EIA DATA COLLECTION GUIDELINES

Environmental Impact Assessments are intended for the protection and regulation of development proposals in the Maldives. The Environmental Protection Agency (EPA) is the authority in charge of administering sound decision statements to all types of development proposals, from land reclamation projects to harbours and tourist resort developments. EIA's are a useful tool for understanding environmental system dynamics complementing architectural, engineering and socio-economic information. A baseline study describing the existing environment (environment and socio-economics) is critical for an optimum construction and operation design. Assessing environmental costs will help quantify economic costs and evaluate the viability of a project. This will benefit investors and the environment. Posterior environmental monitoring is required by law.

This document contains monitoring guidelines suggested by the EIA Department at the EPA. Any queries please do not hesitate to ask. For further information consult The Environmental Impact Assessment Regulations (2007) which are accessible online at http://epa.gov.mv/images/stories/laws%20and%20Regulations/EIA%20regulations%202007.pdf.

1. PHYSICAL MONITORING

1.1. WATER QUALITY TESTING

These parameter guideline triggers have been adopted from the Great Barrier Reef Marine Park Authority (GBRMPA, 2009). The marine ecology in the Maldives is so vulnerable that it should be compared to that in the GBRMP. This will help maintain healthy ecosystems to preserve valuable natural resources that are directly or indirectly part of all people's livelihoods.

Take 3 control water samples away from the project site, 3 water samples from the project site and a representative number of water samples from different locations around the project site. All water samples shall be taken at a depth of 1m from the mean sea level or mid water depth for shallow areas. Record the GPS coordinates of each water sample taken. Analyze the following parameters and check the water quality standards to evaluate the status of the sample.

1.1.1. Temperature: The optimum temperature for coral reef growth ranges between 18^0C and 32^0C. Changes should not surpass 1^0C above the average long term maximum (GBRMPA, 2009). Temperatures above or below the local range can cause stress to coral reefs and seagrass beds.

1.1.2. Salinity: It is recommended that salinity ranges between 3.2% - 4.2% for optimum coral reef and seagrass ecosystems to blossom. Surface salinity can decrease when fresh water is added e.g. floods or pollution from industry, or increase if surface water evaporates. Changes may cause stress to corals and seagrasses (GBRMPA, 2009).

1.1.3. pH: Seawater pH is usually 8.0-8.3. Levels below 7.4 pH stress corals and calcifying seagrasses by decreasing calcification processes.

1.1.4. Turbidity: Corals and seagrasses need UV light for photosynthetic processes. If turbidity is high then these ecosystems will become stressed. Studies suggest that long term turbidity levels which are >3 NTU lead to sublethal stress. However, long term turbidity levels higher than 5 NTU cause severe stress on coral at shallow depth (Cooper *et al.*, 2008).

1.1.5. Sedimentation: Sedimentation is the sediment load that arrives onto the reef which can reduce light availability for photosynthesis, deplete dissolved oxygen and cause smothering of organisms. Sedimentation rates are measured using sediment traps. The maximum mean annual rate for coral reef and seagrass ecosystems is 3mg/cm^2/day, and a daily maximum of 15mg/cm^2/day (GBRMPA, 2009).

1.1.6. Nitrates: Nitrate is an essential nutrient for aquatic plants and seasonal fluctuations can be caused by plant growth and decay (UNESCO/WHO/UNEP, 1996). Natural concentrations, which seldom exceed 0.1 mg l^{-1} NO_3^- N, may be enhanced by municipal and industrial waste-waters, including leachates from waste disposal sites and sanitary landfills (UNESCO/WHO/UNEP, 1996). In islands where there is significant agricultural activity, the use of inorganic nitrate fertilizers can be a significant source.

When influenced by human activities, surface waters can have nitrate concentrations up to 5 mg l^{-1} NO_3^-N, but often less than 1 mg l^{-1} NO_3^-N. Concentrations in excess of 5 mg l^{-1} NO_3^-N usually indicate pollution by human or animal waste, or fertilizer run-off. In cases of extreme pollution, concentrations may reach 200 mg l^{-1} NO_3^-N.

