ENVIRONMENTAL IMPACT ASSESSMENT

Existing Powerhouse and Desalination Plant

Kandooma Tourist Resort, South Kaafu Atoll, Maldives

Environmental Audit Report 2010

Proponent: Kandooma Tourist Resort

Consultant: Ahmed Zahid

Sandcays

August 2010

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DECLARATION AND COMMITMENT BY PROPONENT

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I hereby certify that the information provided by Holiday Inn Resort Kandooma Maldives in this report is correct and accurate to the best of my knowledge. I also acknowledge that we will take into consideration the recommendations made in this report and that we will undertake environmental auditing and monitoring of our power house and desalination plant operations as recommended.

Janaka Vithana
31 August 2010

DECLARATION BY CONSULTANT

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I hereby certify that the data contained in this audit report represent the site conditions and the analytical summaries incorporated into this report are based upon data collected and analyzed by ourselves in a manner consistent with the requirements of the Environmental Protection Agency. Any deviations in the data collection methodologies have been highlighted.

I further certify that the statements made in this environmental assessment or audit for the power system and desalination plant at Kandooma Tourist Resort are true, complete and accurate to the best of my knowledge and abilities.

Ahmed Zahid
EIA Consultant Registration No: EIA 08/07
31 August 2010

1 Introduction

This report has been prepared in order to assess the environmental performance of the existing powerhouse and desalination plant for the purpose of registration of those facilities according to the requirements of the Environmental Protection Agency and the Maldives Energy Authority. This report focuses only on the powerhouse and the desalination plant and no other operations of the resort are incorporated within the context of this report.

Environmental Impact Assessment is required for the registration of desalination plant under the Desalination Regulation of the Maldives and Guidelines for Power System Approval issued recently by the Maldives Energy Authority. Also, power and desalination plant project fall within the list of projects requiring Environmental Impact Assessment study under the Environmental Impact Assessment Regulation of the Maldives. However, since the powerhouse and desalination plant in Kandooma (like many other such facilities in the Maldives) has been operational when the Desalination Regulation, the EIA Regulation and the Guideline for Power Systems Approval came into effect, the scope for this Environmental Impact Assessment has been based on that of an environmental audit of the existing facilities, focusing on the environmental compliance and performance of the existing power system and desalination plant.

Therefore, this report will include a compliance and performance audit. The compliance audit or review will assess how well the project implementation complies with the existing environmental policies or requirements by the registering authority and the performance audit will assess the actual environmental impacts of the project and how well the impacts have been mitigated during the construction as well operational phase. The performance audit will also include a review of the existing monitoring programme, discussing the deficiencies and suggesting improvements for future monitoring.

There have not been any legal requirements for environmental monitoring as there has not been any EIA report for the resort facilities under consideration. Therefore, this report is based on the findings of site investigations carried out by the consultant and necessary information provided by the management and technical staff at Kandooma resort. However, it is noted that the resort has a system in place to monitor environmental performance indicators of which water quality tests undertaken in the recent past by the Proponent have been used in preparing this report.

In addition to discussing the findings of the audit, a matrix will be presented which summarises the status of environmental compliance and performance for activities involving the operation and maintenance of the facility. This report will also provide recommendations for further environmental improvements to the power and desalination plants.

2 Description of Audited Facilities

The audited facilities are the powerhouse and desalination plant in Kandooma Tourist Resort. Kandooma is located towards the south eastern side of South Male Atoll at 3°53'18"N and 73°23'43"E at about 35km away from Male International Airport.

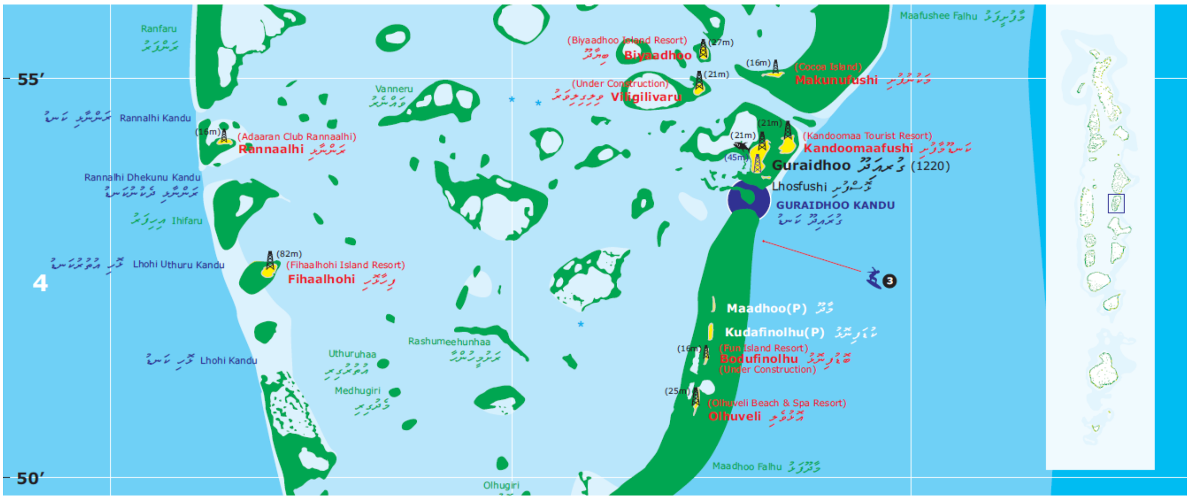
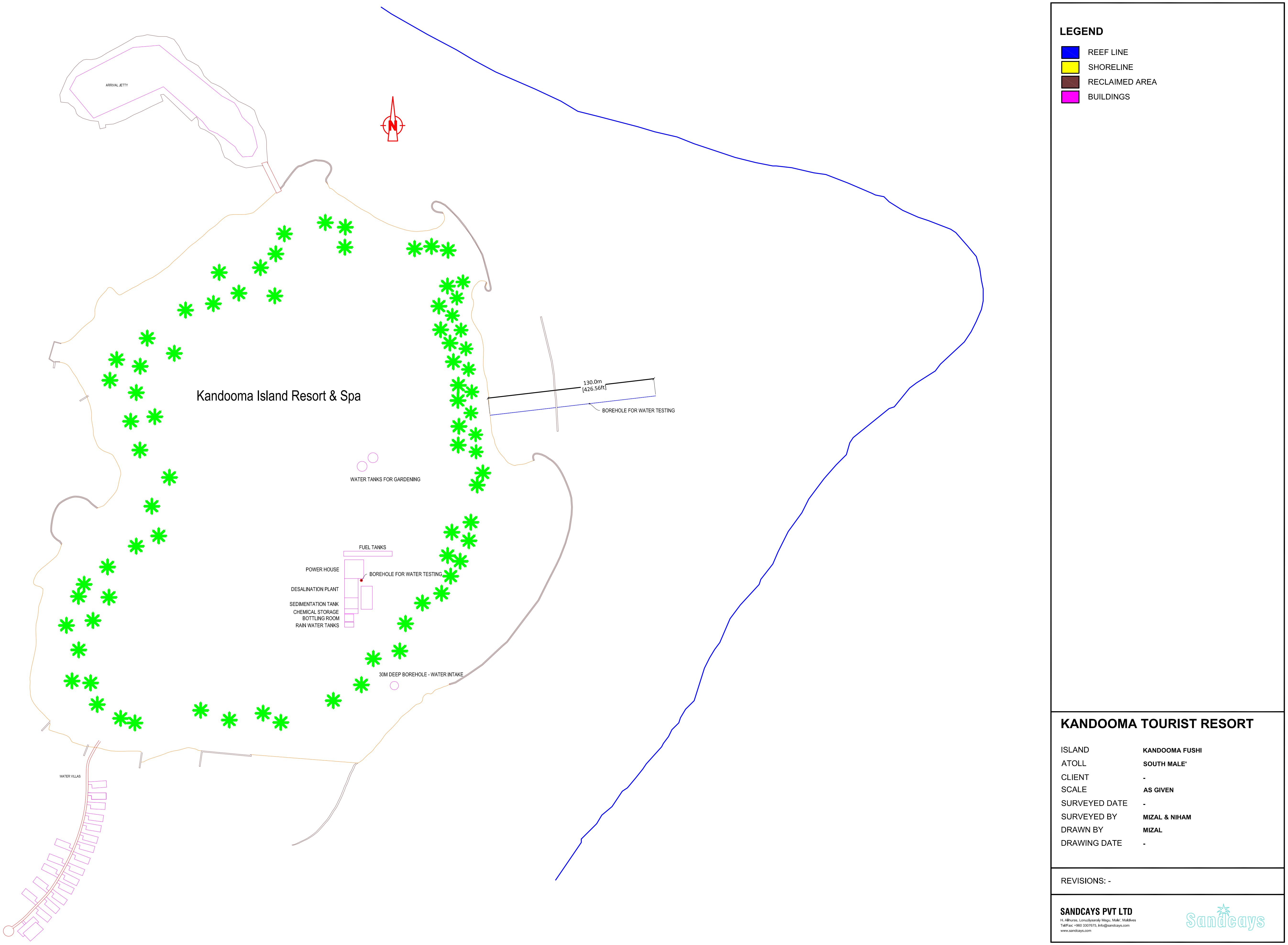


Figure 2-1: Location of Kandooma Tourist Resort.

As per the requirements of the Terms of Reference, this section provides full description of the existing power and water supply infrastructure using maps at appropriate scales. Details of power and water supply requirements, land use, capacity, intake arrangements, pump house details, exhaust and brine reject arrangements, and disinfection and reticulation mechanism have been considered here. The following figure shows the powerhouse and desalination plant and associated infrastructure on the resort with respect to the overall layout of the resort.

Figure 2_2: Site Plan indicating the powerhouse and desalination plant facilities



2.1 Need and Justification

While it is almost impossible to justify the powerhouse and desalination plant on environmental grounds, these facilities have enormous socio-economic implications on which they can be justified. Electricity is the driving force behind all economic activities and tourism being the largest foreign exchange earner, it is really necessary to provide adequate power to resorts. Kandooma is a four star resort and energy requirements are very high. Similarly, Kandooma has high demand for safe water for direct human consumption as well as non potable water for toilet flushing and overall management of the resort's landscaping and other needs. It is estimated that the resort produces about 295 litres per capita per day of desalinated water to meet demand. With such high demand for water, it would be almost impossible to supply water using rain and groundwater. In addition, the Tourism Regulations prohibits the use of groundwater for any purpose and encourages the installation of desalination plant. Therefore, desalination is the normal practice and the feasible means of catering for the water supply demands in Maldivian resorts.

Both the Environmental Protection Agency and the Maldives Energy Authority requires that power infrastructure and desalination plants are operated only under license from the respective agencies. Environmental assessment (including audit and monitoring) is a requirement for the registration as well as renewal of the registration. This report will fulfil such requirements for the renewal of registration of power and desalination infrastructure and help in the verification of regulatory environmental compliance. The report will also provide a status of the current management practices and identify opportunities for improvement.

