3 BASELINE ENVIRONMENT

3.1 Site Location

The site lies within the districts of Grand Port along the Flacq-Mahebourg Coast Road (B28) between the villages of Pointe aux Feuilles and Grand Sable and is about 725 m long.

The location plan of the site is shown in Drawing M190/PAF-GS/DD/01 in Appendix C.

3.2 Site Context

3.2.1 General

The site shoreline comprises the 725m long waterfront between the 'Ferme Marine de Mahebourg' at Pointes aux Feuilles and a temple at the northern extremity of Grand Sable village, as shown in Figure 3-1. The site lies about 5km from the fringing reef and is exposed to the ocean through a reef opening (Figure 3-1, Figure 3-2). B28 Road runs on the landward side of the site, forming a narrow strip of land from the coastline.

The site environs and key features within a 1km radius are depicted in Drawing M190/PAS-GS/EV/01.



Figure 3-1: Pointes aux Feuilles – Grand Sable Site and Environs



Figure 3-2: Site Environs - Seaward side

3.2.2 Built Environment

There are no developments at the site except the headquarters of the marine farm at its northern limit and the outskirts of the village of Grand Sable to the south. The Bambou Mountains lie immediately to the north of the site (Figure 3-1).

3.2.3 Airport Obstacle Limitation Surface

The site does not fall within the obstacle limitation surfaces of the Sir Seewoosagur Ramgoolam International Airport, which is situated some 15km to the south east.

3.3 Environmentally Sensitive Areas (ESAs)

3.3.1 General

There are no ESAs at the site. However, according to the ESA Report (2009), the following ESAs are located within a 1km radius from the site boundaries:

- Sea grass in the lagoon area in an embayment to the south west of the site
- Feeder Festival, Feeder Mapou and Feeder Grand Sable to the south west and unnamed natural water courses to the north of the site (Figure 3-1)
- Mud flats to the south west
- Coral reefs to the east and south east

3.3.2 Watercourses

There are no natural water courses on the site. The nearest natural watercourse is located at some 60m to the south west of the site. Feeder Festival, Feeder Mapou and Feeder Grand Sable are located further south at about 470, 480 and 900m respectively. Two other unnamed natural watercourses are located at some 200m and 450m to the north of the site at Pointe aux Feuilles.

In view of their respective significant distances from the project site, these watercourses will not be impacted by the project.

3.3.3 Tidal Mudflats

There are no tidal mudflats at the site. The ESA Report mentions the existence of a tidal mudflat along the coastline at Grand Sable, located some 200m to the south west of the site boundary.

As per the ESA Report (2009), other than the Rivulet Terre Rouge Estuary Bird Sanctuary, all other tidal mudflats are rated Category II on its role in defining terrestrial-marine ecotone and sediment control.

3.3.4 Mangroves

Mangroves were not identified at the site during the field surveys.

3.3.5 Sea Grass

There are no sea grasses at the site.

According to the ESA Report 2009, the lagoon to the south of the site contains sea grasses.

The ecological survey carried out by Diospyros Ltd, which covered some 50m of the lagoon from the shoreline has not revealed the existence of sea grass beds within the study area.

3.3.6 Coral Reef

The nearest coral reef is at some 5km to the east of the site and as such will not be impacted by the proposed works.

3.4 Physical Site Description/Existing Situation

3.4.1 Site Limits

The limits of the site are defined by a fish breeding station (Ferme Marine de Mahebourg) at the northern end and a temple at the start of Grand Sable village at the southern end as shown in Figure 3-3.



Figure 3-3: Site Limits

3.4.2 Land Use Survey

The site has the following land uses/activities and features:

- Public road along the whole length of the site waterfront
- Marine farm at the northern end of the site
- Temple at the southern end of the site
- Old fortification
- Agricultural and farrow lands to the north.



Public road



Temple





Fortification building





Fish breeding farm

Disused bench at southern end





Sugar cane cultivation N of site

Figure 3-4 Land Use

3.4.3 Site Topography

The site has been topographically surveyed along the waterfront strip between the inner edge of the coast road and the High-Water Mark (HWM).

The surveys carried out at this site have also been tied to the Mauritius geodetic network named 'Local Grid Mauritius' (LGM2012), as established by the Ministry of Housing and Lands.

The features surveyed have been mapped as represented in Drawings M190/PAF-GS/DD/02, M190/PAF-GS/DD/03 and M190/PAF-GS/DD/04.

3.4.4 Lagoon Bathymetry

The lagoon at the site has also been bathymetrically surveyed and mapped up to the -1.5m MSL contour along the site waterfront.

The -1.0m MSL seabed contour lies approx. 40m off the high-water line at the northern end of the site and about 125m off the high-water line at the southern end.

The seabed contours are shown in Drawings M190/PAF-GS/DD/02, M190/PAF-GS/DD/03 and M190/PAF-GS/DD/04.

3.4.5 Stormwater Drainage

Stormwater from higher grounds at the site drains towards B28 Road and discharges to the sea through 12 culverts that cross the coast road at various intervals at the site (Figure 3-5).

Roadside, open drains exist over almost the entire length of the landward side of the Coast Road as shown Drawings M190/PAF-GS/DD/02, M190/PAF-GS/DD/03 and M190/PAF-GS/DD/04. These drains intercept and channel surface run-off from the higher grounds to these culverts.



Open stone masonry drain



Pipe culvert outlet



Culvert outlet in stone masonry wall



Erosion at outlet



Open drain along inland side of coast road



Collector of open drain to culvert discharge

Figure 3-5: Storm Water Drainage

According to the 1:25000 survey sheets of Mauritius, there are no classified watercourses at the site.

3.4.6 Services/Utilities Infrastructure

Power, potable water and telecommunication networks exist near the site and run under or alongside the coast road. Water infrastructure is mainly underground. Overhead electricity and telecommunication lines run off the landward side of the Coast Road, with underground telecommunication cables running along its seaward side. Cracks are visible at several locations along the Coast Road at the site.





Overhead Utilities





Underground Utilities





Cracks on road at site

Figure 3-6 Utilities/Infrastructure at Site

3.5 Site Conditions

3.5.1 Waterfront Features

The site waterfront lies along B28 Road over a length of about 725m and presents a convex curvature to the sea. The road is retained by a stone masonry wall along almost the entire site waterfront, except at the small headlands at either end of the site and midway.

The highest point of the headland at the northern limit of the site is at +4.5m MSL and ground level is about +3.5m MSL at the southern limit. In between, the road dips to a lowest point at +2.53m MSL.

The HWM lies at the foot of the road retaining wall along the major part of the site.

The shoreline comprises greyish to pale, yellow sand to sandy-silt, consisting of gravels, fragmented corals and shells pebbles overlain with pebbles and occasional boulders.

The stone masonry retaining wall has been undermined at several places and small erosion escarpments exist where there is no retaining wall (Figure 3-7).



Western limit of Site near marine farm



Southern limit of Site near Grand Sable temple



Existing shoreline: headland



Existing shoreline: masonry wall



Undermined stone masonry retaining wall



Scarp at headland

Figure 3-7: Site Waterfront

3.5.2 Coast Road (B28 Road)

The horizontal alignment of the Coast Road (Figure 3-8) comprises generally three straights and three curves. The vertical alignment of the road has low points at CH 111 (level +2.53m MSL) and CH 607 (level +2.63m MSL) and highest road level of +4.42m MSL is at CH 353. (The CH 0 point is near the temple). The road cambers alternately towards the sea, reverses to landward and again to seaward along the length. The road is retained by a stone masonry wall over most of the site, except at the small headlands at either end of the site and midway.





Figure 3-8: Coast Road (B28)

No pedestrian facilities were noted at either the landward side of seaward side of the coast road and inhabitants of the localities perforce walk on the carriageway pavement.

3.5.3 Aquaculture

According to information obtained from the Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping, floating cages for aquaculture are operational at Grande Riviere Sud Est, Quatre Soeurs, Pointe aux Feuilles and Bambous Virieux. The marine farm at Pointe aux Feuilles is operated by Ferme Marine de Mahebourg (FMM).