1.1.7. Ammonia: Unpolluted waters contain small amounts of ammonia and ammonia compounds, usually <0.1 mg l^{-1} as nitrogen. Total ammonia concentrations measured in surface waters are typically less than 0.2 mg l^{-1} N but may reach 2-3 mg l^{-1} N. Higher concentrations could be an indication of organic pollution such as from domestic sewage, industrial waste and fertilizer run-off. Ammonia is, therefore, a useful indicator of organic pollution. Natural seasonal fluctuations also occur as a result of the death and decay of aquatic organisms, particularly phytoplankton and bacteria in nutritionally rich waters (UNESCO/WHO/UNEP, 1996).

1.1.1. Phosphates: Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate each compound contains phosphorous in a different chemical arrangement. These forms of phosphate occur in living and decaying plant and animal remains, as free ions or weakly chemically bounded in aqueous systems. In the marine environment, phosphorus limits algal growth therefore when in excess causes euthophication and slower reef growth (UNESCO/WHO/UNEP, 1996). In most natural surface waters, phosphorus ranges from 0.005 to 0.020 mg l^{-1} PO_4^-P (UNESCO/WHO/UNEP, 1996).

1.1.2. Sulphate: Sulphate is naturally present in surface waters as SO_4^{2-}. It arises from the atmospheric deposition of oceanic aerosols and the leaching of sulphur compounds, either sulphate minerals such as gypsum or sulphide minerals such as pyrite, from sedimentary rocks. Industrial discharges and atmospheric precipitation can also add significant amounts of sulphate to surface waters. Sulphate can be used as an oxygen source by bacteria which convert it to hydrogen sulphide (H_2S, HS^-) under anaerobic conditions. Sulphate concentrations in natural waters are usually between 2 and 80 mg l^{-1}, although they may exceed 1,000 mg l^{-1} near industrial discharges or in arid regions where sulphate minerals, such as gypsum, are present (UNESCO/WHO/UNEP, 1996).

1.1.3. BOD: The biochemical oxygen demand (BOD) is an approximate measure of the amount of biochemically degradable organic matter present in a water sample (UNESCO/WHO/UNEP, 1996). It is defined by the amount of oxygen required for the aerobic micro-organisms present in the sample to oxidise the organic matter to a stable inorganic form. BOD measurements are usually lower than COD measurements. Unpolluted waters typically have BOD values of 2 mg l^{-1} O_3 or less (UNESCO/WHO/UNEP, 1996).

1.1.4. COD: The chemical oxygen demand (COD) is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate (UNESCO/WHO/UNEP, 1996). The COD is widely used as a measure of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the effluents from sewage and industrial plants. The concentrations of COD observed in surface waters range from 20 mg l^{-1} O_2 or less in unpolluted waters to greater than 200 mg l^{-1} O_2 in waters receiving effluents (UNESCO/WHO/UNEP, 1996).

Table 1. Water quality parameter optimum conditions.

PARAMETER	OPTIMAL RANGE	REFERENCE

TEMPERATURE	18^0C and 32^0C *Changes should not surpass 1^0C above the average long term maximum	GBRMPA, 2009
SALINITY	3.2% - 4.2%	GBRMPA, 2009
PH	8.0-8.3 *Levels below 7.4 pH cause stress	
TURBIDITY	3-5 NTU >5 NTU causes stress	Cooper *et al.* 2008
SEDIMENTATION	Maximum mean annual rate 3mg/cm^2/day Daily maximum of 15mg/cm^2/day	GBRMPA, 2009
NITRATES	<5 mg l^{-1} NO_3^-N	UNESCO/WHO/UNEP, 1996
AMMONIA	Max. 2-3 mg l^{-1} N	UNESCO/WHO/UNEP, 1996
PHOSPHATE	0.005 - 0.020 mg l^{-1} PO_4^-P	UNESCO/WHO/UNEP, 1996
SULPHATE	2 mg l^{-1} and 80 mg l^{-1}	UNESCO/WHO/UNEP, 1996
BOD	< 2 mg l^{-1} O_3	UNESCO/WHO/UNEP, 1996
COD	< 20 mg l^{-1} O_2	UNESCO/WHO/UNEP, 1996

1.2. BATHYMETRY AND HYDROLOGY

Waves, currents, tides: These parameters are important for understanding sediment transportation and the rate of effluent water dispersion. Ideally, presented a map illustrating the extent of sediment plumes and highlight the sites which will be affected by high sedimentation and turbidity rates. This study will complement coastal erosion monitoring.