2.2 Power System

The power system on the island of Kandooma comprises of a powerhouse with diesel generators and fuel handling area outside the powerhouse as well as the power distribution network. The powerhouse, desalination plant, sediment tank, chemical storage and bottling room are under one roof located near staff mosque. The areas of environmental concern are potential fuel spillages, emissions and noise levels in the vicinity of the powerhouse. There are three 500kVA, one 450kVA and one 250kVA diesel generators, one of each is used as backup.

Electricity is distributed through low voltage underground cables. Underground distribution system also consists of distribution substations, distribution feeder boxes, and service cables. Glass reinforced polyethylene (GRP) distribution boxes are used and the distribution cables are made of four core copper conductors insulated on the outside with polyvinyl chloride (PVC) and steel armoured mechanical protection for physical protection.

Fuel is supplied from the valve at the jetty to the fuel tank using galvanized iron (GI) pipes laid underground. From the fuel tank, fuel is supplied to smaller day tanks which supply individually to the separate generator sets.

The fuel tank has external bund walls with the same material and the day tanks have external concrete bund walls to contain spill. Fuel is stored in tanks of adequate capacity.

2.3 Desalination Plant

Kandooma has two RO units, one with a capacity of 250 ton/day and the other with a total capacity of 100 ton/day. The product water is stored in two tanks of capacities 750 and 296m^3. The largest one is a cylindrical metal tank while the other is a concrete tank.

Feed water is drawn from a 30 meter deep borehole on the east side of the island near the beach and the brine concentrate is discharged to the east side of the island reef approximately 130 meter away from the shoreline. The locations of the intake pipe and brine discharge pipe are shown in Figure 4-3.

Seawater from intake pipe is connected to sedimentation tank through a pump well. The pumps are located on the island close to the desalination plant. The intake water passes through a sedimentation tank or settling tank to help minimize clogging of the membranes from silt present in the water. The sedimentation tank is about 21tons. The desalting process at the plant uses a reverse osmosis (RO) membrane which reduces the salt content greatly producing freshwater for use in washing, bathing and flushing toilets and brine, which is returned to sea via a pipe that's placed on the eastern reef flat approx. 130m away from the shoreline. Freshwater is pumped into the storage tank. Water pumped into the storage tank is disinfected using chlorine solution for distribution via underground distribution network to all guest rooms, pools and public areas.

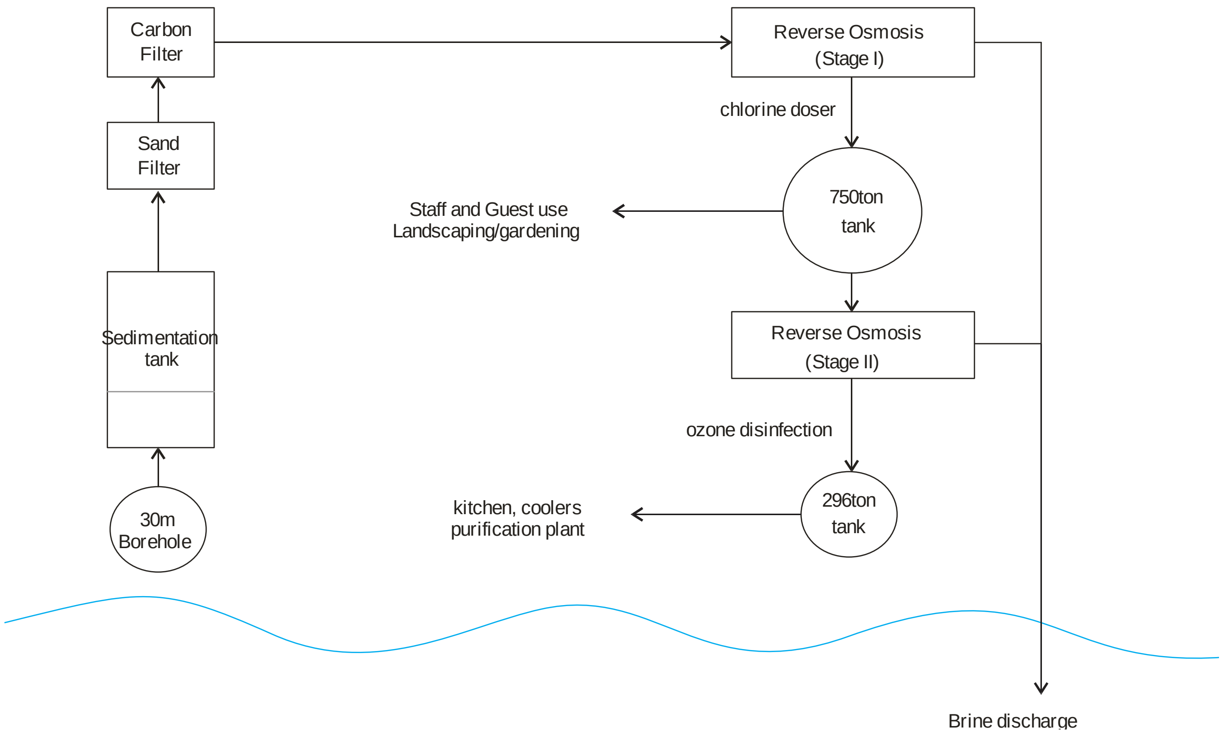


Figure 2-3: Schematic illustration of the desalination plant facilities

2.4 Operation and Maintenance

The power system and the desalination plant have been developed quite a long time ago and upgrades based on prevalent requirements of the Government have been made. Both infrastructure are operated and managed by the resort's Engineering Department but the systems are maintained by Pneumatic Maldives Pvt. Ltd., whose office is located in Malé. Operations and maintenance manuals and catalogues are available for the Aqua Tech plant however the Static Plant documents and borehole design and documents are not available.

3 Regulatory Aspects

The legal and policy instruments that are of relevance to the powerhouse and desalination plant under operation in Kandooma are the Environmental Protection and Preservation Act, EIA Regulations, Regulation on the Protection and Conservation of the Environment in the Tourism Industry, Desalination Regulation of the Maldives, National Energy Policy and the Guidelines for Power System Approval. These legal as well policy instruments and their relevance to the power and desalination infrastructure in Kandooma are discussed below.

3.1 Environmental Protection and Preservation Act

The main legal instrument pertaining to environmental protection and preservation for sustainable development in the Maldives is the Environmental Protection and Preservation Act (Law No. 4/93) passed by the Citizen's Majlis in April 1993. The following clauses of the Environmental Protection and Preservation Act (Law No. 4/93) are relevant to the project:

Clause 5a: An impact assessment study shall be submitted to the Ministry of Environment, Energy and Water (as it is called at the time the EIA Decision Statement was issued but now Ministry of Transport, Housing and Environment) before implementing any development project that may have a potentially detrimental impact on the environment.

Clause 5b: The Ministry of Environment, Energy and Water shall formulate the guidelines for EIA and shall determine the projects that need such assessment as mentioned in paragraph (a) of this clause.

Clause 6: The Ministry of Environment, Energy and Water (now MHE) has the authority to terminate any project that has an undesirable impact on the environment. A project so terminated shall not receive any compensation.

Clause 9a: The penalty for minor offences in breach of this law or any regulations made under this law, shall be a fine ranging between Rf5.00 (five Rufiyaa) and Rf500.00 (five hundred Rufiyaa), depending on the actual gravity of the offence. The fine shall be levied by the Ministry of Environment, Energy and Water or by any other government authority designated by that Ministry.

Clause 9b: Except for those offences that are stated in (a) of this clause, all major offences under this law shall carry a fine of not more than Rf100,000,000.00 (one hundred million Rufiyaa), depending on the seriousness of the offence. The fine shall be levied by the Ministry of Environment, Energy and Water.

Clause 10: The government of the Maldives reserves the right to claim compensation for all damages that are caused by activities that are detrimental to the environment. This includes all activities mentioned in Clause No. 7 of this law as well as those activities that take place outside the projects that are identified here as environmentally damaging.

Clauses 9 and 10 are of specific relevance to this Audit. The EIA Regulations, which came into force in May 2007, has been developed by the powers vested by the above umbrella law.

3.2 EIA Regulations

The EIA Regulations, which came into force in May 2007, has been developed by the powers vested by the above umbrella law. The EIA Regulations have been the basis for Environmental Impact Assessment in the Maldives and since its advent it had helped to improve the quality of EIAs undertaken in the country. Today, registered consultants are required to sign EIAs, the EIAs are reviewed by two independent reviewers and final decisions based on the reviews. This Audit would also be subject to these requirements and review criteria.

Schedule D of the EIA Regulations lists the different environmental projects that require an Environmental Impact Assessment study and power plants and desalination plants have been included in the list. However, the power and desalination infrastructure in Kandooma were developed prior to the EIA Regulations or the Environmental Protection Act. Therefore, the development of the facilities were not scrutinised by an EIA study. With the recent Desalination Regulation of the Maldives and Guidelines for Power System Approval, EIA has been mandated for the registration of these facilities. Hence, an environmental assessment in the form of an Audit was required for the re-registration of the facilities as there has not been any EIA done in the past for these developments in Kandooma. Although the EIA Regulations have not set out the requirements for environmental audits, contents of environmental impact assessment has been given in Schedule E and format for monitoring reports have been given in Schedule M. Therefore, these requirements have been taken into consideration in preparing this Audit report.

3.3 Regulation on Protection and Conservation of Environment in the Tourism Industry

The Regulation on the Protection and Conservation of the Environment in the Tourism Industry came into effect on 20 July 2006. Section 6 of the Regulation deals with water supply in tourist facilities. It requires every resort to have a desalination plant registered according to the Desalination Regulation and requires that daily logs of water quality to be recorded and maintained. It also asks for the provision of water storage sufficient for 5 days supply.

It further states that groundwater shall not be used for drinking by guests or staff, and shall not be supplied to guest rooms or toilets of guest rooms or for use by staff. Furthermore, any type of oil (e.g. used engine oil) or any other chemical which may damage the environment shall not be drained to the ground.

The regulation does not cover powerhouses or emissions from power plants including noise. However, clause 2.4 of the regulation requires that EIA be prepared before commencing any construction project or activity listed in clause 2.1 of the regulation, which covers coastal protection, dredging, reclamation, vegetation clearance, demolition of existing structures, import and export of living species, conducting research of land, sea and lagoon and anything that may adversely affect the vegetation and freshwater lens of the island.