The two sites operated by FMM at Pointe aux Feuilles are located at approximately 3km from the coast where the water depth is 25m[4]. These sites are beyond the 1km project study area.

3.6 Biodiversity/Ecology

3.6.1 General

An ecological study was carried out at the site during the preliminary design stage of the project for the purpose of providing baseline terrestrial and marine ecological information to allow the successful planning of coastal protection measures in relation to the biodiversity and ecosystems present and their relative sensitivity to impacts.

The surveys and assessment of the coastal and lagoon ecosystems were done in terms of:

- Flora, fauna and ecological compositions, diversity, state of health
- Biotopes, species composition, their relative abundance and state of health
- Ecological sensitivity of the different biotopes
- Geomorphological zonation of the affected lagoon area.

The findings of the biodiversity report are given in the following sub-section while the Biodiversity Survey Report is enclosed in Appendix B.

3.6.2 Terrestrial Environment

Flora

The coastal vegetation along this stretch is poor as a result of the limited space available, except along the ledge. The only native species present are a few Thespesia populnea or Sainte Marie trees and some Ipomoea pes-caprae or liane batatran plants. Alien plants which consist mainly of Pongamia pinnata or coqueluche (a proclaimed invasive), Terminalia catappa or badamier trees and Cocos nucifera or coconut trees are common along the edge of the road.

Fauna

No terrestrial fauna was seen during the visits.

[4] *Information obtained from FMM website http://www.fmm.mu/*

3.6.3 Marine Environment

Flora

The pebble beach in the upper eulittoral zone has no algal cover. However, the subtidal pebble zone is quite densely covered by algae of the Gracillaria, Eucheuma and similar groups.

Fauna

Annelid – Polychaete worms

At least two species are common, even abundant, in the sand of the upper eulittoral zone.

Crustacea

No crabs or other Crustacea were seen.

Mollusca

Apart from the polychaetes, the only other fauna present were gastropod snails in the upper eulittoral and subtidal zones and bivalves (mussels) in the lower eulittoral and subtidal zone.

Gastropods

Clopeomorus bifasciatus occasional in the eulittoral zone, Drupella rugosa present in the eulittoral zone, Littoraria glabrata in the supratidal zone, Morula granulate common in the lower eulittoral and subtidal zones, Nerita plicata occasional in the supratidal zone, Nerita undata common in the lower eulittoral to subtidal zones Planaxis sulcatus common forming patches on the rocks in the upper eulittoral zone.

Bivalves

The mussel Brachyodontes variabilis was common, covering some boulders and rocks with a dense mat in the lower eulittoral to subtidal zones. The oyster Saccostrea cucullata was occasional in the eulittoral zone.

Echinoderms

No echinoderms were seen.

Fish

Two specimens of Lethrinus harak or batardé were seen in the shallow channel past the pebble beds.

The Biodiversity Survey Report is enclosed in Appendix B.

3.7 Geomorphology and Sediment Survey

3.7.1 Geology

The geological map of Mauritius (Figure 3-9) indicates that the Pointe aux Feuilles – Grand Sable site was formed from ancient volcanism of basaltic flows along the coast.

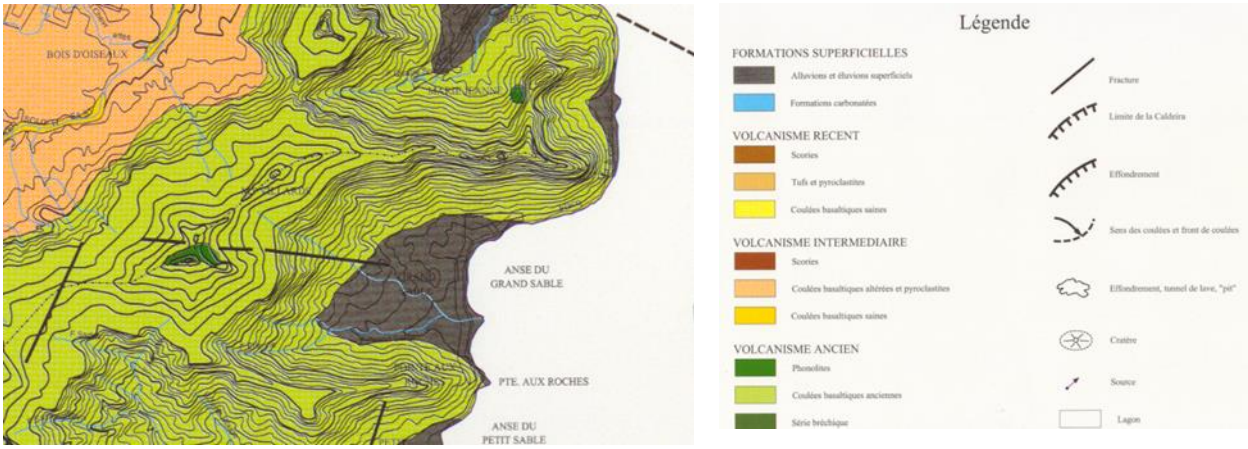


Figure 3-9: Site Geology

The natural strata of site consist of *Mountain Slopes Complexes S1* and some *Regosols* (Coral Sand) along the coast, which occurs on deep unconsolidated coral around the coast line. Coral sand is a mixture of fragmented corals, shells and sand.

3.7.2 Site Observations

The site lies to the ESE of Mt Villars (Figure 3-10). Along the western stretch of the site, the road is retained by masonry and concrete walls, which have been damaged at several locations, most probably from wave attacks. These retaining structures have also been damaged by trees (Figure 3 11).

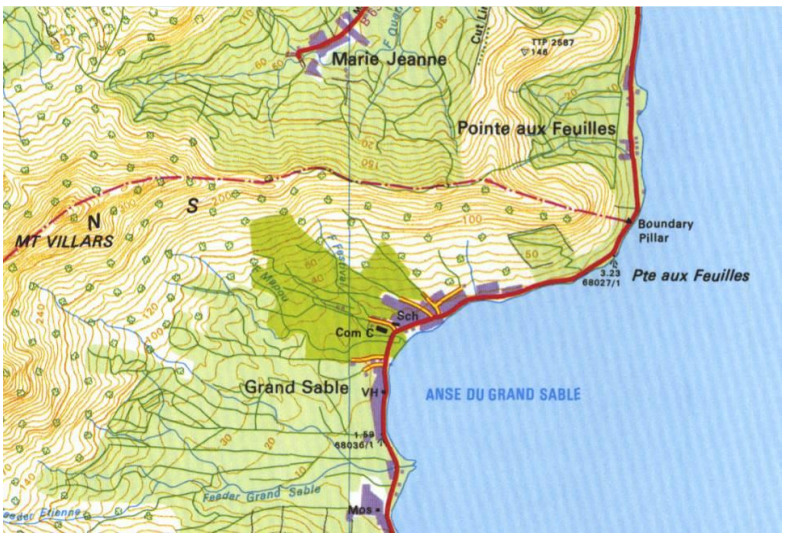


Figure 3-10: General Topography at Site Environs



Damage to road retaining wall



Trees growing in road retaining wall

Figure 3-11: Road retaining Wall

Along the eastern part of the site, there is a ledge of soil between the coast road and the shore, with widths up to 16m near the marine farm (Figure 3-12).





Figure 3-12: Road Verge

3.7.3 Sediment Sampling and Test Results

Sediment sampling was carried out along five profiles at this site. These were collected at the High-Water Mark, Mean Sea Level, the Low Water Mark and at the -1 m contour respectively. Drawing No M190/PAF-GS/EV/02 shows the locations of the collected samples. During the sampling exercise, particle sizes greater than 63 mm were discarded.

Sixteen samples were collected and tested for grain size. Dry sieving was carried out in the range of 63 mm to 63-micron particle size.

