System complexities, thresholds and non-linearities, for example related to sand transport.
- A combination of extreme events, such as sea storms during high tides plus sea level rise, will have the greatest impacts and will increasingly overwhelm existing infrastructure as climate change related factors set in time.

The main drivers of change related to the above are thus waves and sea water levels (and to a lesser extent winds and currents). A detailed discussion are contained in a separate document.

The shoreline response and flooding impact is influenced by coastal parameters/processes such as: topography, geology, inshore wave action, sea level (including the tidal state and future rise), bathymetry and foredune volume.

To be of more use in hazard quantification and ultimately in finding ways of reducing risks and deriving practical adaptation measures, it is necessary to be able to predict or forecast the coastal response and severity of impacts. To this end, given the lack of historic data and information along the Mozambican coastline, three flooding scenarios are defined to establish the hazard levels at the specific sites in terms of possible flooding due to the various factors associated with 'normal' meteorological factors as well as the effects of climate change.

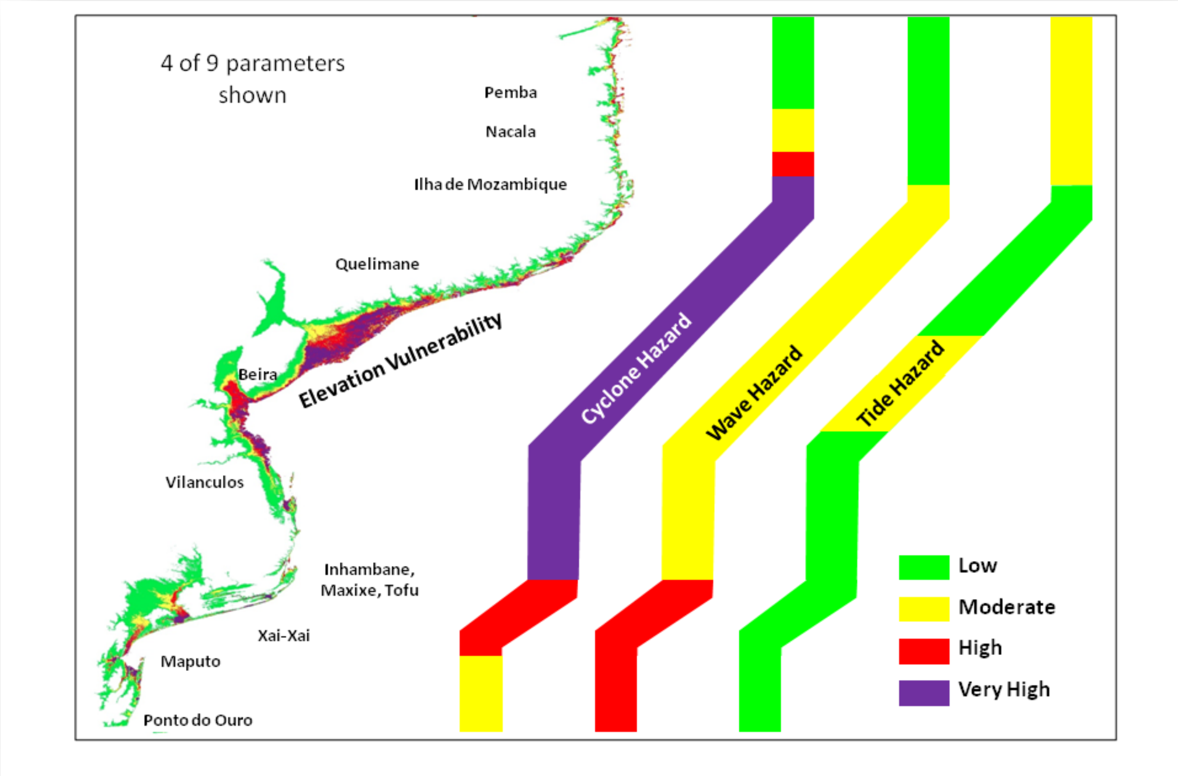
These three flooding level scenarios were calculated for each of the study towns and cities as depicted in the figure below (*the 3 bars for each town)*.