3.4 National Energy Policy

As one of the first countries to sign and ratify the Kyoto Protocol in 1998 and as a member of the UN Framework Convention on Climate Change, the Maldives is committed to implement national policies towards sustainable energy management and reduction of greenhouse gas emissions. The President has recently announced that the Maldives would work towards becoming the world’s first carbon neutral country by 2020. The National Energy Policy introduced subsequently is focussed on this goal. As such the National Energy Policy looks at existing issues, constraints and emerging issues. The policy addresses issues of energy supply, consumption, environment, renewable energy, energy efficiency and sustainability. Sustainable supply and consumption is the main focus of the policy.

The key policies outlined in the National Energy Policy are:

Policy 1: Provide all citizens with access to affordable and reliable supply of electricity

Policy 2: Achieve carbon neutrality by Year 2020

Policy 3: Promote energy conservation and energy efficiency to reduce costs

Policy 4: Increase national energy security by diversifying energy sources

Policy 5: Promote Renewable Energy Technologies

Policy 6: Strengthen the institutional and legal framework of the energy sector

According to the policy document, only 3% of energy is from biomass and solar energy while the rest is from refined petroleum products with diesel fuel accounting to 83% of the total energy consumption in the Maldives. Therefore, there is a great deal of work that needs to be done if carbon neutrality were to be achieved by 2020.

3.5 Desalination Regulation of the Maldives

The Desalination Regulation of the Maldives came into force from 2002 when this plant was operational. However, in order to meet the requirements of the Desalination Regulation, the desalination plant at Kandooma was registered with the Maldives Water and Sanitation Authority in 2004 as required by the Regulation. The Desalination Regulation states the requirements for application, plant capacity determination, intake and source water, plant operation and maintenance, brine discharge as well as water quality monitoring requirements. The Environmental Protection Agency is currently in the process of reviewing the Desalination Regulation to incorporate the current regulatory requirements as well as administrative framework. This regulation is the only regulation currently in force for the water and sanitation sector and has been established with the primary objective of safeguarding public water supplies, the environment and the interests of service providers.

3.6 Relevant Standards

3.6.1 Air Quality

Environmental management in the Maldives is still at infancy and lacks the necessary environmental standards and the institutional capacity to manage. Therefore, water quality, air quality and noise standards are based on international standards or standards of developed countries. For instance, water quality standards are based on WHO standards. For air quality, the Maldives has not yet established ambient air quality standards to serve as a basis for air quality management. Consequently, the standards of other countries will have to be employed in evaluating project impacts on air quality. However, standards vary for different countries depending on their circumstances. Table 3-2 represents ambient air quality standards for the USA, Japan, Germany, Thailand, Malaysia and the Philippines for PM and SO_2. The standards vary among these countries. The standard for PM adopted by the USA is the most stringent while the standard for SO_2 adopted by Japan is the most stringent.

Table 3-1: Air quality standards of some selected countries (in $\mu g/m^3$)

Country	PM_{10}		SO_2	
	1-yr average	24-hr average	1-hr average	24-hr average
USA	60			365
Germany	100			150
Japan		100	260	100
Thailand	100	330	500	300
Malaysia	90	260	350	100
Philippines		180	500	360

In the Maldives, for reference purposes, the air quality standards set by the USEPA have been used (Hodges 1995, Zahid 1996, CDE 2005). Therefore, in this assessment the USEPA standards given in Table 3-3 have been used as a reference standard for air quality. However, it is important to note that the people of the Maldives are most probably subject to less atmospheric pollution than those living in the industrialized world. Therefore, it may be necessary to assess the general environmental pollution levels in the country and establish standards based on those. Furthermore, the special geographic features as well as the dependence on the fragile ecosystems must be taken into consideration.

Table 3-2: USEPA ambient air quality standards

Pollutant/Critical Parameter	Primary Standard	Averaging Times	Secondary Standards
Carbon Monoxide	$10 mg/m^3$ $40 mg/m^3$	8-hour 1-hour	None None
Lead	$1.5 \mu g/m^3$	1-hour	Same as primary
Nitrogen Dioxide	$100 \mu g/m^3$	Annual mean	Same as primary
Particulate Matter (PM10)	$50 \mu g/m^3$ $150 \mu g/m^3$	Annual mean 24-hour	Same as primary
Particulate Matter (PM2.5)	$15 \mu g/m^3$ $65 \mu g/m^3$	Annual mean 24-hour	
Sulphur dioxide	$365 \mu g/m^3$	24-hour average	

World Bank standards are also often cited in reports, especially for IFC and World Bank funded projects such as annual monitoring undertaken by Villa Shipping and Trading Company Ltd. Therefore, these standards are also given below.

Table 3-3: Air Pollution standards from World Bank

Pollutant	Air Emission Limits	Ambient Air Quality Guidelines	
	IFC (World Bank) Averaging Period	Averaging Period	World Bank Guidelines for Use at Thermal Power Plants ($\mu g/m3$)
Nitrogen Dioxide (NO_2)	<2000 mg/Nm3	1 hour 24 hours 1 year	- 150 100
Sulphur Dioxide (SO_2)	0.2 te/day/MWe plus maximum of 500 te/day	1 hour 24 hours 1 year	- 150 80
Particulate Matter (PM_{10})	50 mg/Nm3	24 hours 1 year	150 50
Total Suspended Particles (TSP)	-	24 hours 1 year	230 80

3.6.2 Noise

Similarly, there are no national standards for noise. Noise is one of the major environmental problems associated with power houses and desalination plants. The only requirement with regard to noise emissions is the clause in the Desalination Regulation which specifies that adequate noise protection gear shall be provided to staff working in the desalination plant house if the noise inside the premises are higher than 85dB(A).

In the absence of local standards, internationally acceptable noise standards have been adopted in addressing noise emanating from the power house and desalination plant. Table 3-4 gives noise standards implemented by USEPA and Germany, which is similar to European standards.

Table 3-4: Some selected noise standards

Country/Body	Standard	Averaging Times
US EPA	<65 dB(A) <55 dB(A)	Day time Night time
Germany	<55dB(A) <40dB(A)	Day time Night time

The noise standards enforced by the USEPA for residential areas are 65dB (A) during day time and 55dB (A) during night time, slightly lower than the corresponding German standards of 55dB (A) and 40dB (A). USEPA noise standards were adopted for the Third Power Project as well as the Fourth Power Project for Malé due to the high background noise levels and past history of noise from the old powerhouse in Malé.

However, given that this is a resort setting with a highly sensitive human environment; it is desirable to follow the German standards or even better standards for those areas. However, given the small area and the necessary facility congestion required, noise levels below 55dB (A) would not be feasible to be achieved for some parts of the staff area closer to the powerhouse. However, it may be necessary to consider 45dB (A) standard for night time as in the World Bank standards given below.

Table 3-5: Noise standards according to the World Bank Pollution Prevention and Abatement Handbook, 1998

	Maximum allowable log equivalent (hourly measurements), in dB(A)	
Receptor	Day (07:00 - 22:00)	Night (22:00 - 07:00)
Residential, institutional, educational	55	45
Industrial, commercial	70	70

In cases where the baseline noise level is already above these levels, the plant noise should not cause an increase of more than 3dB (A).

Source: World Bank Pollution Prevention and Abatement Handbook, 1998

3.6.3 Oily water disposal

Water with an oil content of less than 10ppm may be introduced into all public rivers, lakes and *open sea* according to all internationally recognized environmental standards.

4 Existing Environment

This section provides baseline information regarding the relevant environmental characteristics of the study area (including disposal sites). These include ground and marine water quality for standard parameters given in the approved Terms of Reference and also the quality of the product water from the desalination plant. The intake is located on the east side of the island from a 30m deep borehole and brine is discharged in the eastern wave surf area approximately 130m away from the shoreline. Groundwater quality was assessed close to the location of the powerhouse and desalination plant. Product water quality is regularly assessed at site, therefore, that data has been used to assess compliance and performance. Additional water quality assessment for product water would be done only if there is non-compliance with reference to in-house water testing undertaken in the past few months.

Noise levels in the vicinity of the powerhouse and desalination plant and how they affect recreational quality and public and occupational health has also been assessed. Also, it was identified if the existing power house emissions have any negative impact on the living, recreational and working environment. Visual inspections were also made of the emission stacks and fuel handling areas.

4.1 Methodology

Existing environment was studied using standard methods used in EIA studies. Field visit was undertaken on 06 May 2010. Checklists were used to assess site conditions with specific reference to powerhouse and desalination plant facilities. Water quality was assessed using YSI field water quality logger, which was calibrated day before the field trip. Water quality was assessed, as given in the TOR, at mid point where it is shallower than 1m and at about 1m where it is deeper than 1m. Water quality at the receiving environment for the brine discharge was taken at about 3m from the discharge point. Additional samples were brought to the laboratory in Malé for testing for BOD, COD and nitrates. Groundwater quality was the main environmental parameter for oil spill measurements. Since there are no arrangements for groundwater sampling, a shallow borehole was dug and made permanent using an 8-inch pipe covered at the top. Samples were taken from this borehole and only BOD could be tested at the lab. Once the laboratory resumes tests for total hydrocarbon and COD, those tests will be carried out.

Noise was measured using an IEC Type 2 noise meter. Spot SPL measurements which were recorded are presented in this report. Sensitive areas in the vicinity of the powerhouse and desalination plant were included. Other relevant and useful observations were also recorded on site.

4.2 Energy Generation

Energy requirements are met by electric generator sets running on imported diesel. The main environmental elements of the power system are:

- Location of power plant
- Fuel handling and management
- Exhaust stack and stack emissions
- Noise
- Waste fuel and wash water disposal
- Health and safety
- Environmental aesthetics

4.2.1 Location of Powerhouse

The powerhouse is located southeast side of the island of Kandooma away from the sensitive environments namely guest areas and accommodation. It is also kept at a distance from the staff accommodation units although the location of the powerhouse is constrained by the size of the island.

4.2.2 Emissions

The TOR requires to identify if the existing power house emissions have any negative impact on the living, recreational and working environment and to make visual inspections of the emission stacks and fuel handling areas. Given the small scale of the power generation on the island, it would be meaningless to undertake separate air quality assessments. However, emission estimates have been done, which will be discussed in Section 5 of this report.

There are five separate emission stacks, which are about 4m high and is located away from other amenities in the area. There are no major concerns with regard to stack emissions in Kandooma.

Safety

The following safety measures are noted for the powerhouse and related infrastructure.

- The powerhouse has noise attenuation and there is good level of ventilation.
- The machine room is kept tidy and so is the control room.

- All large and small fuel tanks have external bund as per requirements. All fuel pipes are of reinforced rubber hose or GI pipes.
- Distribution is by underground cables. Glass reinforced polyethylene (GRP) distribution boxes are used and the distribution cables are made of four core copper conductors insulated on the outside with polyvinyl chloride (PVC) and steel armoured mechanical protection for physical protection.