Based on the laboratory test results, the upper stratum at the site comprises pale yellow gravelly sand to sand of coralline origin, consisting of fragmented corals, shells and sand. Test results show that the sediment distribution from the coast seaward varies from sandy gravel to gravelly sand (ie, distribution of particles/grains from coarse to fine fraction).

Table 3-1 presents a summary of the soil classification at the site.

Table 3-1: Summary of Soil Classification

Water Mark	Sample Location				
	SM/0	SM/60	SM/120	SM/180	SM/240
High (H)	Gravelly Sand	Gravelly Sand	Gravelly Sand	Gravelly Sand	Sand
Mean (M)	Gravelly Sand	Gravelly Sand	Gravelly Sand	Gravelly Sand	Gravelly Sand
Low (L)	Gravelly Sand	Sandy Gravel	Sandy Gravel	Gravelly Sand	Gravelly Sand
Chart Datum (CD)	Gravelly Sand	Gravelly Sand	Gravelly Sand	Gravelly Sand	Sand

3.8 Sediment Transport and Morphology

3.8.1 General

The Pointe aux Feuilles to Grand Sable site faces ESE onto a shallow lagoon with fringing reef approximately 5.2 km offshore at its nearest point. There is also a reef to the SE of the site.

The waterfront is exposed to waves from the ESE to ENE directions. The cyclone design conditions are characterized by large locally generated sea waves, but significant swell waves with longer periods are also experienced. The protection provided by the reef does limits the size of the swell reaching the site through wave breaking and dissipation of wave energy

3.8.2 Sediment Transport and Morphology

Figure 3-13 compares aerial image in 1999 and 2013 which indicates that the shoreline has been relatively stable. The coastline is in an eroded state with a very narrow intertidal zone along the Coast Road and narrow strips of vegetation still present along some coastal transects. The coastal road present along the site is a hard structure preventing further recession of the coastline.



Figure 3-13: Historical aerial image from 1999 (left) and google earth image from 2013 (Right)

The direction of the mean wave energy flux under operational conditions are presented in Figure 3-14 as well as wave roses at two points along the site..

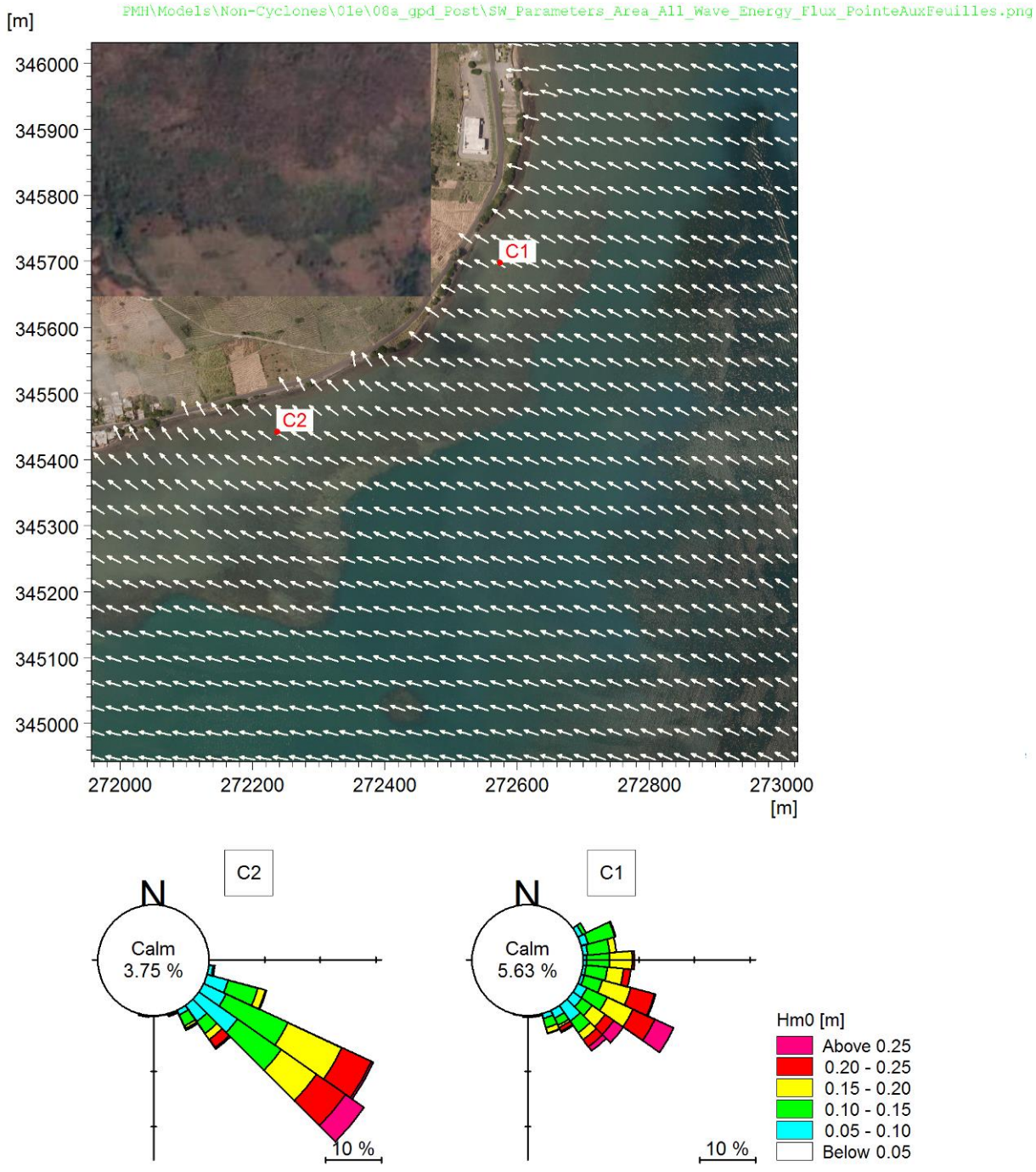


Figure 3-14: Direction of mean wave energy flux (top) and wave rose (bottom)

The direction of the mean wave energy flux shows a divergence of potential longshore sediment transport along the site due to the convex shape of the coastline. To the south of the site there is a southward longshore sediment transport potential and to the north of the site the wave energy flux direction is more shore normal and slightly northward resulting in low longshore transport potential.

There are no rivers providing the site with a steady supply of sediment and it is sand starved. It can be observed that the morphology of the site has not changed significantly over time as a result of the hardened coastline and lack of sediment supply.

3.9 Risks and Impacts of Climate Change

The site elevation varies between +2.53 m MSL and +4.5 m MSL. Comparing these levels to run-up levels in Table 3-8 it is seen that the site is vulnerable to flooding during a 10 year storm in 2020 and will experience severe overtopping and flooding taking into account climate change to 2070.

3.10 Coastal Hydrodynamics – Baseline Modelling

3.10.1 Water Level Analysis

Water level data measured at Port Louis was available from the University of Hawaii Sea Level Center (Caldwell, et al., 2015). The dataset comprises measured water levels for a period of 31.2 years between 1986 and 2017. The vertical datum of the raw dataset is “Tide Staff Zero”, which is 1.321 m below Chart Datum (CD) (Mauritius Meteorological Services, 2016). At Port Louis, Chart Datum is 0.37 m below Land Levelling Datum (LLD), which is also commonly referred to as Mean Sea Level (MSL). The raw measured data is shown relative to MSL in Figure 3-15:.