Coastal flooding levels for 11 towns/cities

S.2.2 Coarse scale coastal vulnerability assessment

Broadly speaking, the low lying central delta coast areas (e.g. Beira) are very vulnerable in terms of elevation (see Figure below). The highest occurrence of cyclones (very high hazard) is found along the central parts of Mozambique, tapering off to the south (from roughly Tofo) and also sharply to the north (from about Ilha de Mocambique).



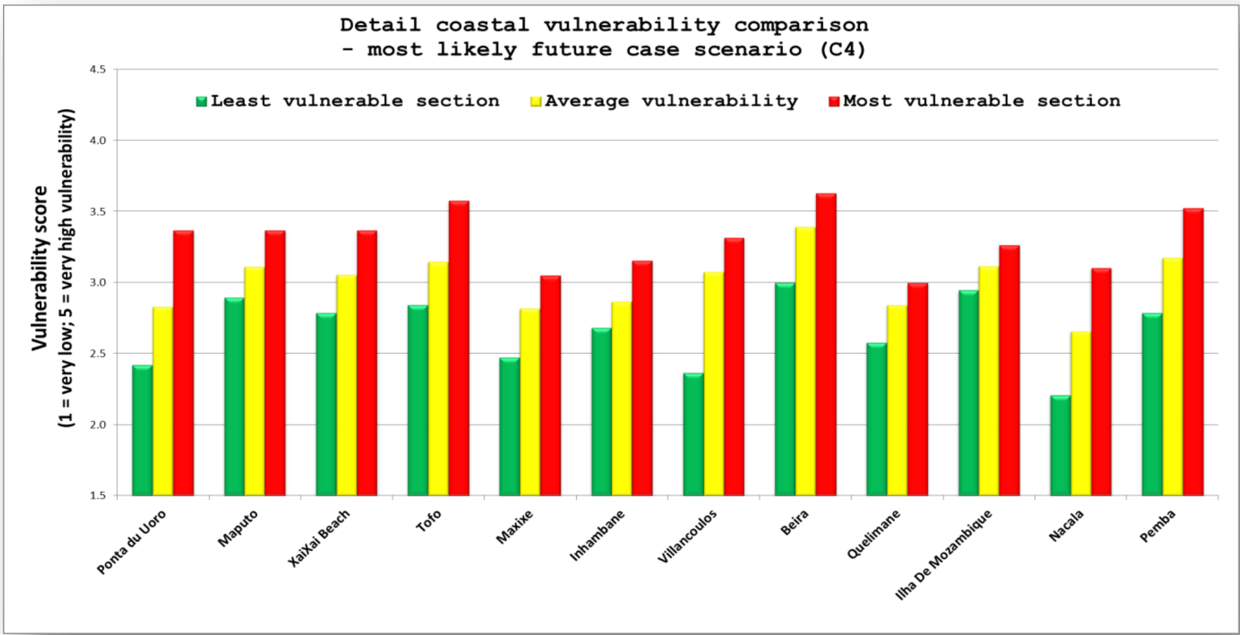
Coarse overview of hazards and vulnerability of Mozambican coast

S.2.3 Local / micro scale coastal vulnerability assessment

Analyses were carried out to determine the vulnerability of key coastal cities and towns (identified by the INGC) to the impact of a range of biophysical change scenarios.

The vulnerability to the forces from the sea of approximately 10 km of shoreline at each site was assessed by evaluating 14 abiotic parameters against an agreed to set of criteria. The vulnerability assessment was done with and without climate change factors, and also with and without the effect of cyclones. Total vulnerability maps are available for each of the study sites, for the 8 scenarios that include cyclones (i.e. C1 to D4).

The figure below shows the detailed coastal vulnerability comparison of the 12 coastal study sites when the most likely future climate change scenario, C4, is used. (Scenario C4 considers a 1m sea-level rise by 2100 and includes both the effects of cyclones and an increase in storminess due to climate change.



A comparison of the vulnerabilities of the 12 study sites under the most likely future case scenario (C4)

Results show that the most vulnerable towns are Ponta do Ouro, Maputo, XaiXai Beach, Tofo, Villanculos, Beira and Pemba. Beira is identified as the most vulnerable city.