4.2.3 Fuel handling and Management

Resort operations require the regular delivery, handling and disposal of fuels, oils and other hazardous chemicals that have the potential to cause:

- Marine pollution spills during transfer operations;
- Soil and groundwater pollution via land spills and leaks.
- Explosion or fire;
- Health and injury risks (including skin, eye and lung damage, poisoning and/or cancer risks).

There's a range of fuels and other hazardous chemicals handled at the resort including flammable gases, petrol dry cleaning solvents, paint thinners, corrosive acids and so on of which only diesel will be within the scope of this assessment or audit. Like all hazardous substances, there are environmental issues related to the supply (shipment) and handling of diesel fuel. However, the supply to site is not covered within the scope of this report. The fuel tank has external bund walls with the same material and the day tanks also have external concrete bund walls to contain spill.

Table 4-1: Power and fuel consumption 2009

2009	Electricity (kWh)	Fuel (litres)	Per capita power (kWh/p/d)	Per capita Fuel (l/p/d)
January	387,165	139,256	20	7
February	407,934	120,488	21	6
March	469,977	138,131	25	7
April	454,078	138,154	24	7
May	467,382	145,539	24	8
June	336,542	115,408	18	6
July	387,165	128,110	20	7
August	407,934	133,278	21	7
September	352,276	117,112	18	6
October	391,544	125,397	21	7
November	410,401	135,325	21	7
December	336,542	137,169	18	7
TOTAL	4,808,940	1,573,367	21	7

4.2.4 Disposal of waste fuel and wash water

Waste fuel is used in the operation of incinerator. Washing of engine parts are undertaken in a confined area inside concrete bunds behind the powerhouse.

4.2.5 Noise

The noise levels in the vicinity of the powerhouse and desalination plant were studied. The results are shown in Figure 4-3. The results indicated that the levels are well below the USEPA requirement of 65dB (A) during day time for the staff area and well within the German standards of 55dB (A) during day time. Night time levels have not been assessed.

4.2.6 Environmental Aesthetics

Kandooma is generally clean and the environmental aesthetics of the powerhouse and desalination plant can be considered to be good.

Figure 4-1: Wash area with the day tanks at the back

4.2.7 Energy conservation

Energy conservation measures are in place. Guest and staff are made aware of the need to conserve energy. However, there is room for improvement and commitment for the country's goal to become the world's first carbon neutral nation would be a great challenge for Kandooma too.

4.3 Water Resources and Supply

4.3.1 Water Resources

Available water resources are rainwater and groundwater of which only rainwater can be considered freshwater. Rainwater is collected in 6 HDPE tanks of 10 tons capacity each. Groundwater from 30m below the ground level is drawn to the sedimentation tank near the desalination plant. This is not expected to show any drawdown effect on the fresh groundwater lens due to the depth from which the water is drawn. The borehole draws water from the Pleinocene limestone layer, which is highly permeable.

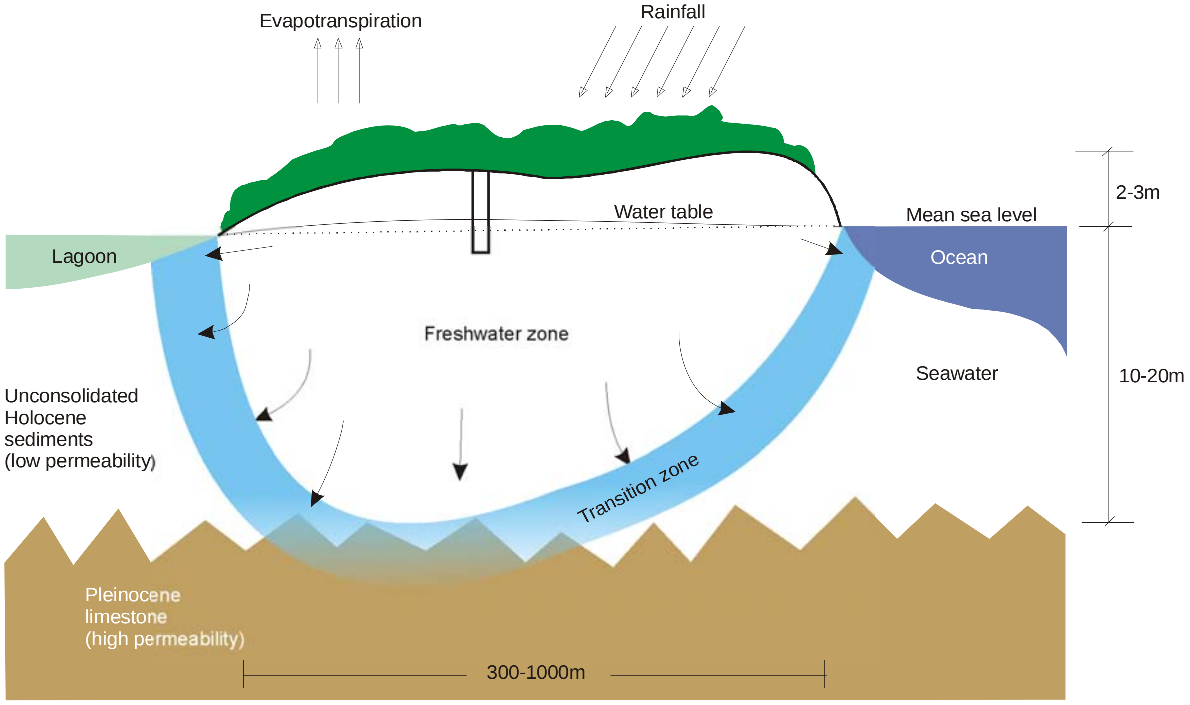


Figure 4-2: Conceptual Illustration of freshwater lens in a small coral island (after Falkland).

The above is typical of most of the islands. Borehole test carried out in Malé (MWSC site) indicates an upper zone with loosely packed sandy soil increasing in permeability until a very permeable zone is reached at about 20m below the surface. The freshwater lens is generally formed up to a depth of about 10m and a brakish transition zone occurs below this depth up to about 20m, below which it is saltwater. The water table in Naifaru is expected to vary between 0.5m to 1.1m from the ground surface. The water table would also fluctuate with tide. It has also been established that there is no hydraulic connection between the upper zone and the lower zone and lower zone is hydraulically connected to the sea. Further, the upper zone is observed to be not affected by tides. Falkland (2001) also observed that there existed a linear relationship between the size of the island and the size of the aquifer. It was observed that as the island width gets narrower, the salinity of wells becomes greater and vice versa. At a width of less than 250m, the groundwater salinity is likely to be brackish at the surface.

4.3.2 Water Consumption

Water production for the year 2009 is given in the table below. From the table, it can be seen that the average per capita daily consumption is 295litres/person/day given that there is 80% occupancy on average. Assuming per capita consumption by staff is below 200litres per person per day and that the rest of the daily consumption is attributed to tourists, per capita tourist consumption would be about 440litres per day. This includes landscaping and other service-related water demands of the resort.

Table 4-2: Monthly desalinated water production/consumption

	Production (m3)	Daily average (m3/d)	Per capita (l/p/d)
January	5,370	173.2	281
February	4,603	148.5	241
March	5,620	181.3	294
April	5,600	180.6	293
May	5,826	187.9	305
June	6,036	194.7	316
July	7,168	231.2	375
August	5,898	190.3	309
September	5,099	164.5	267
October	5,093	164.3	267
November	5,530	178.4	290
December	5,817	187.6	305
TOTAL/AVERAGE	67,660.00	181.9	295

4.3.3 Water Quality

Water quality testing has been done for groundwater and seawater at site and samples brought to the lab for further analysis. The water quality test results from field and lab tests are given in the table below.

Parameter	Unit	SW1 (Sedimentation Tank)	SW2 (downstream of brine discharge)	DW1 (Desalinated Water from Storage tank)	DW1 (Desalinated Water from Plant)	GW1 (groundwater)
pH		7.9	8.1	7.4	7.2	7
Electrical conductivity	uS/cm	50,200	51,350			2,640
Total Dissolved Solids (TDS)	mg/l			254	205	
Dissolved oxygen	mg/l					5.24
Biochemical oxygen demand	mg/l	22				126
Chemical oxygen demand	mg/l	CNBT	CNBT	CNBT	CNBT	CNBT
Nitrate	mg/l	0.0				0.1
Phosphate	mg/l		0.15			1.7
Total Organic Carbon (TOC)	mg/l					59.4
Total Coliform Count (TCC)	MPN/100ml			4	0	

The above results indicate that the brine discharge location does not cause hyper salinisation of the receiving environment. This is because there is good flow in the receiving environment. COD and Total Hydrocarbon could not be tested (CNBT) in the National Health Laboratory at the time. Additional sampling and testing will be done once the laboratory resumes undertaking these tests. Although phosphate in groundwater is slightly high, the source of phosphate contamination is not clear. Therefore, further testing and observations need to be done.

Monthly testing of product water is undertaken by the management by sending samples to the National Health Laboratory. The results of these tests have not been provided so far.

4.3.4 Water Conservation

Similar to energy conservation, water conservation measures are in place. Guest and staff are made aware of the need to conserve water with information sheets and notices in guest rooms. In addition, water efficient faucets and shower heads have been fitted in all areas and guest rooms and water saving equipment are used in the kitchen, restaurant and bar. Since the resort is heavily dependent on desalination, water conservation results not only in the reduction of water use but also energy/fuel use.

4.4 Occupational Health

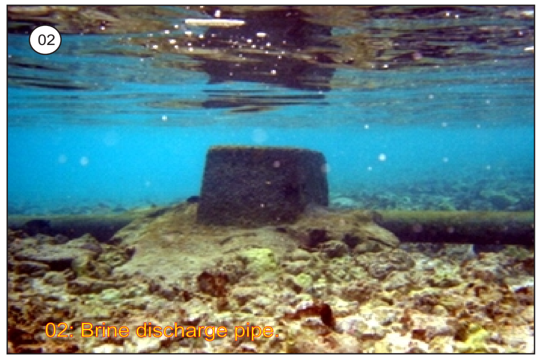
Adequate personal protective equipment is provided for persons working in the powerhouse and desalination plant area including noise mufflers. The control room is air-conditioned with adequate noise insulation.

The resort also provides health and safety training to the staff working in the powerhouse and the desalination plant facility. The Engineering Department is equipped with the necessary skills while fire fighting equipment is provided in all areas of the resort.

There are no occupational health hazards in the work environment. All hazardous areas are well managed and all risks are minimized. No visible fuel spills have been observed. There are also no wet surfaces in any of the work areas.

Figure 4-3: Illustrated summary of site conditions


01: Brine discharge pipe.


02: Brine discharge pipe.


03: Desalinated water tanks.