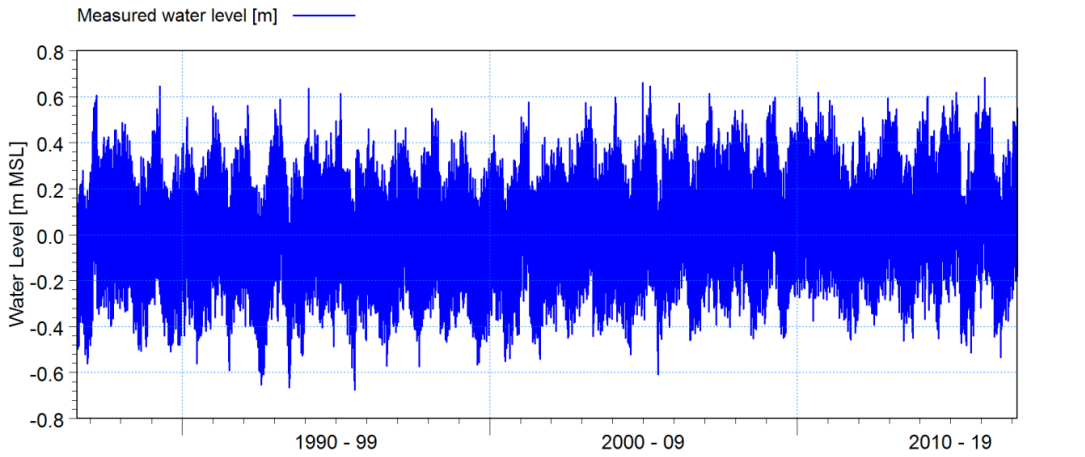


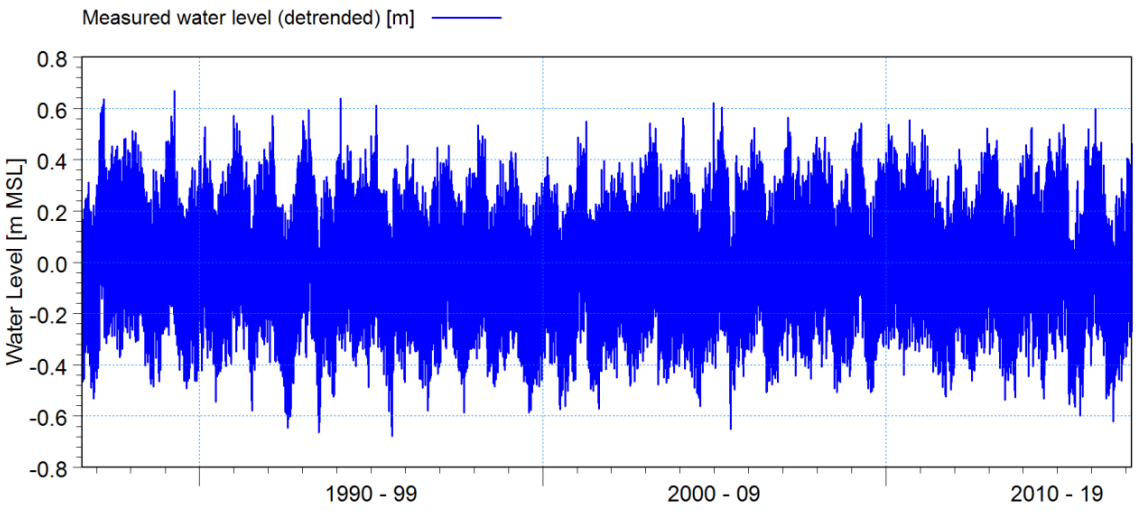
Figure 3-15: Raw water level data measures at Port Louis (Caldwell, et al, 2015), shown relative to Mean Sea Level (MSL)

3.10.2 Tide Levels

The measured water level data presented a notable long-term trend in the mean water level. Prior to conducting a tidal analysis of the measurements, the trend in the long-term data was removed. This was done applying a linearly-varying correction based on a trend line fitted through the data.

The correction was applied such that the mean level of the de-trended dataset is equal to the mean level of the original dataset at 1995, calculated as the average of

the period of 1986-2005. This was done in order to have a baseline water level dataset which could be compared against the projections for sea level rise, which use 1995 as a baseline date.



\PMH\Data\Water Levels\UHSLC\UHSLC PortLouis UTC Timeseries Detrended ML1995.png

Figure 3-16 Water level data measured at Port Louis (Caldwell, et al., 2015). The data shown was detrended, with a mean level equal to the measured mean level at 1995, calculated as the average over 1986-2005.

A tidal harmonic analysis was carried out on the de-trended dataset, using the Tidal Analysis of Heights Tool in the MIKE 21 Toolbox (DHI, 2016e). The output of the tool is a set of tidal constituents for the site. Using the same tool, the tide at Port Louis was predicted using the constituents obtained from the analysis. The resulting predicted tidal water levels are presented in Table 3-2 relative to MSL and to CD.

Table 3-2 Predicted tidal water levels carried out through analysis of the de-trended water level measurements at Port-Louis. The ML of the de-trended dataset corresponds to the mean level in 1995, calculated as the average over 1986-2005

Tide Level	Predicted from de-trended measurements (m MSL)	Predicted from de-trended measurements (m CD)
Highest Astronomical Tide (HAT)	0.458	0.828
Mean High Water Springs (MHWS)	0.278	0.648
Mean High Water Neaps (MHWN)	0.072	0.442
Mean Level (ML)	0.004	0.374
Mean Low Water Neaps (MLWN)	-0.062	0.308
Mean Low Water Springs (MLWS)	-0.247	0.123
Lowest Astronomical Tide (LAT)	-0.498	-0.128

The maximum measured residual tide is approximately 0.5m. Most of the residuals appear to be associated with cyclones.

3.10.3 Climate Change and Sea Level Rise

The measured tidal data was used to estimate the average sea level rise (SLR) for different time periods. Based on analysis of the Port Louis tidal measurements the following SLR trends have been determined (as shown in Figure 3-17:):

- +3.9 mm/yr for 1986 to 2016 (all 30 years)
- -3.2 mm/yr for 1986 to 2000 (first 15 years)
- +6.1 mm/yr for 2001 to 2016 (last 15 years).

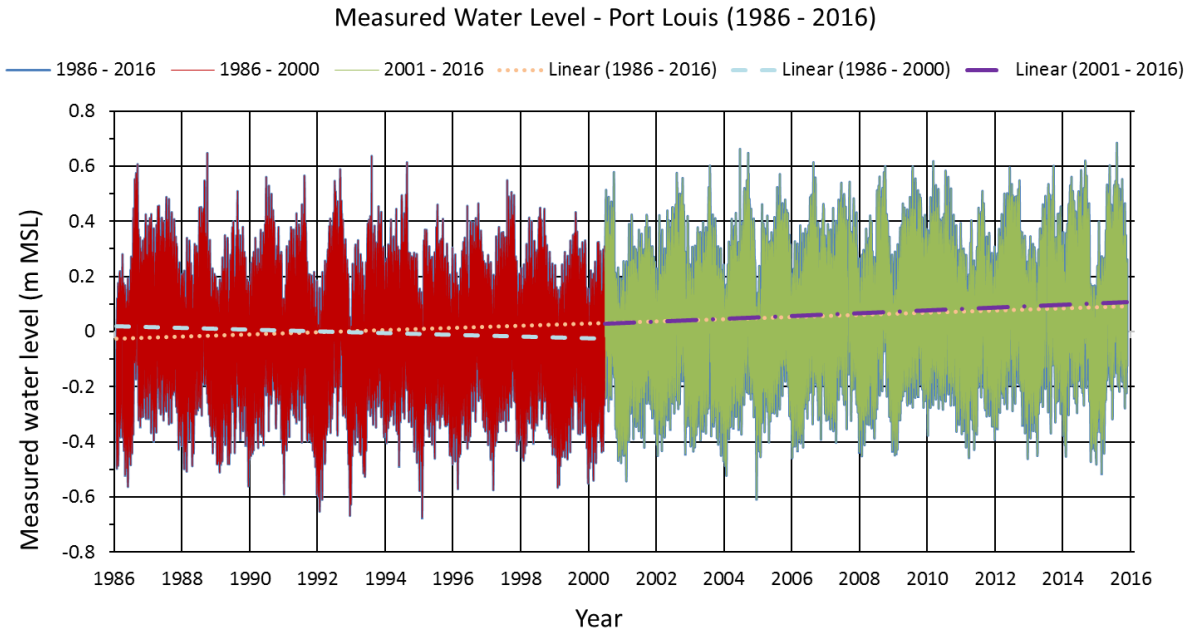


Figure 3-17: Measured Water Level at Port Louis with SLR Trend Lines

The data indicates that some variability is visible in the region's water levels, but in general an increasing trend in the mean water level has been observed.