Present bathymetric data on an A3 map. Identify the sites which have high water dispersion and dilution rates as well as intense erosion performances. State the tidal ranges in the area including neap and spring tides throughout the year. Mark the areas where wave action is more intense (e.g. where waves break).

This data is key for sewerage projects, desalination plants, dredging activities, aquaculture ventures, agriculture and all those which involve water dispersion and sediment transport activities. Sewerage outfall pipes shall be located where currents quickly disperse effluent. Brine water from desalination plants ought to be placed in high energy waters too, however, the impacts from this are still relatively unknown.

1.3. COASTAL EROSION

Monitoring should detect which parts of the shoreline change the most, where the beach migrates on a seasonal basis, and should track changes in the dynamic and vegetated shoreline on both inhabited and uninhabited. Two simple procedures are to be used to monitor change in beach volume and change in position of the edge of the dynamic beach (beach toe) and edge of vegetation: i) Beach profiling and ii) GPS mapping (Table 2). These methods are the most common form of coastal monitoring and are rapid and easily repeatable to allow a greater number of sites to be monitored.

Table 2: Key indicators and associated methods for monitoring coastal change

Indicator	Methods
Change in beach volume	Beach profiles
Change in position of toe of beach Change in position of edge of vegetation	GPS mapping
Decadal island change	Aerial photo analysis

Monitoring coastal erosion is important in management. Accretion sites should be identified prior to construction so that less investment is needed in protection structures (e.g. groins, breakwaters) and in beach nourishment activities in the case of touristy sites. Impacts on the environment will also be greatly reduced if no action is taken to modify natural sediment transport systems.

1.3.1. Beach profiles: Create a two-dimensional, cross-shore profile to show simultaneous removal and accumulative changes which the shoreline behaviour mapped by GPS does not express (Fig. 1). These surveys record detailed information on the elevation and distance of the shoreline from fixed benchmarks on the island. Surveys typically start at benchmarks, run across the beach perpendicular to the vegetated shoreline and terminate below low tide level on the adjacent reef flat. Such surveys allow changes in the elevation and relative position of the beach with respect to the benchmarks to be determined. Typically such surveys have an accuracy of ±0.1m (Kench 2009).

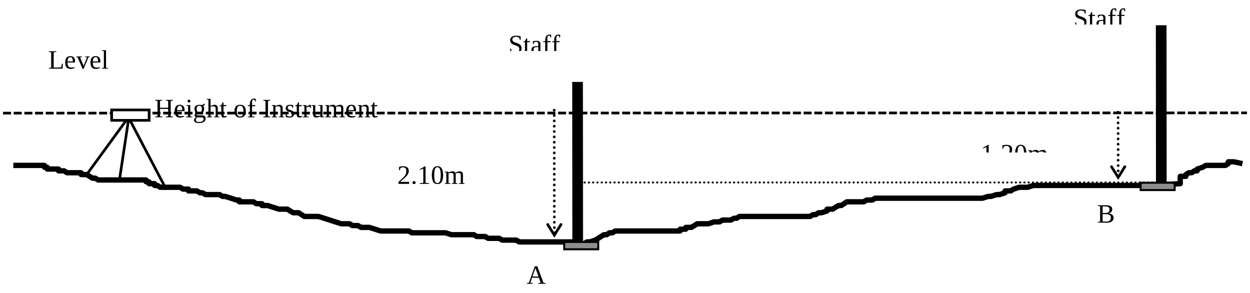

Fig. 1. Cross section of a beach profile.