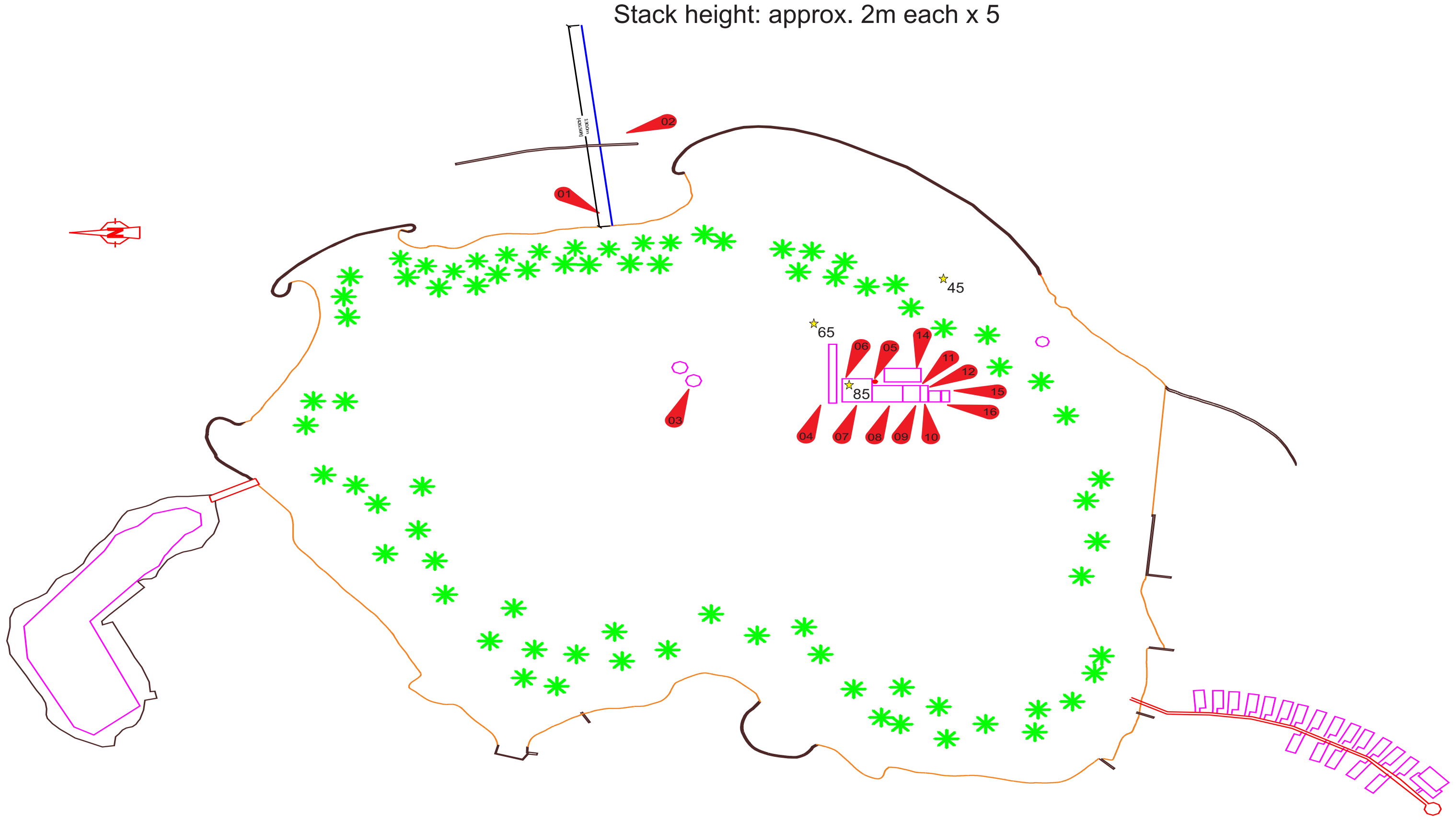

04: Fuel stack house.


05: Ground water testing borehole near powerhouse.


06: Powerhouse stacks (Silencers).

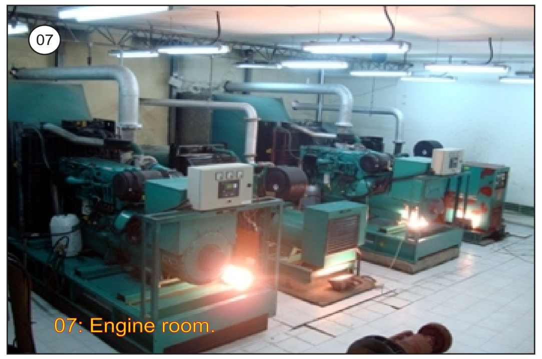
Basic Data for Kandooma Tourist Resort.
Location: Kandoomafushi, South Malé Atoll,Maldives
No. of beds: 320
Avg occupancy: 70%
Staff: 360

Powerhouse and desalination plant are located in the southeast area of the island
Capacities:
Diesel Engines: 1x250kVA, 3x500kVA, 1x450kVA
Desalination plant: 250+100 tonnes/day
Groundwater intake: 30m groundwater intake borehole.
Brine discharge: approx. 130m long pipe with outfall near eastern surf break zone.
Stack height: approx. 2m each x 5


Kandooma Tourist Resort, Maldives.


17: Fuel washing area behind powerhouse.


16: Fuel washing area behind powerhouse.


07: Engine room.


08: Desalination Plant.


09: Sedimentation tank and Chemical storage.


14: Desalinated water storage tank.


13: Desalination plant area


12: Water intake pump.


11: Sedimentation Tank.


10: Chemical storage area.

5 Environmental Compliance and Performance

This section will identify operational impacts of the powerhouse and desalination plant facilities to verify environmental compliance and address environmental performance issues. As such, the following would be considered:

- Identify if the brine is discharged in appropriate location and if exhaust emissions are appropriately discharged.
- Discuss the short term as well as long term effects of any emissions or discharges on the environment, especially the health of the staff.
- Identify any information gaps and evaluate their importance for decision-making.
- Determine how well the existing infrastructure complies with existing environmental policies and regulations

5.1 Power House

5.1.1 Location

The power house is located as far away from noise sensitive areas as possible. Appropriate distance has been kept from noise sensitive locations such as the mosque and the senior staff block, which are the closest noise sensitive locations. The noise levels inside these premises are within acceptable range.

5.1.2 Air quality

Particulates and sulphur dioxide emissions are of concern when it comes to air pollution loads from diesel engines. Therefore, using the WHO Rapid Assessment Model, estimates have been made for the powerhouse in Kandooma.

The emission levels from the powerhouse are quite low. Estimates using fuel data provided by the Engineering Department indicate an hourly average of 1.06ug/m^3 of particulate emissions. This is equivalent to an annual average of 0.74ug/m^3, which is well below USEPA standard of 60ug/m^3 annual average for particulates. Similarly, SO_2 emissions (assuming marine diesel oil with average sulphur content of 0.9% sulphur) are estimated to be at an hourly average of 1.52ug/m^3, which is only a fraction of the USEPA standard of 260ug/m^3. Therefore, it can be safely concluded that the powerhouse emissions are well within acceptable emission standards.

5.1.3 Greenhouse Gas Emissions

Using a Tier 1 approach described in IPCC (2006), the following carbon dioxide (CO2) and other gaseous emissions are estimated for Kandooma based on the power output from the diesel consumed for the year 2009.

	IPCC factors (kg/TJ)	Power output (TJ)	Emission (kg)	Emission (tons)	Per capita (ton)	Per capita (g)
CO2	74100	17.3122	1,282,832.83	1,282.83	2.08252	
Methane	3	17.3122	51.94	0.052	0.00008	84.31
N2O	0.6	17.3122	10.39	0.010	0.00002	16.86
SO2	0.9	17.3122	15.58	0.016	0.00003	25.29

Carbon dioxide is the most significant greenhouse gas emitted from the combustion of marine diesel oil. According to the Carbon Dioxide Information Analysis Centre (CDIAC), the per capita emissions for the Maldives are 2900kg of CO_2 in 2006. Assuming an increase of a maximum of 150kg per year, the 2009 estimates would be 3,350kg per person. The 2006 estimates by CDIC put Maldives in the middle of the list of 212 countries. The list varies from 49,000kg CO_2 per capita for Qatar to 36.7kg CO_2 for Somali. Most of the emissions for the Maldives are related to the Tourism sector, with tourists coming from developed countries whose emissions per capita varies at an average of about 9,000kg CO_2 in 2006. Therefore, based on the estimates given above, it may be assumed that tourists have a much lower carbon footprint during their time in the Maldives even if their emissions from air travel have been incorporated into the equation.

Table 5-1: Total Emissions for Maldives from 2000 to 2006 (source: CDIAC)

Year	Total	Gas Fuel	Liquid Fuels	Solid Fuels	Per Capita
2000	499.12	0	499.12	0	1.8717
2001	576.19	0	576.19	0	2.0919
2002	689.96	0	689.96	0	2.4589
2003	598.21	0	598.21	0	2.0919
2004	752.35	0	752.35	0	2.6057
2005	678.95	0	678.95	0	2.3121
2006	869.79	0	869.79	0	2.8993

Note: all emission estimates above have been expressed in thousand metric tons of carbon dioxide and per capita estimates are in metric tons of carbon dioxide.

5.1.4 Noise levels

Noise levels for the powerhouse are well within acceptable levels. As has been discussed earlier, noise from the powerhouse can be hardly felt in the mosque, which is the closest noise sensitive premise. Therefore, noise emissions are in compliance despite the constraints of locating the powerhouse due to the small size of the island.

5.2 Desalination Plant

5.2.1 Emissions

The atmospheric emissions and GHG emissions related to the desalination plant are incorporated into the calculations given for the powerhouse above. Therefore, no further discussions are necessary.

5.2.2 Performance

5.2.2.1 Groundwater intake

The intake is located on the island at the southeast of the island. It is an 8-inch HDPE pipe located at about 30 metre deep from ground level. According to the site operations engineer the boreholes were intact and in good condition. It was assumed that the boreholes were completely buried intentionally. The resort does not have the drawings of the boreholes and there has been no water quality monitoring carried out near the borehole site to see the impact on groundwater.

5.2.2.2 Pump well

The pump house and the two pumps in it have been well maintained and appears to be in good condition.

5.2.2.3 Sedimentation tank

The sedimentation tank is of good size (possibly oversized). The tank has three chambers where water is retained for settling before being pumped to the desalination plant inlet. The water from boreholes is clear with very few or no sediments and no odour. When observed by filling up a glass bottle from the third chamber of the sedimentation tank, there were no sediments or suspended particles seen. Due to the clear intake water it is expected that the life of the filters and membranes will be longer. Very fine settled sediments were observed at the bottom of the third chamber. This accumulation may have occurred during a long period of time because almost no floating sediments were observed at the time of inspection. According to the Engineer in charge of operations, the tank has not been cleaned for a long time, for almost a year.