3.11 Climate

3.11.1 Water Levels

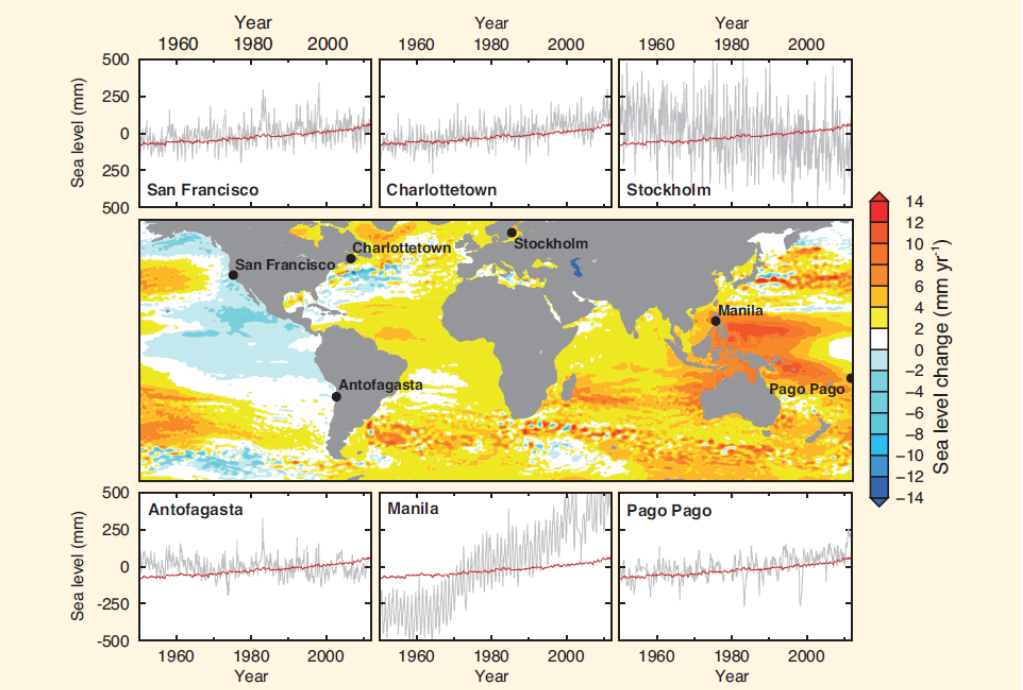
Various literature references were consulted, including the previous project studies. The key findings are summarised below:

- SLR dropped between 1986 and 2000 at Port Louis due to regional water level variability (Church,2006)
- +1.5 mm/yr at Port Louis including measurements in the 1950s and 1960s (Church, 2006)
- +2.1 mm/yr based on tidal data for 2003 to 2013 as sourced by Mauritius Meteorological Services (JICA, 2016)
- The IPCC (2013) estimates an average SLR between 1993-2010 of 3.2 mm/yr (ranging between 2.8 to 3.6 mm)
- +3.9 mm/yr for an analysis of the Port Louis tidal data 1986 to 2013 (JICA, 2016)
- +5.6 mm/yr has been predicted for the period 2003-2012 by the Sea Level Rise centre of the University of Hawaii (Thompson et al, 2016) as referenced by (JICA, 2016)
- +3.9 mm/yr for 1986 to 2016 (all 30 years) based on an analysis of the Port Louis data (discussed in Section 3.10 above)

- -3.2 mm/yr for 1986 to 2000 (first 15 years) based on an analysis of the Port Louis data (discussed in Section 3.10 above)
- +6.1 mm/yr for 2001 to 2016 (last 15 years) based on an analysis of the Port Louis data (discussed in Section 3.10 above)
- Mauritius is situated in a region which experienced ~6 mm/yr SLR in the period between 1993 – 2012, which is above the global average (IPCC, 2013) as shown in Figure 3-18:.

Based upon the literature and the measured data for Port Louis, Mauritius appears to be near to the upper limit of the current global SLR observations.

The global mean sea level rise projections (IPCC, 2013) provide a basis for estimating the SLR for different years in the future. The recommended upper limit SLR can be predicted based upon the upper limit of the peer-reviewed climate models (as shown in Figure 3-18:). This translates to an SLR of 0.25 m for 2040 and 0.55 m for 2070.



FAQ13.1, Figure 1 | Map of rates of change in sea surface height (geocentric sea level) for the period 1993–2012 from satellite altimetry. Also shown are relative sea level changes (grey lines) from selected tide gauge stations for the period 1950–2012. For comparison, an estimate of global mean sea level change is also shown (red lines) with each tide gauge time series. The relatively large, short-term oscillations in local sea level (grey lines) are due to the natural climate variability described in the main text. For example, the large, regular deviations at Pago Pago are associated with the El Niño-Southern Oscillation.

Figure 3-18: Extract from Chapter 13 - Sea level change in the Fifth Assessment Report (IPCC,2013)

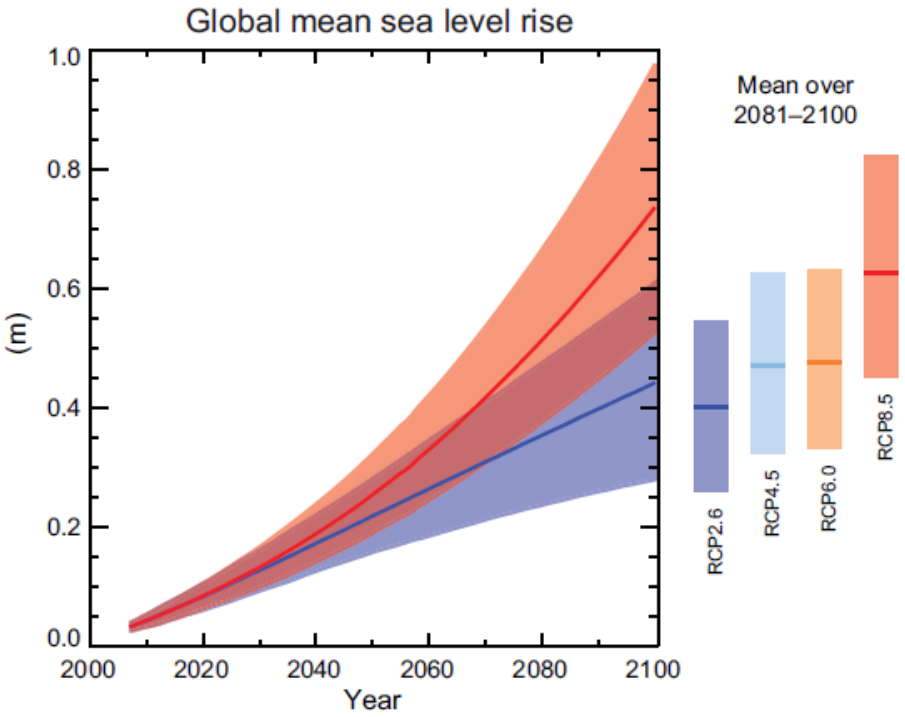


Figure 3-19: SLR projections for this century, showing upper limit values for 2040 and 2070 (IPCC, 2013)

The recommended design SLR for the three different design years are provided in Table 3-3. The recommendation of 0.1 m SLR for 2020 is based upon the actual measured data: an average increase of 3.9 mm/yr increase for 25 years is approximately 100 mm by 2020.