Take a representative number of beach profiles from different accretion and erosion sites around the island, e.g. four sites. These sites should be surveyed every six months (one in SW Monsoon and one in NE Monsoon). The following should be identified:

- Edge of vegetation;
- Island scarp or berm;
- Instrument height;
- Water level (record time to standardise profiles against tide charts);
- Beach step;
- Toe of beach;
- Reef edge / seagrass / rubble

Include the superimposed beach profiles (SW and NE Monsoons) in the EIA document and state the changes in metres.

1.3.2. Toe of Beach GPS surveying: GPS mapping of shoreline change: This creates a map of the edge of the dynamic beach and vegetated interior to visualize changes over time.

GPS should be used to map the following for each island surveyed (Fig.2). Data from the different monsoon season should be superimposed on one single map to evaluate the changes in sediment accretion and erosion (in metres).

- Edge of vegetation
- Toe of beach

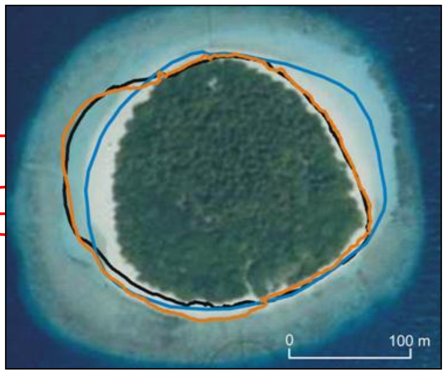

Fig 2. GPS surveying should identify the location of the toe of beach and compare data from one season to the next. Overlapping surveys from different seasons the degree of change will be easily identified.

GPS survey images should be included in the EIA report with appropriate data labels and scale.

1.3.3. Aerial photograph analysis: This will produce a map showing changes in the edge of the dynamic beach and vegetated interior over a decadal time scale. This data provides a rich source of information to establish whether reef islands have changed in size and position on reef surfaces.

1.3.4. Frequency: An annual cycle is observed in the Maldives with position of sediment dependent on the prevailing monsoon. Timing is therefore a primary aspect in monitoring.

- *Baseline:* the first time an island is surveyed, the full seasonal cycle should be monitored requiring three visits: i) end of NE monsoon, ii) end of SW monsoon and iii) end of NE monsoon to see if sediment returned to its original position.
- *Annual:* on return visits, survey once at the end of the SW monsoon for the first five years.
- *Decadal:* monitoring every five or so years after the end of the SW monsoon.

2. BIOLOGICAL MONITORING

The first action in developing a long-term monitoring program is establishing the key questions about the study. This will guide the selection of methods, sites and times of sampling (English *et al.*, 1994). It is important to select sites for monitoring that are representative of the system as a whole, and not necessarily the closest or most pristine areas. Such “pristine” sites may be essential as “controls”, if the aim of monitoring is to determine impacts at test sites (English *et al.*, 1994). All site selection should be made following a “pilot study” of the area, if the project is localized. The number of sites chosen for monitoring will necessarily be a balance between trying to achieve the maximum amount of information and the amount of resources and time available (English *et al.*, 1994). The monitoring program should be designed around a series of sites that can be visited on a regular basis, e.g. every year. Recording the GPS coordinates of the sites are really important for survey repetition. The first step is to establish a sound baseline description of the system before construction occurs.

2.1. CORAL REEF, FISH & INVERTEBRATES MONITORING

2.1.1. Pilot study: Manta tow: The manta tow technique is used to assess broad changes in the benthic communities or coral reefs where the unit of interest is often an entire reef or large portion thereof (English *et al.* 1994). Therefore this technique can be used to perform preliminary assessments to design a comprehensive monitoring study.

- Tow an observer, using a rope and manta board, behind a small boat powered by an outboard motor. Tows are carried out at a constant speed around the perimeter of a reef and are broken into units of 2 minutes duration (English *et al.* 1994).
- During each 2 minute tow, observations are made on several variables (e.g. percent cover of live coral, dead coral and soft coral). Additional information may be collected, dependent on the survey objectives, e.g. percent cover of sand and rubble.
- This technique is not recommended for fish counts. A pilot study for fish is not necessary since reef fish will inhabit the healthiest available reef. Exclusive fish and invertebrates surveys will be carried out in the main study.