5.2.2.4 Desalination units

One plant which is installed by Aqua Tech, Singapore has the drawings and necessary documents, but the second plant has no such document. Only one plant was being operated during the observation, the other plant was under maintenance.

The following are some of the issues identified;

- The engineer in charge of the plants has good knowledge of the plants O&M; however he is not dedicated for the desalination facility only. The local operators need training and basic understanding of the operation and maintenance of the plants.
- No spare parts list but some stock is available.
- Operations and maintenance manuals and catalogues are available for the Aqua Tech plant however the Static Plant documents and borehole design and documents are not available.
- There is no regular log kept for the plant's operations.
- Chlorine is used for treatment via dosing system. Disinfection is carried out after the production (before storage). There is no treatment at the storage and chlorine is not measured before distribution.
- No operations diagrams, precautions and instructions such as warning signs.
- Chlorine meters used are not appropriate to measure chlorine in desalinated (or drinking) water.
- Water quality testing reports are adequately maintained but not interpreted; plant production and water usage data are input in to computers and interpreted. In Addition there are some water quality tests which the EPA requires which have not been carried out. It was informed by the engineer that they are preparing to do all required tests regularly.
- There has been scheduled preventive maintenance carried out. Rusting parts and leakage was observed in many parts of the both plants. These issues were brought to the attention of the engineer.
- Some flow meters, valves and pressure gauges needs to be replaced urgently. Attention is needed for leaking pumps and some pools of salt water in the plant room.
- Chemicals are stored in an area near the sedimentation tank. This area is not closed and people can easily enter the area. There are no warning signs or chemical handling procedures displayed.

5.2.3 Water Quality

Groundwater quality and seawater quality has no baseline data to compare with. However, the data obtained for the purpose of this study indicate that the marine water quality is in pristine condition and that there are no hyper salinity issues at the brine discharge location. The groundwater sample taken at or close to the powerhouse fuel handling area indicates that there is no contamination of the groundwater lens from fuel handling activities.

As discussed earlier, monthly testing of product water is undertaken by the management by sending samples to the National Health Laboratory. This is in accordance with the conditions of initial registration of the desalination plant. The results have not been shared with the consultants by the time this report was completed.

5.2.4 Operation and Maintenance

The desalination system does not appear to be well maintained. Operations Manual was available for the Aquatech plant but the Static plant does not have such a manual. Also, the borehole design details and relevant documents are not available on site. Regular logs of the plant operations have not been kept.

5.3 Audit Summary

The following matrix provides a summary of compliance of the powerhouse and desalination plant

Table 5-2: Compliance matrix for powerhouse and desalination plant in Kandooma

Environmental and socioeconomic aspects	Compliance/Performance					Remarks/Observations	Recommendations
	None	Low	Fair	Good	High		
Water quality				X		Regular water testing in place	Digital measurements of free and residual chlorine desirable
Exhaust emissions					X	Well within limits	
Environmental noise				X		Within acceptable limits	
Occupational health				X		No issues identified	
Oil handling				X		Oil handling is adequate but can be further improved	
Disaster management				X		Adequate emergency and fire safety procedures in place and the powerhouse is at low ground above normal flood level	Future upgrades shall consider raising the powerhouse floor to even higher levels
Risk management					X	Good housekeeping. No accidents reported	
Environmental aesthetics					X	Clean and tidy inside and outside.	Further plantation of trees around the powerhouse and other areas
Energy conservation				X		Measures for energy conservation, efficient technology and a great deal of awareness	Annual energy audits may be useful and would help reduce costs dramatically
Renewable energy			X			High dependence of diesel and few renewable energy options	Renewable energy options to be identified and put to increasing use to assist the national goal of carbon neutrality by 2020. Annual energy audits would be useful too
Water conservation				X		Measures for water conservation, efficient technology and a great deal of awareness exist	Annual water audits may be useful and would reduce cost to a great extent. Per capita water consumption figure is high.
Operation of desalination plant			X			Daily logs not taken, chlorine dozing unit, flow meter and pressure gauge needs fixing and manual for one plant and details of borehole is not available at site	Improve operational performance by appropriate maintenance and making manuals and design details available on site
Water quality				X		Water quality monitoring is not well understood by the staff	Water quality monitoring needs to be improved, data shall be based on average reading of 3 samples

6 Mitigation and Management of Negative Impacts

This section will identify possible measures to prevent or reduce significant negative impacts to acceptable levels with particular attention paid to intake system, brine disposal, emission and noise control and operation and maintenance issues. Cost the mitigation measures, equipment and resources required to implement those measures will also be estimated.

6.1 Energy Generation

The main impact of energy generation on Kandooma is the green house gas emissions from the burning of diesel. It is the primary source of power and diesel fuel consumption is high. The greatest known impact of fossil fuel burning is the production of greenhouse gases, especially carbon dioxide in high quantities, which result in global climate change resulting in frequent floods, hotter days, frequent cyclones and other natural hazards and sea level rise on a global scale. While there is increasing awareness of the dangers of climate change including global warming and sea-level rise, there is little action on a global scale. The Maldives has been greatly concerned about rising sea levels, although climate change on a global scale may lead to even greater catastrophic events, this small nation has been at the forefront of lobbying sustainable development and now it is moving to act and is striving to become the world's first carbon neutral country. Therefore, it is important to contribute to the country's goal of achieving carbon neutrality.

6.1.1 Clean Energy Options

Clean energy or sustainable energy options are not often dependable. This is one of the reasons why clean energy has not found its way into the market on a commercial scale. Therefore, dependence on fuel, which is dependable as long as supplies, last, is high. However, it is important to find alternatives and to continue to replace fossil fuels such as diesel with cleaner fuels (e.g. biodiesel) that produce lower levels of greenhouse gases or preferably those that do not emit greenhouse gases at all such as solar, wind, tidal, ocean thermal, etc.

Some electricity service providers in some countries are now offering consumers the opportunity to obtain their electricity from a package of electricity supplies that include highly desirable renewable resources, sometimes combined with the cleanest available conventional technologies. Considering the increasing awareness of global changes due to increasing greenhouse gas emissions, tourists would certainly prefer or at least show preference to sustainable energy options. Therefore, it may be worthwhile to try to incorporate green, new, low-impact renewable resources. The options include solar energy, wind energy, hydro energy, tidal energy, wave energy, energy from ocean currents, ocean thermal energy and biomass. Biodiesel is also considered a possibility for the Maldives. Of these solar energy and ocean currents are considered to be the only practicable options. Even solar energy can be used to some extent as there is a lack of space on the island to tap solar energy. Wind is not suitable due to small size of the island and aesthetic impact of wind turbines on the resort. However, the proposed 75MW wind farm on Gaafaru is expected to find its grid into Kandooma too if the proposed project can provide dependable energy at lower cost. Bio-fuel (or bio-diesel) is also becoming increasingly important as a replacement for fossil fuels. However, they cannot be considered clean energy as they emit carbon dioxide into the atmosphere, however, unlike fossil fuels they do not cause additional carbon dioxide emissions since the plants use carbon dioxide for photosynthesis. It is believed that algae biofuels have very high energy values and the shallow coastal waters and warm climate of the Maldives makes it ideal for growing algae on a commercial scale. Kandooma can actually provide incentives for bio-fuel production in the Maldives after doing feasibility. Energy generation from burning biomass have recently been tried and the applicability is yet to be demonstrated.

Ocean thermal energy can be put to use in resorts to replace cooling needs, which account for over 40% of total energy demand. A deep sea cooling system was installed at Soneva Fushi as a pilot project. It demonstrated that it is practicable, however, more so for islands on the rim reefs from where pipelines can be located at deep waters. Since Kandooma is close to the rim reef, such systems are quite practicable for Kandooma. In addition, tidal, wave and ocean currents can generate electricity, however, no studies have been done for the Maldives so far. Maldives does not have the required tidal swing, therefore is tidal energy does not seem to be an option for the Maldives whereas wave and ocean currents can be considered possible options in the long run. Wave and ocean current based generators can be used on conjunction with mineral accretion technologies to create artificial reefs or promote reef growth. However, at present these options are not viable as the technology is not so far developed.

While efforts are underway to address renewable energy policy of the country, the process of Renewable Energy Technology (RET) transfer might run the risk of stagnation after completion of the RE programs as not enough attention is being paid to local entrepreneurial activities and the creation of a domestic market for RETs (Alphen *et al* 2006). Therefore, if renewable energy was to work as a longterm solution, local know-how and research capacity has to be developed prior to implementing renewable energy programmes.

6.1.2 *Peak Load Management*

Peak load management helps to minimize fuel consumption and is the smarter energy management option. Peak load management simply involves not doing certain works that demand high energy during peak load hours, generally during noon when air-conditioning needs are very high. Some of the things that Kandooma can do include:

- Conduct awareness campaigns for the staff to reduce energy consumption during peak load hours. The campaign could provide information on how to reduce energy consumption in generally used items and procedures for energy efficiency.

- Keep drying, ironing, and similar high load activities for the night.
- The waste heat from power plant can be extracted and could be used for air conditioning of new buildings by implementing a cooling network. Furthermore the waste heat may also be used for production of ice or providing chilled water for air conditioning.
- Provide tourists with the option of doing certain outdoor activities during day time while keeping their air-conditioners off.

6.1.3 Energy Conservation

Several studies have shown that energy conservation through awareness helps to reduce energy consumption by one-third. Energy conservation has to be further encouraged in Kandooma with special programmes targeted at staff. Energy smart technologies and building design has to be incorporated to assist in energy conservation. Natural lighting and ventilation has to be maximized in all rooms and public buildings. There are options for further improvement, including the replacement of lights with nano-crystal LED lamps or energy saving lamps.

6.1.4 Atmospheric emissions and Noise

Improving the quality of diesel by increased octane number and reduced sulphur content result in reduction of SO_2 emissions and particulate matter emissions, especially PM_{10}. Furthermore, improved quality also results in less environmental damage in case of spillage. Therefore, it is useful to explore the possibilities of using high quality fuels although they may be slightly expensive. Improving maintenance by having appropriate maintenance procedures would also result in greater engine efficiency and subsequent reduction in fuel consumption.

Increasing plantation in the powerhouse and staff area where there are open spaces would also help the environment in a special way by helping to reduce carbon dioxide levels in the atmosphere. Each plant is expected to offset or sequester about 20kg of carbon dioxide annually. Vegetation would not only act as a carbon sink but would also help to minimize noise if a vegetation buffer can be laid near the power house and staff accommodation blocks.

6.1.5 Fuel Handling

Fuel handling is in conformity with acceptable practices. However, further improvements shall be sought.