Table 3-3 Applied design SLR for 2020, 2040 and 2070 based on 1995 level

Design Year (yr)	SLR (m)	Average rise from 1995 (mm/yr)
2020	0.10	3.9
2040	0.25	5.6
2070	0.55	7.3

3.11.2 Cyclones

Cyclone track data for this study has been sourced from the International Best Track Archive for Climate Stewardship (IBTrACS) from 1980 to 2015 (NOAA, 2016), as shown in Table 3-4 and Figure 3-20:.

Table 3-4 Meteo France La reunion (MFR) storm classification system

Category	10 min average V_{max} (m/s)	10 min average V_{max} (km/h)
Tropical disturbance	<14	<50
Tropical depression	14 – 17	50 – 61
Moderate tropical storm	17 – 24	61 – 86
Severe tropical storm	24 – 32	86 – 115
Tropical cyclone	32 – 46	115 – 166
Intense tropical cyclone	46 – 59	166 – 212
Very intense tropical cyclone	>59	>212

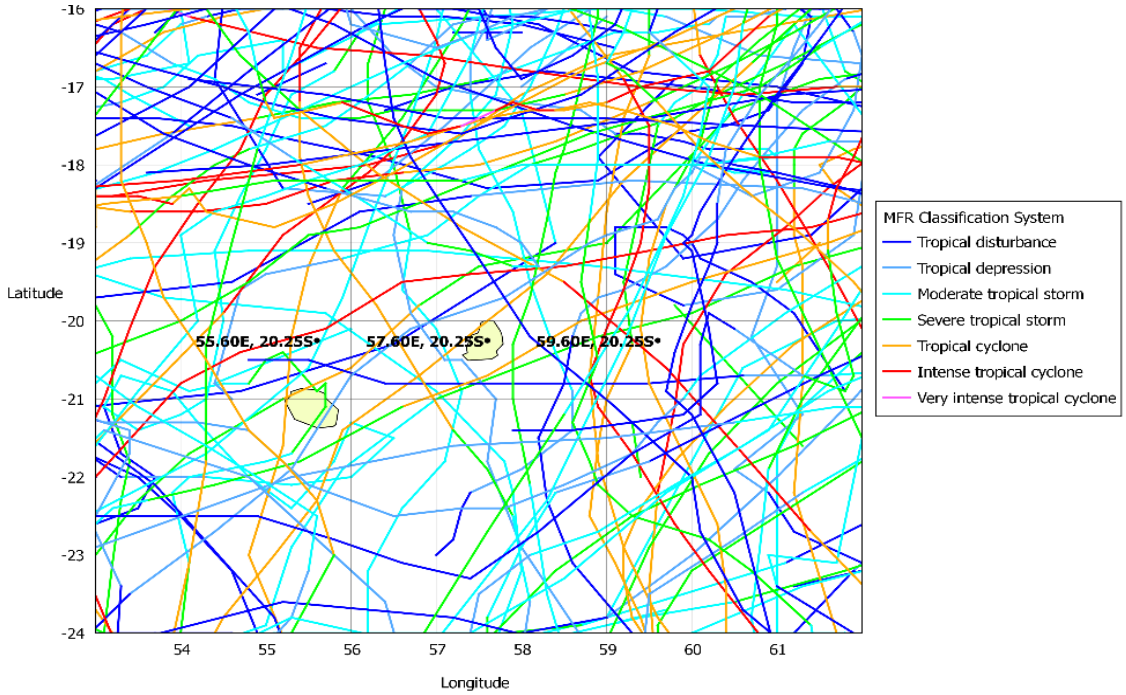


Figure 3-20: MFR best track data for the years 1980 to 2015. Also indicated are the three locations used in the calculation of extreme wind speed.

A parametric wind field model was run to determine time-series of wind speed at any location of interest. The time-series of modelled wind peaks for all available historical tropical cyclone events were extracted at three locations with 2° spacing in longitude for the Mauritius area (Figure 3-20:). The resulting time series (Figure 3-21:) shows scatter but no clear trend to support an increasing trend in cyclone wind speeds over the last 35 years.

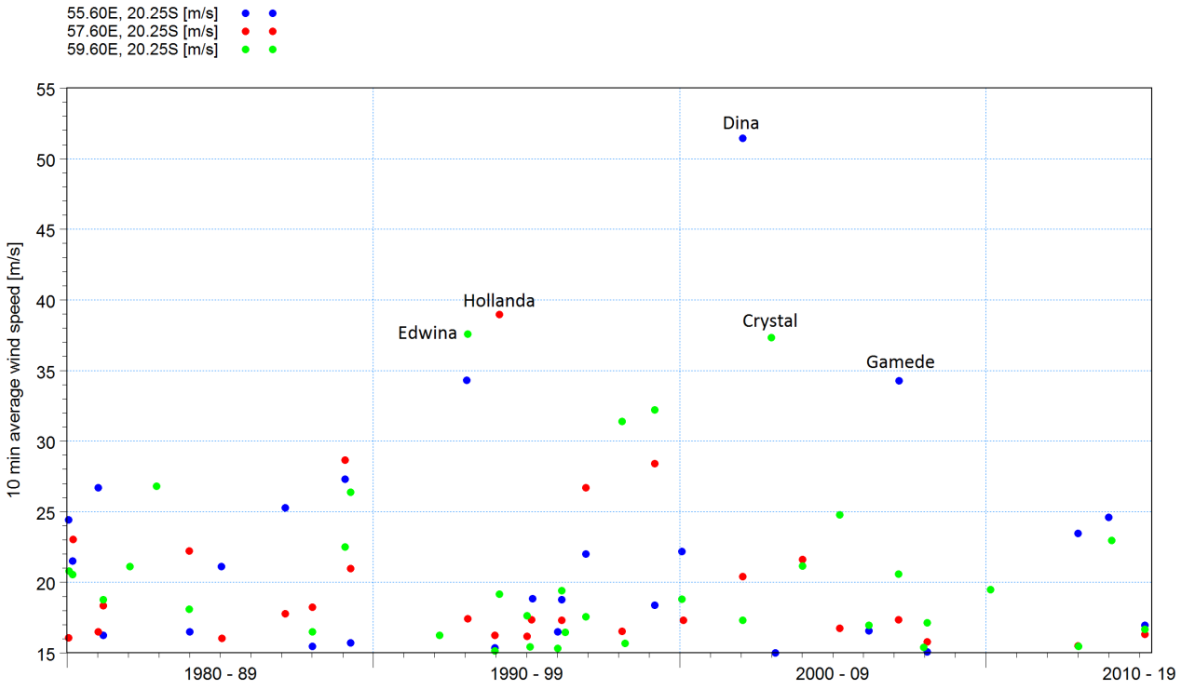


Figure 3-21: Time-series of modelled peak wind speeds for all historical tropical cyclones from 1979 to 2015 at the three locations in Mauritius

Based upon literature, cyclone frequency is expected to decrease or remain unchanged for 21st century (IPCC, 2013). However, on average an increase in cyclone intensity of approximately 10% is predicted for some basins. Additionally, mean cyclonic wind speeds are expected to increase between +2% and +11% (IPCC, 2013) with regional variation, likely. There is low confidence in these projections at this stage.

Other sources cite the following findings:

- an increase in the frequency of intense storms in the Mauritius area from 1993 to 2008 (Fairhurst,2011)
- an increase in Category 3 storms and larger after 1997 in the region while no increase in total number of storms (Malan, 2013)
- the frequency and intensity of cyclones indicated overall increased activity during 1980 – 2007 (Mavume, 2009).

The IPCC (2013) predicts a 10% 'best estimate' increase in the lifetime maximum intensity of tropical cyclones for the South Indian Ocean, with a range of 0% to 15%.

Based on the above, the values shown in Table 3-5 have been used in this study.

Table 3-5 Applied increase in cyclone wind speed

Design year (yr)	Change in wind speed (%)
2020	0
2040	+5
2070	+10

3.11.3 Wind

The potential increase in non-cyclonic winds have also been evaluated as this could impact upon the wind and swell wave design conditions, particularly for the operational case.