S.2.4 Appropriate adaptation measures

A comprehensive literature review led to the identification of a number of management options and "soft" and "hard" coastal engineering methods available to protect the shoreline (available as a separate document).

By considering the coastal processes and characteristics of the study area, and factors governing suitability for coastal development, various potential response options were identified.

Based on the foregoing evaluation considerations and criteria, and including all appropriate options, the priority adaptation/"no-regret" measures were grouped according to type and impact, covering the most relevant climate change issues for Mozambique coastal towns and cities.

The results together with site investigations allowed coastal engineers to determine the most appropriate adaptation options to introduce for a particular area within the study areas. Following a conservative and precautionary approach, a list of prioritised adaptation response actions for each town and city was recommended. These are available as separate documents for each site.

S.3 KEY CONSIDERATIONS AND FINDINGS

S.3.1 Integrated coastal planning and management

The adoption and implementation of the strategic principles and guidelines on planning for and responding to coastal impacts and including specifically climate change impacts is seen as the first and most important action point.

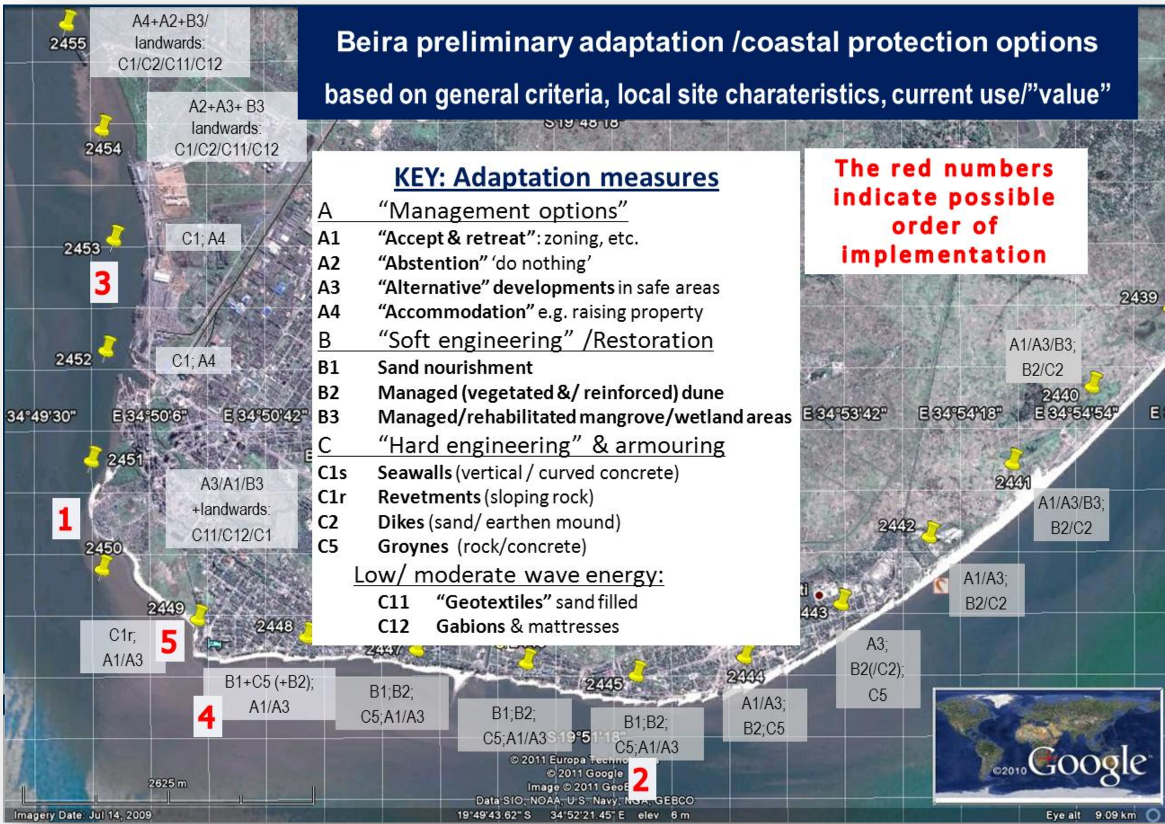
Most of the response options are purposefully what can be termed "soft" options or "working with nature". Following an integrated coastal planning approach is in line with strategic principles and best practise guidelines in terms of coastal management and responding to climate change. This simple management level decision will go a long way in reducing the need for constructing expensive coastal defences in many instances, especially in the long-term. Activities are, amongst others:

- Plan any coastal construction so that it is a safe distance away from the high-water mark and reinstate natural defence mechanisms with the necessary environmental authorisations.
- Undertake holistic planning and implementation through the development and implementation of Coastal Management Programmes that incorporate Shoreline Management Plans.
- Establish a coastal development setback line which is designed to protect both the natural environment from encroachment from buildings as well as protecting beachfront developments from the effects of storms and accelerated coastal erosion.

- Work with nature by protecting the integrity of buffer dune systems, which should be vegetated with appropriate dune species as per the original natural zones and maintained.
- Maintain, or even better, increase the sand reservoir (volume) stored in the dune system.
- Protection, restoration and maintenance of natural systems like mangroves and coral reefs.

S.3.2 Site specific adaptation options

To illustrate the assessment approach and the way the results are presented for each study site, the city of Beira is used as the example below. The results for the other study sites are presented in a similar manner in separate documents.



Adaptation / coastal protection options based on general criteria, local site characteristics and current use/"value" for Beira

The key adaptation measures found to be appropriate for Beira is summarised in the large white block in the figure, which include four "Management options" (labelled A1 to A4), three "Soft engineering"/Restoration measures (B1, B2 & B3), four "Hard engineering" & armouring options (C1s, C1r, C2, C5), and two options more suitable for low/moderate wave energy sites (C11 & C12).

The three or four options or combination of options considered most suitable for each 0.5 km alongshore section of the coast at Beira are indicated in the small white block adjacent to each marker on the map. The labels within each small block (e.g. A1 or C5, etc.) refer to the labelled options described in the large white block.

The large red numbers (1 to 4) on the figures indicate the recommended order of implementation of the identified coastal adaptation measures for Beira. In other words, the figure represents a "plan" or "map" summarising the preferred adaptation options along each 0.5 km section of the western, southern and south-eastern Beira coast.

It should be noted that specific engineering design details and accurate costing of each option can only be done once site specific engineering and environmental investigations have been carried out. It is absolutely critical to involve experienced coastal engineering and coastal environmental professionals in the detailed planning, design and implementation of the chosen options.

S.3.3 Seek opportunities for public-private-partnerships (PPP)

In many cases sound planning and future development beyond the reach of the sea forces can be implemented successfully. Many opportunities for entering into 'design-&-build' type PPP exist which have the potential to co-fund the implementation of the more costly "hard"-engineering adaptation options.

S.3.4. Continue active engagement and communication with stakeholders to disseminate the outputs and facilitate uptake

Observations by the study team during interaction with stakeholder groups at various levels of authority leads to the following recommendations presented for consideration:

The recommendations fall into three categories, namely (a) those that relate to the various decision-makers, (b) those at a more technical/scientific level, and (c) those that relate to knowledge dissemination and decision-making.

S.4 MONITORING AND EVALUATION REQUIREMENTS

S.4.1 Establish a baseline

Following on the present Phase II work, it is expected that there will be an implementation phase. In any follow up phase of work, it is essential to include as priority additional data collection and monitoring to address the critical gap in regional, national and local level data and information required to enable detailed site planning and design and to increase the level of confidence in the key sets of information on which the adaptation measures identified in this study are based.

The parameters and issues which should be monitored include the following:

- ✓ Cyclone characteristics – done when appropriate.

- ✓ Winds and local wave regime (and sea storms) – ongoing.
- ✓ Inshore sea water levels (tides and sea level trends) - ongoing
- ▪ Shoreline stability and trends (erosion / accretion) - a baseline survey as soon as possible followed by repeat surveys every three to five years, and after each major cyclone.
- ▪ Integrity of built coastal defences/structures - a baseline survey followed by repeat surveys every three to five years. This should be a critical input into an effective infrastructure maintenance plan.
- ▪ Integrity of natural coastal defences (dunes, mangroves, coral reefs, wetlands) – a baseline followed by regular repeats as appropriate. This should also be a critical input into an effective maintenance and wider integrated coastal zone management plan.
- ▪ It is of utmost importance to collect sufficiently detailed topographic and bathymetric data at identified priority areas. This can mostly be a "once off" baseline data collection task, but should be repeated at longer intervals, perhaps every 10 years for the topographic data, or immediately after any major change caused by, for example, a cyclone that will then form the new baseline.