6.2 Desalination

Desalination plants are energy intensive, depending on diesel fuel as solar desalination is not well developed. For this reason they are not considered environment-friendly. However, desalination plants are regarded by some as a tool to preserve natural water resources and therefore as a means to protect environment and the question whether desalination systems are environmentally friendly is not necessarily relevant. Yet, this section looks at the different impacts of the desalination plant and how some of the impacts can be mitigated.

6.2.1 *Intensive energy use*

The intensive use of energy by the desalination plant results in indirect environmental impacts, since the energy requirements of the plant increase the production of electricity, the burning of fossil fuels and in turn the contribution to global warming. Based on various publications, it is estimated that the amount of electricity required to produce 1m^3 of water varies between 3.5-4.5 kWh/m3 (Rachel *et al* 2002). The daily water production capacity in Kandooma Tourist Resort is estimated to be about 180m^3 for which an estimated maximum of 730kWh of electricity is consumed for desalination daily. Burning of this fossil fuel contributes to global emission of greenhouse gas which in turn contributes the global warming and climatic change. The CO_2 emissions from burning of fuel in Kandooma have been given earlier and have been shown to comply with USEPA standards, which have generally been used in the Maldives.

6.2.2 *Alternative water resources*

Rainwater and groundwater are the only sources of water available for the island. However, use of groundwater is restricted and rainwater catchment is limited by the size of the island. Therefore, desalination has been adopted. However, it may be worthwhile considering the use of groundwater for flushing toilets, which would minimize desalinated water production. However, the Tourism Regulations do not allow the use of groundwater for some unknown reasons. There are no technical papers supporting this policy.

6.2.3 *Source water intake*

Any seawater desalination facility would require an intake system capable of providing a reliable quantity of clean seawater with a minimum ecological impact. There are basically two options for source water intake and they are seawater and groundwater. For seawater, there are two options, i.e. take from 5m beyond the reef or inner lagoon, as prescribed in the Desalination Regulation. For groundwater, there are two options (groundwater direct from the water lens) and brackish water using a borehole drawing water from below the water lens at about 10m below the water table. Of these, the option of drawing direct from the water lens would reduce costs dramatically, however, may not be allowed as per the requirements of the Tourism Regulations. Even the deep borehole option is expected to be cheaper than the seawater intake option in that the draw water would be generally free of sediments thereby increasing membrane life. However, most resorts use the seawater intake possibly due to ease of installation and for some potential for anoxious conditions resulting in ammoniacal or hydrogen sulphide smell in the product water if groundwater were used. However, In Kandooma the intake pipe comes from a 30m deep borehole in the ground and there have been no issues of smell or any other issues reported so far.

6.2.4 *Brine Concentrate Discharge*

Brine concentrate is discharged directly to the surf breaking area. The TDS of receiving water usually increase by 50-80% due to the discharge of the concentrate without treatment and that of differential temperature remains 0-1°C (Sommariva *et al*, 2004). Section 5.2.3 discusses the water quality analysis undertaken for the brine discharge location. There is no impact of hypersalinisation owing to the high degree of movement of the coastal waters, which aids in rapid mixing. Since this observation is based on single spot measurements, it may be necessary to do further studies to ascertain this. However, based on experience and professional judgement it can be said that the receiving water is expected to have acceptable quality and the zone of impact is away from the housereef of the island. Although the brine contains materials originated from the ground (source water), its high specific weight and the potential presence of additional chemicals introduced in the pre-treatment may harm the marine ecology within the zone of discharge, if it was discharged directly onto the reef, which is not the case for Kandooma.

6.3 Uncertainties in Impact Prediction

Environmental impact prediction involves a certain degree of uncertainty as the natural and anthropogenic impacts can vary from place to place due to even slight differences in ecological, geomorphological or social conditions in a particular place. There is also no long term data and information regarding the particular site under consideration, which makes it difficult to predict impacts. However, the level of uncertainty, in the case of the facilities under consideration for Holiday Inn Kandooma Maldives may be expected to be low due to the experience of similar projects in similar settings in the Maldives and the fact that the power and desalination facilities have been operational for quite a number of years. Nevertheless, it is important to consider that there will be uncertainties and to undertake voluntary monitoring as described in the monitoring programme given in this report.

Table 6-1: Mitigation measures for negative impacts and impact significance after mitigation measures

Activity	Negative Impacts	Mitigation Measures	Impact Significance before mitigation	Impact Significance after mitigation
1. Land clearance	• Loss of vegetation in the powerhouse and desalination plant area	• Plant more trees	Moderate	Minor
2. Feed water intake	• Abnoxious conditions in the borehole	• Check borehole regularly	Minor/negligible	Negligible
	• Aquifer salinization due to leaks in the borehole	• None	Negligible	N/A
3. Brine concentrate discharge	• Chemical contamination • Temperature variation	• None	Negligible	N/A
4. Fuel use and management	• Global warming and climate change	• Energy conservation (continue with due diligence) • Consider alternatives in future	Moderate	Minor
	• Spillage into ground	• Good housekeeping, training and appropriate supervision	Moderate	Negligible
	• Potential for spillage during transport	• Alternative energy (e.g solar and wind)	Moderate	Negligible
5. Use of raw materials	• Generate solid waste (used membranes, filters etc)	• Reuse membranes and filters after backwashing to highest possible level	Moderate	Minor
6. Engine and pump operation	• Noise pollution	• Maintain pumps and generators • Provide workers with safety equipment	Moderate	Minor
7. Stack emissions from powerhouse	• Air pollution	• Substitute with clean fuel • Modify operation practices	Moderate cumulative impact	Minor to negligible
8. Waste oil handling	• Spillage into environment and pollution	• Training and appropriate supervision	Minor	Negligible

7 Environmental Management and Monitoring Plan

7.1 Introduction

This section will cover the management and monitoring needs of the powerhouse and desalination plant facilities in Kandooma. The environmental performance evaluation exercise conducted on Kandooma Tourist Resort showed that there are limited environmental management issues with reference to powerhouse and desalination plant. In fact, there is good environmental management and performance. However, there are no written environmental management strategies and monitoring data is lacking. Data relating to environmental management and monitoring helps to not only demonstrate compliance but also helps to measure the effectiveness of or the success of the environmental impact mitigation measures. There are number of good reasons why an effective environmental management plan is needed for any such development, which can be summarised as follows.

- It can help manage environmental matters in a coordinated manner
- It can provide information that can be used for documentation and verification of environmental impacts
- It can help to provide an immediate warning whenever a predicted indicator approaches a predetermined critical level
- It can provide information that can be used for evaluating the effectiveness of implemented mitigation measures
- It can provide information for better decision making and future improvement of environmental quality.

7.2 Environmental Management Plan

The following outlines the environmental management and monitoring needs of the powerhouse and desalination plant infrastructure on Kandooma. It is important to note that some of these measures are currently in place and the resort has an acceptable level of environmental management although there are certain areas in which environmental management is poor due to lack of written procedures and guidelines. Therefore, it may be necessary to have a Resort Environmental Management and Safety Management Action Plan developed for the entire resort operation, which could serve as a manual for environmental management.

7.2.1 Fuel and Hazardous Chemicals

The following table outlines the possible impacts, management objectives, performance targets and monitoring indicators for fuel and hazardous chemicals management in Kandooma. Please note that although hazardous chemicals are included here, not all hazardous chemicals are covered under the scope of this report.

Table 7-1: Environmental Management Plan for fuel and hazardous chemicals

Potential Impacts	Management Objectives	Performance Targets	Monitoring Indicators
• Marine pollution from diesel fuel spills.	• Resort has the right to refuse fuel deliveries from tankers not complying with national maritime and spill prevention regulations or policies. • Diesel transfers to be closely supervised by tanker captain and allocated resort staff. • Crew and resort staff maintains visual surveillance during transfer operations. • Couplings and fuel lines are evacuated and regularly checked (eg pressure-tested).	• No deliveries from tankers with inadequate fuel line evacuation and flow monitoring equipment. • No leaks from fuel line couplings or resort fuel lines. • No marine oil spill incidents.	• Number of marine spill incidents. • Number of leak incidents involving coupling or resort fuel line.
• Soil contamination and/or groundwater pollution from fuel, lubricant or chemical leaks and spills.	• All liquid chemicals stored in appropriate containers on impermeable floored areas. • Fuel and oil drums are stored on sealed floors or spill trays. • Floor coverings or strong plastic ground sheets at all oily service and repair areas. • Regularly clean out oil traps in diesel tank bund. • Pressure-testing of below-ground diesel pipelines.	• No liquid chemicals, fuel or oil stored on open ground. • No lubricant servicing or repairs on open unprotected ground. • No build-up of oily leaf litter in diesel bund and oil traps. • No diesel fuel leaks from underground fuel lines. • No fuel or chemical leak or spill that threatens groundwater quality.	• Number of petrol or oil drums kept on open ground. • Number of sites with contaminated soils. • Number of bund and oil trap inspections and clean ups. • Annual diesel line pressure-testing results. • Number of land spill and leak incidents.
• Explosion or fire from ignition or mixing of volatile or flammable chemicals during storage, use or disposal	• Flammable chemicals protected from ignition sources by appropriate storage, equipment, warning signs, training & supervision	• No fuel, gas or chemical fires or explosions. • All incompatible chemicals are stored and handled separately.	• Number of chemical ignition accidents. • Number of hazardous chemical incidents reported by staff.
• Injury and health risks from contact/exposure to hazardous chemicals.	• Minimise risks by staff training, protective clothing and equipment, and using MSDS information.	• No injuries or illnesses caused by contact or exposure to chemicals.	• Number of chemical accidents requiring medical attention.

7.2.2 Fire Prevention and Control

The following table outlines the possible impacts, management objectives, performance targets and monitoring indicators for fire prevention and control in Kandooma. Please note that the report does not need to cover all aspects of fire fighting system in the resort although the following management plan would try to do so.

Table 7-2: Environmental Management Plan for fire prevention and control in Kandooma

Potential Impacts	Management Objectives	Performance Targets	Monitoring Indicators
• Burn injuries and fatalities to staff and guests. • Loss or damage of resort infrastructure • Loss or damage of personal property.	• Competent and regularly tested fire detection systems (both automatic and human). • Prompt recognition, reporting and removal of fire hazards. • Regular training and fire drills for fire-wardens and other staff • Fire information notices in all guest units. • Sufficient fire-fighting equipment near all fire-prone areas. • Regular inspection and testing of water pumps, foam units, hydrants, hoses, extinguishers & other fire-fighting equipment. • Evacuation procedures for dangerous areas in Emergency Response Plan.	• Reliable fire detection systems. • No fire hazards or fires • Trained fire-wardens prepared for immediate response. • All fire-fighting equipment in good working order. • Adequate fire-fighting equipment near all fire prone areas. • Emergency Response Plan has evacuation and assembly procedures for dangerous areas.	• Number and type of reported fire hazards. • Number of fire drills. • Servicing dates for fire fighting equipment. • Number and type of fires.