2.1.2. Line Intercept Transects (LIT): It is the standard method recommended by the Global Coral Reef Monitoring Network (GCRMN) to determine percentage cover and colony size for management level monitoring, and obtains information on percentage cover of benthic communities e.g. hard coral, soft coral, sponges, algae, rock, dead coral. The community is characterized using lifeform categories which provide a morphological description of the reef community.

- These categories are recorded on data sheets by divers who swim along lines which are placed roughly parallel to the reef crest at depths of 3 metres and 10 metres at each site (English *et al.*, 1994).
- Place 5 x 20m long replicate transects at each of the two depths (shallow: 3 m and deep: 9-10 m depths). If permanent transects are used, place metal stakes, hammered deep into the substratum (at least 0.5m). If a typical reef flat, crest and slope is present, the shallow transects will be located on the reef slope, approximately 3 metres below the crest. The deeper transects will be located approximately 9-10metres below the crest. If the site is on a reef without a well defined crest, then transect depth should be approximated to a depth below mean water mark. If there is little or no coral at 10m then transects should be laid at 6-8m and not difference.
- A representative number of sites around the island should be surveyed including those that are directly and indirectly affected by construction. A "control" site shall be selected and test sites thereafter. These shall be sufficient to make a quantitative assessment of the impacts caused by construction all around the island.
- Observers must be as consistent as possible when recording benthic lifeforms. The same observers should collect data at all sites and, where possible, during repeat surveys.

2.1.3. Coral Recruitment Plates: The larval supply of coral species is examined by estimating the number of new corals settling on replicated units of substratum (terracotta tiles). The tiles are deployed at 5 metres depth on a regular basis (e.g. monthly) and are collected after exposure for equal amounts of time, 3 months is recommended. After collection they are examined microscopically to count the new corals. Year round sampling should be undertaken to determine the period, or periods, of recruitment. When they are known, sampling effort can be concentrated in these periods.

It is ideal for EIA monitoring because it will evaluate whether the system is recovering after it has been damaged and at what rate. This will help understand the impact significance in later projects in the Maldives.

2.1.4. Settlement Quadrats: This is used to measure the growth, mortality ad recruitment of corals in a permanently marked (fixed) quadrat located at metres depth on the reef slope (English *et al.*, 1994). It complements the LIT method by providing changes in individual corals and recruitment to a mapped area.

This provides abundance estimates of recruits that have survived the first year, thus giving a more reliable estimate of future coral species composition than recruitment tiles that look at newly settled recruits

- Using a 25cm x 25cm quadrat, swim in a haphazard fashion around the reef and place the quadrat on the substratum in areas lacking large (>25 cm diameter) sessile invertebrates;
- Count all small (maximum diameter 2 cm) stony corals within the quadrat. Record to genus if possible;
- Repeat 80 times.

2.1.5. Sedimentation on the reef: This is to measure direct sedimentation on the reef resulting from land clearing activities, construction, dredging, mining and drilling activities. Sedimentation reduces light availability for photosynthesis, deplete dissolved oxygen and cause smothering of organisms. Sedimentation rates are measured using sediment traps.

- Attach sets of 3 PVC sediment traps to the reef. The base of the traps should be 20cm above the substratum. Place 4 sets n the reef slope at 3 metres, 2 on either side of the permanent quadrat at one metre intervals.
- Collect traps every month, replace traps immediately with new clean traps. Dry and weigh sediments to the nearest milligram.
- Monitor monthly for the first year and then every 3 months for the next 2 year.