As far as can be determined, the first three items (indicated by a tick) are being monitored to some degree or can be derived indirectly from existing monitoring actions. However, the last four items (indicated by a square dot) are not being monitored (as far as it is known). These items are also critical for any proper integrated coastal zone management and sustainable coastal developments assessments and plans. Thus, it is strongly recommended that actions be taken to ensure that effective monitoring of all the above mentioned parameters is undertaken.

As indicated, while some of the parameters need to be collected at very short time intervals (e.g. sub-hourly wind data), others need only be collected every few years (e.g. topographic data).

S.4.2 Ongoing monitoring, evaluation, dissemination and response

Building onto the recommendation on decision-support that arose through the interaction with stakeholder groups, it is considered of strategic and tactical importance to implement a national programme of ongoing monitoring and reporting of key environmental indicators that are relevant to the climate change parameters identified during this study.

The INGC has a well established and proven network for near real-time information gathering, evaluation and response during the lead up and in emergency events, such as cyclones, floods, fires etc. It is therefore recommended that a complementary network for data gathering, evaluation and information dissemination regarding climate change effects, possible trends in the identified hazard drivers, and resulting impacts to build up the scientific database and knowledge on which informed decisions can be made be set up as soon as possible.

GLOSSARY OF TERMS (DEAD & P, 2010)

Accretion	The accumulation of (beach) sediment, deposited by natural fluid flow processes
Alongshore	Parallel to and near the shoreline; same as longshore
Astronomical tide	The tidal levels and character which would result from gravitational effects, e.g. of the earth, sun and moon, without any atmospheric influences.
Bar	An offshore ridge or mound of sand, gravel, or other unconsolidated material which is submerged (at least at high tide), especially at the mouth of a river or estuary, or lying parallel to, and a short distance from, the beach.
Bathymetry	The measurement of depths of water in oceans, seas and lakes; also the information derived from such measurements.
Bay	A recess or inlet in the shore of a sea or lake between two capes or headlands, not as large as a gulf but larger than a cove.
Beach	(1) a deposit of non-cohesive material (e.g. sand, gavel) situated on the interface between dry land and the sea (or large expanse of water) and actively "worked" by present-day hydrodynamics processes (i.e. waves, tides and currents) and sometimes by winds. (2) the zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation. The seaward limit of a beach – unless otherwise specified – is the mean low water line. A beach includes foreshore and backshore. (3) (smp) the zone of unconsolidated material that is moved by waves, wind and tidal currents, extending landward to the coastline.
Beach erosion	The carrying away of beach materials by wave action, tidal currents, littoral currents or wind.
Beach profile	A cross-section taken perpendicular to a given beach contour, the profile may include the face of a dune or seawall, extend over the backshore, across the foreshore, and seaward underwater into the nearshore zone.
Bed	The bottom of a watercourse, or any body of water.
Benefits	The economic value of a scheme, usually measured in terms of the cost of damages avoided by the scheme, or the valuation of perceived amenity or environmental improvements.
Buffer area	A parcel or strip of land that is designed and designated to permanently remain vegetated in an undisturbed and natural condition to protect an adjacent aquatic or wetland site from upland impacts, to provide habitat for wildlife and to afford limited access.
Cay	A small, low island composed largely or coral or sand.
Cliff	A high steep face of rock.
Climate change	Refers to any long-term trend in mean sea level, wave height, wind speed, drift rate etc.
Coast	A strip of land of indefinite length and width (may be tens of kilometres) that extends from the seashore inland to the first major change in terrain features.
Coastal management	The development of a strategic, long-term and sustainable land use policy, sometimes also called shoreline management.
Coastal processes	Collective term covering the action of natural forces on the shoreline, and the nearshore seabed.
Coastal zone	The land-sea air interface zone around continents and islands extending from the landward edge or a barrier or shoreline of coastal bay to the outer extent of the continental shelf. In its wider meaning it is often taken as extending landward up to where littoral processes are active or could have an effect (which could be some kilometres inland in certain areas).