Various differing predictions for the change in extreme wind speeds have been sourced, i.e. (Young, 2012) estimated the trend in the 100-year wind speeds at 10 m elevation, which resulted in a decadal trend of 3.6 m/s per decade (if based upon a starting point of 44 m/s this results in approximately 8% increase per decade). (Bhaskaran, 2014) reports that an increase in the wind speeds (+3.2 m/s) and corresponding wave heights (+1.52 m in last 21 years) can be seen between the latitudinal belts of 40°S to 55°S (which would result in an increase of 3.5% per decade if 44 m/s was the starting point). A 100-year return wind speed of approximately 44 m/s can be estimated for the Roaring 40's based upon research (Young, 2012).

Tokinaga et al (2011) predicts a trend of less than 0.1 m/s per decade for the average wind which corresponds to approximately 1.4% per decade for an average speed of 7 m/s (as shown in Figure 3-22:).

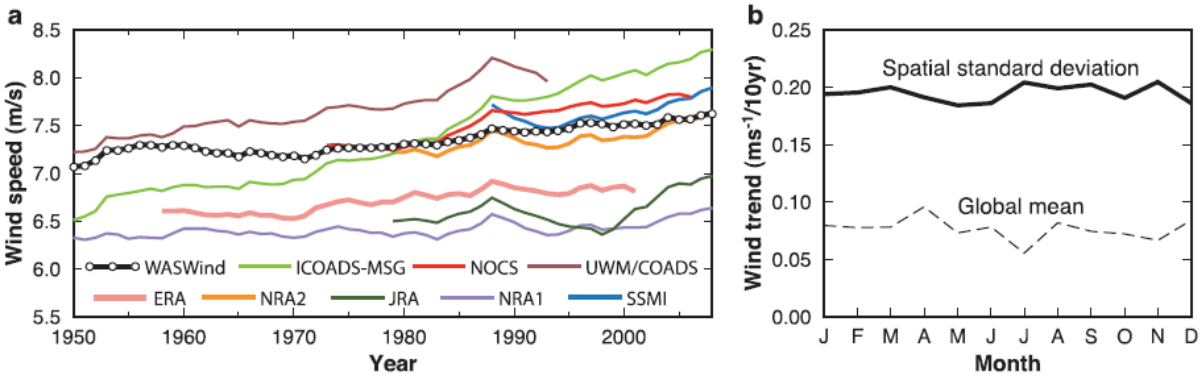


FIG. 14. (a) Time series of globally averaged annual scalar wind speed obtained from nine datasets. Each time series is smoothed with a 5-yr running average. (b) Spatial standard deviation of the scalar wind trend pattern (solid line in m s^{-1} $decade^{-1}$) and the trend of global-mean scalar wind speed (dashed line in m s^{-1} $decade^{-1}$) calculated from WASWind as a function of calendar month.

Figure 3-22: Trends in average wind speed based upon climate change (Tokinaga, 2011)

The IPCC (2013) provided trends in the surface winds speeds (for 10 m elevation) between 1988 and 2010 for various climate models. Most models show an increase in the wind speeds in the area surrounding Mauritius; all show an increasing trend in the roaring 40's, ranging between 0.1 and 0.5 m/s per decade (as shown in Figure 3-22:).

The IPCC (2013) provided trends in the surface winds speeds (for 10 m elevation) between 1988 and 2010 for various climate models. Most models show an increase in the wind speeds in the area surrounding Mauritius; all show an increasing trend in the roaring 40's, ranging between 0.1 and 0.5 m/s per decade (as shown in Figure 3-23:).

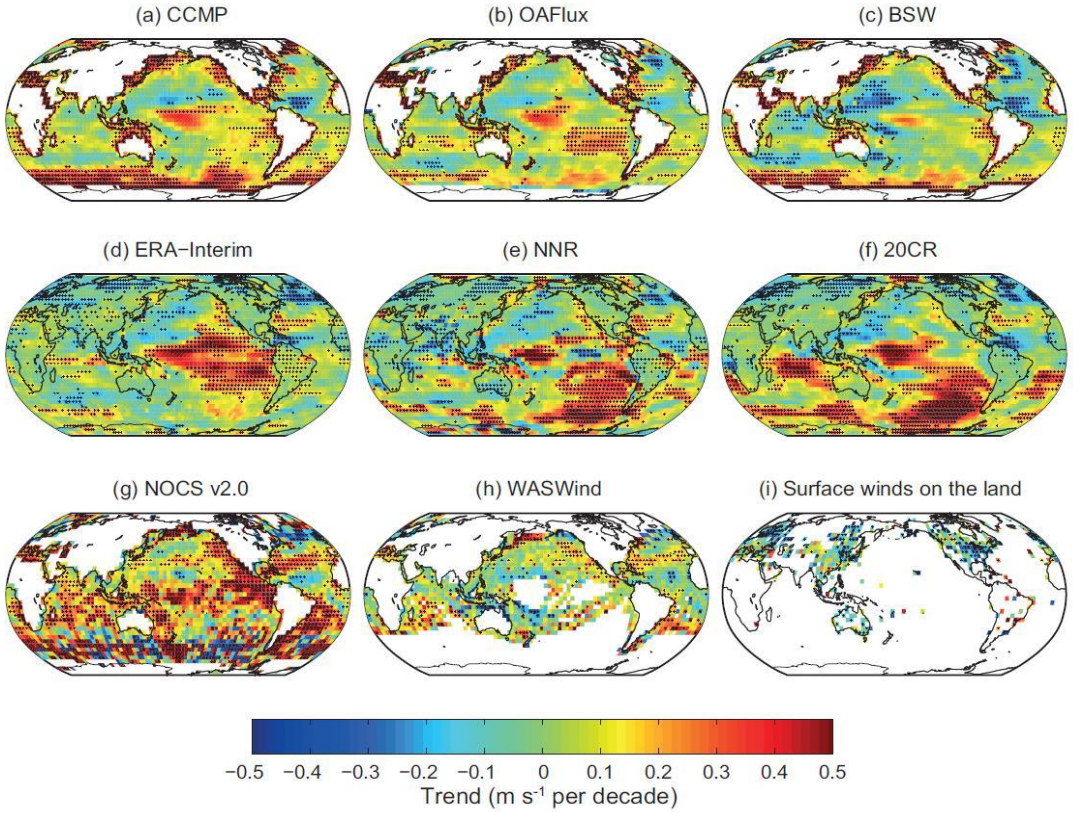


Figure 3-23: Trend in wind speeds per decade for 1998-2010 for different climate models (IPCC, 2013)

This decadal increase translates to between 1% and 5% for an average wind of 10 per decade; or 0.5% and 2.5% for two decades for an average wind of 20 m/s. There is a significant variation in the percentage change for the different models. For this study a decadal increase of 0.4 m/s is applied (for an average wind of 20 m/s); which translates to +5% increase in the wind speed by 2040, double that is applied for 2070.

Table 3-6 Applied increase in wind speed

Design year (yr)	Change in wind speed (%)
2020	0
2040	+5
2070	+10

3.11.4 Waves and Surges

To estimate the expected increase in wind-generated waves resulting from increased wind speeds, the approach detailed in the Coastal Engineering Manual (US Army Corps of Engineers, 2002) was used for fetch and duration limited waves. The expected significant wave height was calculated for different wind speeds, durations and fetches. Wave heights increased more for duration than fetch-limited conditions for the same wind speed increment. Based on these analyses the applied design values are provided in Table 3-7.

Note that when modelling the effect of climate change in this study, these increases in wave heights were only used to increase the waves on the boundary of the regional wave model. When modelling cyclone waves and locally-generated wind-waves, the approach was to adjust the applied wind speed in the model and allow the model to predict the corresponding increase in wave height.

Table 3-7 Applied percentage increase in wave height corresponding to a change in wind speed

Design Year (yr)	Change in Wind Speed (m)	Change in Wave Height (mm/yr)
2020	0	0
2040	+5	+6
2070	+10	+15

3.12 Hydrodynamic Modelling for Pointe aux Feuilles – Grand Sable Site

The results of the hydrodynamic modelling exercise carried out for the project site is detailed in Table 3-8.