2.1.6. Coral Reef Fish Census: Belt transect: The aim is to simultaneously estimate the abundance and size of fish along 50 metre transects. A visual census is conducted during daylight hours along 3 of the same transects as the line intercept but the fish census transects must be 50 m long at 2 depths (3-5 m and 8-10 m). Wait for 5 to 15 minutes after laying the line before counting to allow fishes to resume normal behaviour, then swim slowly along the transect recording fish encountered in a 5 m belt and 5 m tunnel above the transect. There are two techniques:

- Detect differences in assemblages of reef fishes at different sites using abundance categories (table 3). It provides baseline data for zoning, management and monitoring, or;
- Count individual fish and estimate their total lengths to determine the standing stock and population size structure of specific species (those that are favoured by fishermen e.g. Serranids, Siganids, Acanthurids, Lutjanids, Lethrinids, Haemulids, Balistids). This is to determine the standing stock and population size structure of specific species.

Table 3. Fish abundance categories.

Category	Number of fish
1	1
2	2-4
3	5-16
4	17-64
5	65-256
6	257-1024
7	1025-4096
8	4097-16384

2.2. SEAGRASS MONTIORING

Seagrass meadows occur in shallow, sheltered soft-bottomed marine coastlines (Kirkman, 1990). They physically help to reduce wave and current energy, help to filter suspended sediments from the water column and stabilise bottom sediments

(Fonseca *et al.*, 1982). The habitat complexity attracts high biodiversity and abundance of animals. They are also nutrient sinks, buffering or filtering nutrient and chemical rich waters (Short and Short, 1984). The high primary production rates are linked to high fishery production rates.

Monitoring seagrassess consists of mapping the distribution and density of existing meadows to determine the natural variability (e.g. seasonal dieback) before estimates of loss or gain due to perturbation can be made (English *et al.*, 1994). Percentage cover are measured within replicate quadrats placed at regular intervals along the length of a transect.

- Place transects perpendicular to the shore and that extend to the outer limits of the beds (where seagrass disappears). Transects should be parallel and separated by reasonable distances from each other (50m to 100m). Take 3 replicate transects at each site. Swim along the transect along a compass bearing, perpendicular to the shore.
- Place 25cm x 25cm quadrats at regular intervals (5m-10m) and estimate the percent cover using similar categories to those used in coral reef surveying.
- Estimate the abundance and length of fish the same way as performed in the coral reef visual census.

2.3. TERRESTRIAL MONTIORING

Terrestrial environments in the Maldives play an important role in sustaining island shapes and many indigenous species. Vegetation maintains the soil on the ground and hosts 70 bird species, many interesting reptiles and amphibians and mangrove communities. In Environmental Impact Assessments, terrestrial monitoring should include evaluating the damages caused by the project development on the following flora and fauna:

- Land clearance activities including removal of trees, shrubs, seedlings, forest litter;
- Mangroves survey including area, species, health;
- Reptiles and amphibians including species, population size, location;
- Birds including species, population size and location;
- Marine turtle tracks;
- Soil texture changes, and,
- Garbage description.

A general procedure for collecting island data is through focus group discussions where islanders can identify the major changes in flora and fauna. All stakeholders should attend this meeting.

Finally, the legislation states that:

- No trees shall be felled for tourism ventures (Regulation on the Protection and Conservation of the Environment in the Tourism Industry)
- The maximum area for construction allowed for tourism ventures is 20%.
- The buffer zone between the high water mark and the first construction is 20 metres minimum.

3. SOCIO-ECONOMIC MONITORING

Public consultation is an important part of the project assessment since stakeholders will influence the success or failure of the project. If stakeholders and members of the public fully support the development activities will process much easier and benefits by both parties will be apparent. The following is important in all consultations:

- List of stakeholders and key informants, describe chronological plan of interviews and meetings and key points of discussions;

- Apply for all the necessary permits for project development;
- Census of the economic activities in the area (project island and neighbouring islands);
- Employment and economic opportunities and diversification in the area;
- Impacts on ground water from construction and operational phase and water availability for locals;
- Increased demands for natural resources and services in the area, e.g. water supply, energy, waste water treatment, solid waste generation, health services, population pressure, space availability, food and nutrition security –fisheries, agriculture, other- etc.
- Impacts on tourism, and
- Social destabilization of the island community.

The key outcomes from each stakeholder and key informant consultation ought to be included in the EIA. Follow up consultation will validate the success of the project, failures and suggest improvements.

4. REFERENCES

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