Coastline	(1) technically, the line that forms the boundary between the coast and the shore. (2) commonly, the line that forms the boundary between land and water. (3) (smp) the line where terrestrial processes give way to marine processes, tidal currents, wind waves, etc.
Conservation	The protection of an area, or particular element within an area, accepting the dynamic nature of the environment and therefore allowing change.
Continental shelf	The zone bordering a continent extending from the line of permanent immersion to the depth, usually about 100 m to 200 m, where there is a marked or rather steep descent toward the great depths.
Contour line	A line connecting points, on a land surface or sea bottom, which have equal elevation. It is called an isobaths when connecting points of equal depth below a datum.
Cross-shore	Perpendicular to the shoreline.
Debris line	A line near the limit of storm wave up-rush marking the landward limit of debris deposits.
Deep water	In regard to waves, where depth is greater than one-half the wave length. Deep-water conditions are said to exist when the surf waves are not affected by conditions on the bottom.
Deep water waves	A wave in water the depth of which is greater than one-half the wave length.
Depth	Vertical distance from still-water level (or datum as specified) to the bottom.
Design storm	Coastal protection structures will often be designed to withstand wave attack by the extreme design storm. The severity of the storm (i.e. return period) is chosen in view of the acceptable level of risk of damage or failure. A design storm consists of a design wave condition, a design water level and a duration.
Design wave	In the design of harbours, harbour works, etc. the type or types of waves selected as having the characteristics against which protection is desired.
Direction of waves	Direction from which waves are coming.
Direction of wind	Direction from which wind is blowing.
Dunes	(1) Accumulations of windblown sand on the backshore, usually in the form of small hills or ridges, stabilized by vegetation or control structures. (2) a type of bed form indicating significant sediment transport over a sandy seabed.
Duration	In forecasting waves, the length of time the wind blows in essentially the same.
Ecosystem	The living organisms and the non-living environment interacting in a given area.
Erosion	Wearing away of the land by natural forces. (1) On a beach, the carrying away of beach material by wave action, tidal currents or by deflation. (2) The wearing away of land by the action of natural forces.
Estuary	(1) a semi-enclosed coastal body of water which has a free connection with the open sea. The seawater is usually measurably diluted with freshwater. (2) the part of the river that is affected by tides.
Event	An occurrence meeting specified conditions, e.g. damage, a threshold wave height or a threshold water level.
Fetch	The length of unobstructed open sea surface across which the wind can generate waves (generating area).
Fetch length	(1) the horizontal distance (in the direction of the wind) over which a wind generates seas or creates wind setup. (2) the horizontal distance along open water over which the wind blows and generates waves.
Gabion	(1) steel wire-mesh basket to hold stones or crushed rock to protect a bank or bottom from erosion.
Geology	The science which treats of the original, history and structure of the earth, as recorded in rocks, together with the forces and processes now operating to modify rocks.
Georeferencing	The process of scaling, rotating, translating and de-skewing the image to match a particular size and position (2) establishing the location of an image in terms of map projections or coordinate systems.
High water (HW)	Maximum height reached by a rising tide. The height may be solely due to the periodic tidal forces or it may have superimposed upon it the effects of prevailing meteorological