Table 3-8: Pointe aux Feuilles – Grand Sable Site: Summary Design Waves and Water Levels

Climate change scenario	Return Period	Tide (incl. residual)* (m MSL)	Wind and wave setup (m)	SLR** since 1995 (m)	Design SWL (m MSL)	Sea			Swell		
						Maximum H_{m0} (m)	T_p (s)	Runup level *** [m MSL]	Maximum H_{m0} (m)	T_p (s)	Runup level [m MSL]
2020	1-year	0.47	0.13	0.1	0.7	0.4	2 - 3	1.4	0.2	8 - 21	1.1
2040		0.47	0.13	0.25	0.85	0.5	2-3	1.6	0.3	8 - 21	1.5
2070		0.47	0.18	0.55	1.20	0.5	2-3	2.0	0.3	8 - 21	1.8
2020	10-year	0.53	0.87	0.1	1.50	0.8	1 - 4	2.8	0.5	6 - 14	2.5
2040		0.53	0.97	0.25	1.75	0.8	1 - 3	2.8	0.5	6 - 14	2.8
2070		0.53	1.07	0.55	2.15	0.9	1 - 3	3.2	0.6	6 - 14	3.4
2020	100-year	0.53	1.37	0.1	2.00	1.5	2 - 4	3.8	0.5	8 - 15	3.0
2040		0.53	1.42	0.25	2.20	1.6	2 - 4	4.1	0.5	6 - 15	3.3
2070		0.53	1.47	0.55	2.55	1.7	1 - 4	4.5	0.6	8 - 15	3.8

*1-year return period values calculated as the 90th percentile of high tide levels (including residuals) for all months over the period of 1986-2016.

*10-year and 100-year return period values calculated as the 90th percentile of high tide levels (including residuals) for cyclone months only (Dec-Apr) over the period of 1986-2016.

***SLR**: Sea Level Rise.

3.13 Historical/Heritage Features

The National Heritage Fund Act quotes four national heritage sites in the district of Black River, namely:

- Ruins of French Battery (Pointe du Diable) – located at 2 km from site
- Remains of Old French Battery (Anse Petite Sable) about 2km to the south west.

The above mentioned national heritage site are not located within the limits of the 1km radius of this project's area of study.

It was however noted that ruins of an old fortification were present at the site as shown in Figure 3-4, which is not listed as a heritage feature in the NHF Act.

During a meeting held on 8 March 2018, NHF stated that there was the presence of a ship wreck off the Pointe aux Feuilles site but which was not identified during the field surveys as it most likely located beyond the study area. No further information was obtained from the NHF on this wreck.

3.14 Water Quality

The water quality of the coastal water is given by the Guidelines for coastal Water Quality (Government Notice 620 of 1999).

A water sample was collected for testing to get a better indication of the water quality at the site. The sampling location is shown in Drawing M190/CN/EV/02.

The sample was tested against the requirement of the Guidelines for Coastal Water Quality (Government Notice 620 of 1999) for Category B – Recreation. The test results are presented in Table 3-9.

Table 3-9 Water Quality Test Results at Pointe aux Feuilles- Grand Sable Site

Parameters	Results	Limits Category B Recreation	Units
Temperature	31		ºC
Dissolved Oxygen	5.61	>5	mg/l
COD	Not detected	3	mg/l
Cyanide	Not detected	0.01	mg CN^-/l
Nitrate as N	0.47	0.8	mg NO_3-N/l
Oil & Grease	Not detected	Not detectable	mg/l
pH	8.02	7.5-8.5	no units
Phenols	Not detected	0.05	mg/l
Orthophosphate as P	<0.01	0.08	mg PO_4-P/l
Total Suspended Solids (TSS)	Not detected	5	mg/l
Arsenic	0.01	0.05	mg/l
Cadmium	0.01	0.02	mg/l
Chromium	<0.001	0.05	mg/l
Copper	<0.001	0.05	mg/l
Lead	<0.001	0.05	mg/l
Mercury	not detected	0.0005	mg/l
Total Coliform	Detected	1000	Verified Coliform/100ml
Faecal Coliform	Detected	200	Verified Faecal Coliform/100ml

It is to be noted that the level of DO is at the borderline level of the limits stated in the Guidelines for Coastal Water Quality (General Notice No 620 of 1999).

3.15 Landscape and Aesthetics

Landscape and aesthetics cover all aspects of the environment that are considered to be of visual value.

The severely eroded coastline at the site has impacted negatively on the landscape. However, the coastal frontage and the beachfront view are considered to be of significant value, which need to be preserved. Visuals from the site comprise mainly the ocean in the general westerly direction, and Ilot Flamants and Ile aux Oiseaux some 4.5km to the east.

3.16 Air Quality

The air quality at the site is typical of a low density, residential village along the coastal regions of Mauritius, where main activities are non-manufacturing hence non-polluting.

The most prominent source of pollution as far as air quality is concerned at the site is emissions from exhausts of vehicles along the coast road.

3.17 Traffic

B28 Road, which runs alongside the site is the only road that links the southern and the northern parts of the island via the east coast. This road starts at Mahebourg and ends at Flacq through Bel Air.

Traffic level along B28 Road at the site can be classified as medium and low during peak and off-peak hours respectively.

The coastal road is also a public bus route and is serviced by the individual operators. During the crop season, lorries also use this road to transport sugar cane to the factories.

3.18 Noise

The noise level at the site reflects that of a small coastal village with local traffic being the main noise source.

No other noise-producing activities were identified at the site.

3.19 Socio-economic Activities

3.19.1 Tourist Industry

No such activities have been identified at the site.

3.19.2 Fisheries

According to information obtained from the Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping through the MoESD, there 43 registered fisherman at Grand Sable and there are also floating cages (aquaculture) at Pointe aux Feuilles. Further details on this aquaculture site are given in Section 3.5.3.

The site is located outside the Grande Riviere Sud Est to Pointe aux Feuilles-Trou d'Eau Douce Fishing Reserve. There is no fish landing station or boat ramp at the site.

3.19.3 Other Activities

The narrow open space at the site waterfront is used by the inhabitants of the village for leisure activities as witnessed by the presence of benches at the site.

The waterfront is devoid of areas used for recreational or leisure activities.

3.19.4 Places of Worship

There is a temple at the western extremity of the site at Grand Sable.

3.20 Consultation with Stakeholders

3.20.1 Ministries and Authorities

Consultations were held with the relevant ministries and authorities at inception and preliminary design stages of the project to obtain more information about the site and to have a better appreciation of the functional requirements at this particular site.

The public bodies consulted include:

- Ministry of Housing and Lands
- Ministry of Public Infrastructure
- Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping
- Ministry of Local Government
- Ministry of Tourism
- Mauritius Oceanography Institute
- Forestry Services
- National Coast Guard
- Traffic Management and Road Safety Unit
- Beach Authority
- District Council of Grand Port
- National Heritage Fund
- Road Development Authority.

The consultations were held on the following dates:

- 26 December 2016
- 26 January 2017
- 1 March 2017
- 8 March 2017
- 4 April 2017.

The RDA has requested a 4m ledge along the coast road at this site for future road upgrading.

3.20.2 Public Consultation

During the earlier stages of the project, the Consultant's team has interacted with members of public at the site. These interactions aimed at gathering existing information about the site specificities and were informal.

Consultations were held with stakeholders of the villages Pointe aux Feuilles, Grand Sable and Bambous Virieux on 19 December 2017. The meeting was also attended by representatives of the District Council of Grand Port, the Village Councils of these localities, the Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping, the national Coast Guard, and the Ministry of Housing and Lands.

The following were requested:

- rock revetment as protection measure and landscaping works similar to those carried out at Quatre Soeurs
- Access to the sea at regular intervals
- Walkways/jogging tracks
- Landscaping.

The MSSESD intends to conduct further consultation at community level at a later stage of the project.