	conditions. Non-technically, also called the high tide.
High water mark	A reference mark on a structure or natural object, indicating the maximum stage of tide or flood.
Mean high water springs (MHWS)	The average height of the high water occurring at the time of spring tides.
Mean sea level (MSL)	The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings.
Ocean	The great body of salt water which occupies two-thirds of the surface of the earth, or one of its major subdivisions.
Offshore	(1) in beach terminology, the comparatively flat zone of variable width, extending from the shoreface to the edge of the continental shelf. It is continually submerged. (2) the direction seaward from the shore. (3) the zone beyond the nearshore zone where sediment motion induced by wave alone effectively ceases and where the influence of the sea bed on wave action is small in comparison with the effect of wind. (4) the breaker directly seaward of the low tide line.
Offshore wind	A wind blowing seaward from the land in the coastal area.
Outcrop	A surface exposure of bare rock, not covered by soil or vegetation.
Overtopping	Water carried over the top of a coastal defence due to wave run-up or surge action exceeding the crest height.
Peak period	The wave period determined by the inverse of the frequency at which the wave energy spectrum reaches it's maximum.
Photogrammetry	The science of deducing the physical dimensions of objects from measurements on images (usually photographs) of the objects.
Port	A place where vessels may discharge or receive cargo.
Reach	(1) an arm of the ocean extending into the land. (2) a straight section of restricted waterway of considerable extent; may be similar to a narrows, except much longer in extent.
Recession	(a) a continuing landward movement of the shoreline. (2) a net landward movement of the shoreline over a specified time.
Refraction	The process by which the direction of a wave moving in shallow water at an angle to the bottom contours is changed. The part of the wave moving shoreward in shallower water travels more slowly than that portion in deeper water, causing the wave to turn or bend to become parallel to the contours.
Retum period	Average period of time between occurrences of a given event.
Revetment	(1) a facing of stone, concrete, etc., to protect an embankment, or shore structure, against erosion by wave action or currents. (2) a retaining wall. (3) (smp) facing of stone, concrete, etc., built to protect a scarp, embankment or shore structure against erosion by waves of currents.
Rocks	An aggregate of one or more minerals rather large in area. The three classes of rocks are the following: (1) igeneous rock – crystalline rocks formed from molten material. Examples are granite and basalt. (2) sedimentary rock – a rock resulting from the consolidation of loose sediment that has accumulated in layers. Examples are sandstone, shale and limestone. (3) metamorphic rock – rock that has formed from pre-existing rock as a result of heat or pressure.
Run-up	The rush of water up a structure or beach on the breaking of a wave. The amount of run-up is the vertical height above still-water level that the rush of water reaches.
Sand	An unconsolidated (geologically) mixture of inorganic soil (that may include disintegrated shells and coral) consisting of small but easily distinguishable grains ranging in size from about .062 mm to 2.0 mm.
Scour protection	Protection against erosion of the seabed in front of the toe.
Sea defences	Works to prevent or alleviate flooding by the sea.
Sea level rise	The long-term trend in mean sea level.
Seawall	(1) a structure built along a portion of a coast primarily to prevent erosion and other damage by wave action. It retains earth against its shoreward face. (2) (smp) a structure

	separating land and water areas primarily to prevent erosion and other damage by wave action. Generally more massive and capable of resisting greater wave forces than a bulkhead.
Sediment transport	The main agencies by which sedimentary materials are moved are: gravity (gravity transport); running water (rivers and streams); ice (glaciers); wind; the sea (currents and longshore drift). Running water and wind are the most widespread transporting agents. In both cases, three mechanisms operate, although the particle size of the transported material involved is very different, owing to the differences in density and viscosity of air and water. The three processes are: rolling or traction, in which the particle moves along the bed but is too heavy to be lifted from it; saltation and suspension, in which particles remain permanently above the bed, sustained there by the turbulent flow of the air or water.
Setback	(smp) a required open space, specified in shoreline master programs, measured horizontally upland from a perpendicular to the ordinary high water mark. More commonly used in CZM and coastal engineering terms as a required distance landward of a selected contour line (or the shoreline) to safeguard e.g. infrastructure from marine impacts (such as storm waves or esosion).
Shallow water	Water of such depth that surface waves are noticeably affected by bottom topography. Typically this implies a water depth equivalent to less than half the wave length.
Shoal	(1) (noun) a detached area of any material except rock or coral. The depths over it are a danger to surface navigation. Similar continental or insular shelf features of greater depths are usually termed banks. (2) (verb) to become shallow gradually. (3) to cause to become shallow. (4) to proceed from a greater to a lesser depth of water.
Shore	That strip of ground bordering any body of water which is alternatively exposed, or covered by tides and/or waves. A shore of unconsolidated material is usually called a beach. The *shoreline* is often used as the term for delineating between the land and the sea (e.g. selected as the 0 m to MSL contour line).
Significant wave height	Average height of the highest one-third of the waves for a stated interval of time.
Significant wave period	Average period of the highest one-third of the waves for a stated interval of time.
Soft defences	Usually refers to beaches (natural or designed) but may also relate to energy –absorbing beach-control structures, including those constructed of rock, where these are used to control or redirect coastal processes rather than opposing or preventing them.
Spring tide	A tide that occurs at or near the time of new or full moon, and which rises highest and falls lowest from the mean sea level (msl).
Stillwater level (SWL)	The surface of the water if all wave and wind action were to cease. In deep water this level approximates the midpoint of the wave height. In shallow water it is nearer to the trough than the crest. Also called the undisturbed water level.
Surf zone	The nearshore zone along which the waves become breakers as the approach the shore.
Surf zone	The zone of wave action extending from the water line (which varies with tide, surge, set-up, etc). Out to the most seaward of the zone (breaker zone) at which waves approaching the coastline commence breaking, typically in water depths of between 5 m and 10 m.
Surge	(1) long-interval variations in velocity and pressure in fluid flow, not necessarily periodic, perhaps even transient in nature. (2) the name applied to wave motion with a period intermediate between that of an ordinary wind and that of a tide. (3) changes in water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and that predicted using harmonic analysis, may be positive or negative. (2) NOAA: *Storm surge*: "A rise or piling-up of water against shore, produced by strong winds blowing onshore. A storm surge is most severe when it occurs in conjunction with a high tide." (3) Expansion by the authors:In southern Africa, sea storms (i.e. high waves with run-up, impacts and scouring) are also a big risk; these can be exacerbated by strong winds and high tides.

Survey, control	A survey that provides coordinates (horizontal or vertical) of point to which supplementary surveys are adjusted.
Survey, hydrographic	A survey that has as its principal purpose the determination of geometric and dynamic characteristics of bodies of water.
Survey, photogrammetric	A survey in which monuments are placed at points that have been determined photogrammetrically.
Survey, topographic	A survey which has, for its major purpose, the determination of the configuration (relief) of the surface of the land and the location of natural and artificial objects thereon.
Swash zone	The zone of wave action on the beach, which moves as water levels vary, extending from the limit of run-down to the limit of run-up.
Swell	Waves that have travelled a long distance from their generating area and have been sorted out by travel into long waves of the same approximate period.
Toe	(1) lowest part of sea- and portside breakwater slope, generally forming the transition to the seabed. (2) the point of break in slope between a dune and a beach face.
Topographic map	A map on which elevations are shown by means of contour lines.
Updrift	The direction to which the predominant longshore movement of beach material approaches.
Wave crest	(1) the highest part of the wave. (2) that part of the wave above still water level.
Wave direction	The direction from which the waves are coming.
Wave height	The vertical distance between the crest (the high point of the wave) and the trough (the low point).
Wave hindcast	The calculation from historic synoptic weather charts of the wave characteristics that probably occurred at some past time.
Wave length	The distance, in meters, between equivalent points (crests or troughs) on waves. Wave period: (1) the time required for two successive wave crests to pass a fixed point. (2) the time, in seconds, required for a wave crest to traverse a distance equal to one wave length.
Wave rose	Diagram showing the long-term distribution of wave height and direction.
Wave set-up	Elevation of the still-water level due to breaking waves.
Wave steepness	The ratio of wave height to its length. Not the same thing as the slope between a wave crest and its adjacent trough.
Wave train	A series of waves from the same direction.
Wave trough	The lowest part of the wave form between crests. Also that part of a wave below still water level.
Wave variability	(1) the variation of heights and periods between individual waves within a wave train. Wave trains are not composed of waves of equal heights and periods which vary in a statistical manner. (2) the variability in direction of wave travel when leaving the generating area. (3) the variation in height along the crest.
Wind rose	Diagram showing the long-term distribution of wind speed and direction.
Wind setup	(1) the vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water. (2) the difference in stillwater levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water. (3) synonymous with wind, tide and storm surge. (Storm surge is sometimes reserved for use on the ocean and large bodies of water. Wind setup is sometimes reserved for use on reservoirs and smaller bodies of water. This “incorrect” distinction is not employed in this report.)
Wind waves	(1) waves formed and growing in height under the influence of wind. (2) loosely, any wave generated by wind.
World Geodetic System, 1984 (revised 2004)	An earth fixed global reference frame used for defining coordinates when surveying and by GPS systems.

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