7.2.3 Desalination plant and associated facilities

The types and likelihood of potential environmental and health risk issues posed by the resort's water supply system (including cooling water discharge) can be summarised as follows.

Table 7-3: Hazards and risks associated with water distribution and effluent disposal system

Source	Potential Effect/Hazard	Likelihood /Risk
Power Plant	Marine impact from metals and hydrocarbons entering the cooling water stream	Very low risk if heat exchangers are checked regularly for excessive corrosion and replaced according to manufacturer's recommended life span.
Brine and cooling water discharge	Coral deaths by concentrated natural salts and warm water discharge	Low risk due to short distance between outfall and reef
Leaks in water distribution circuits	Undetected leaks cause wasteful RO water and diesel fuel	Moderate risk unless flow rates along pipeline circuits are checked regularly and pressure tests undertaken to locate suspected leaks.
Water quality testing	Diarrhoeal infections	Low risk if regularly tested and free chlorine levels maintained

The above list shows the important components of the island's water system that requiring regular monitoring and the management plan for the desalination plant and associated facilities is given below.

Table 7-4: Environmental Management Plan for desalination plant facilities in Kandooma

Potential Impacts	Management Objectives	Performance Targets	Monitoring Indicators
• Marine impact near cooling water and brine outfall	• Avoid corrosion of heat exchanges by regular inspection and servicing	• No exceedence of EPA criteria for metals and hydrocarbons in outfall (if such criteria exist)	• Monitor metal and total petroleum hydrocarbon content of discharge
• Incorrect treatment of potable water supply causes health risks to guests and staff	• Adequate treatment, testing and maintenance of potable water supply is conducted on a priority basis	• Levels of contaminants and pathogens meet Water Quality Standards	• Monitor faecal coliform and chlorine weekly • Monitor other parameters monthly and annually
• Wastage of RO water due to leakage in the reticulation circuits.	• Identify and stop leaks in reticulation circuits on a priority basis.	• Water losses via leaks is $<3\%$ of the total annual output from RO plant.	• Monitor flow rates regularly and do pressure tests if leak is suspected.

7.2.4 Management of Product Water Quality

The following is an outline of the management plan for the management of desalinated water produced for potable as well as other purposes.

Strategy: Operate plant in accordance with manufacturer instructions and service agreements. Monitor pathogen and contaminant levels regularly to ensure supply meets accepted standards depending on the use.

Responsibility: Chief Engineer/Assistant Engineer, Services Manager

Monitoring/Reporting: Collect representative and discrete samples of product water supplied to guest and staff facilities from the water storage tank and at least three different supply points on the distribution system. At least three samples must be taken at each point and submitted for laboratory analysis. Following lab analysis, the results must be reviewed and correct actions taken promptly as and when necessary. The following sampling points must be considered at minimum. In addition sparkling water and ice machine water must be tested regularly. Individual results for each sample are to be filed, and a summary of the year's results provided in Periodic or Annual Monitoring Report.

Table 7-5: Sampling locations for product water from desalination plant

Sample Point	Product Water Sample Point Type	Location of Sampling Point
1	RO treated water storage tank	Storage tank no.
2	Staff distribution supply point	Staff Unit No. ; bathroom basin faucet (tap)
3	Restaurant supply point	Restaurant kitchen; basin faucet (tap)
4	Guest distribution supply point	Guest Unit No. ; bathroom basin faucet (tap)

7.3 Monitoring Requirements

In case of adopting a monitoring programme on seawater desalination and powerhouse it is useful to monitor:

- Fuel consumption (existing data collection mechanism is sufficient)
- Fuel storage and handling
- Soil contamination or fuel spill
- Flume temperatures from the exhaust emission
- Marine water quality at source water intake and brine discharge locations
- Water quality in the sedimentation tank
- Groundwater quality particularly within the site of operation (zone of influence)
- Product water quality
- Regular checking of system performance and components

7.3.1 Fuel Data

Fuel consumption data, storage and handling and fuel spill incident reporting are the main aspects of the powerhouse operations that need to be monitored. Fuel consumption data will help to monitor atmospheric emissions from the powerhouse operations. Air quality monitoring would not be necessary due to the small size of the operations. In fact, it would be worthwhile for the Environmental Protection Agency to monitor air quality on a national scale rather than individual operators investing heavily for air quality monitoring.

7.3.2 Water Quality

Conducting a good water quality monitoring programme is extremely important for several reasons apart from demonstrating compliance. Water quality monitoring is currently based on product water only. Besides routine product water quality monitoring, water quality monitoring at the intake, sedimentation tank and brine concentrate discharge location would be necessary. Groundwater quality monitoring at site of operation is essential to demonstrate sound environmental management.

7.3.3 Soil contamination

The experience of the writer on power plants across the Maldives shows that most of the facilities contaminate soils within the zone of operation and impacts irreversibly mainly due to poor housekeeping and management. According to UNEP (2005) majority of power stations inspected were observed with fresh small oil spills into the ground caused mainly by the handling and drawing of oil, leaks in pipe joints and filters. Powerhouse in operation at Kandooma Tourist Resort apparently does not show significant impact on the soil. However, continuous groundwater quality monitoring is recommended. A borehole with an 8-inch pipe for future water sample collection has been built in the powerhouse impact zone as part of the data collection exercise for this report and for future monitoring.

7.4 Recommended Water Quality Monitoring Programme

Outlined here is the water quality monitoring requirements that should be considered for the powerhouse and desalination plant operations in Kandooma. This programme shall change if the facilities or resort infrastructure related to facilities are to be changed. Monitoring programmes are to have full spectrum of base line data on various aspects associated with the operation of powerhouse and seawater desalination facilities on the island.

Water quality monitoring programme is for weekly, six monthly and annual basis considering the EPA and WHO guidelines. In addition daily testing of pH, electrical conductivity and free and residual chlorine on site is recommended.

Table 7-6: Monitoring water quality

Sample type	Parameters	Min. Frequency	Purpose
Product water (desalinated water)	pH, E-Conductivity, dissolved oxygen, free and residual chlorine, total and faecal coliforms	Weekly	-To ensure the quality of water produced -To meet standards -To assure compliance
Product Water (desalinated water)	Chloride, Nitrate, Phosphate, Ammonia, Iron, Total trichloromethanes, Sodium, Pottassium, Calcium, Total Hardness	Six monthly	-To ensure the quality of water produced -To meet standards -To assure compliance
Intake Water (settling tank)	Salinity, Nitrate, Phosphate, Manganese, TOC, Calcium, Sodium, Pottassium, Calcium, Bromine, Bisulphate, Mercury, Copper, Lead, Boron, Arsenic, Flouride, Phenolic compounds, Anionic detergents, Cadmium, Chromium, Cyanide	Annually for two years then revise frequency depending on results	-To ensure the quality of water produced -To meet standards -To assure compliance
Zone of feed water intake	Temperature, pH, Salinity, Turbidity, Total Suspended Solids, TDS, dissolved oxygen, BOD and COD	Every six months	To ensure the quality of feed water and assure compliance
Zone of Brine Concentrate discharge	Temperature, pH, E-Conductivity, TDS, Chloride, BOD and COD	Every six months	To ensure the quality of water at brine discharge and assure compliance
Groundwater	Temperature, pH, E-Conductivity, Turbidity, Total Suspended Solids, TDS, THC (total hydrocarbon), BOD and COD	Annually	To ensure fuel spills are minimal and effect on groundwater is minimized and assure compliance

7.5 Cost of monitoring

The following table gives an estimated cost for the monitoring assuming the monitoring will be undertaken by the resort in collaboration with environmental consultants. Transport, food and accommodation for environmental consultants have not been incorporated. This estimate is based on the monitoring programme and management plan outlined earlier and assuming six monthly monitoring by environmental consultants.

Table 7-7: Costs of annual monitoring

No	Details	Unit cost (US$)	Total (US$)
1	Field allowance for 2 consultants for 1 day (two trips)	400.00	800.00
2	Monitoring equipment depreciation and other charges (two trips)	570.00	1,140.00
3	Laboratory charges	1,500.00	1,500.00
4	Compliance reporting (annual report)	2,500.00	2,500.00
5	Digital colorimeter for on-site testing of free and residual chlorine	900.00	900.00
	Total		**6,840.00**

Environment Protection Agency and the project consultants need adequate data to make accurate impact assessment and improve impact assessment methodologies would have several reasons to undertake monitoring at adequate intervals. Project proponents or developers or operators often find impact assessment and monitoring unnecessary for which reason the commitment of the Proponent to undertake monitoring has been made mandatory under the EIA Regulations. The purpose of providing estimated costs for monitoring is to quantify such commitments. It also indicates that monitoring is not a costly exercise given the benefits of long term cost reductions as well as compliance and environmental performance benefits associated with monitoring.

8 Conclusions and Recommendations

In conclusion, the project's environmental performance can be rated good. The findings of this report indicate that there is compliance with general requirements of environmental infrastructure management, especially powerhouse and desalination plant, which form the focus of this report. There are adequate health and safety measures and there are adequate provisions to build awareness and training on health and safety including fire safety. Machinery and equipment are in working condition but there are maintenance issues as identified in this report.

The following recommendations are made:

- The leaking part of the plants needs urgent attention and the rusting needs to be cleaned and greased.
- Damaged or non-functioning flow meters, valves and pressure gauges needs to be replaced.
- Chlorine should be measured before distribution and levels of chlorine should match the requirements of EPA.

- Preventive maintenance is the most important part of smooth operation of any facility. Due to lack of importance given to these areas many industries suffer huge costs of replacing expensive parts. For an example maintaining filters well will make membrane life longer. To do this the staff must keep the logs regularly, they should be able to interpret the logs, and they should also know by looking at the pressure gauges when the filters need to be backwashed or replaced.
- The plants need regular maintenance. This includes checking operations of plant, pumps and modules for leaks, oiling and applying grease.
- Documents such as manuals, catalogues and design documents must be easily accessible to operators for reference and guidance. Step by step plant operations, chemical handling and safety precautions should be displayed in both English and local language (Dhivehi).
- Proper stock keeping of spare parts, filters and chemicals must be practiced. Especially, care must be taken to store chemicals in appropriate atmosphere.
- The staff should learn how to check the pressure from the system, assess the functioning, flow and production of the plant.
- Carryout regular water quality tests, including groundwater from the borehole located for baseline monitoring for the purpose of this 2010 Audit.
- It is possible that there is loss in the power system because the amount of diesel consumed for a unit of energy produced is slightly higher than in some other resorts. This needs to be checked separately.
- It is also recommended to undertake an Energy Audit as well as a Water Audit annually. This will help minimize costs dramatically and improve performance of utilities.
- An Environmental Management System or Environment and Safety Management Plan needs to be in place to show the resort's commitment to maintain good compliance and performance in matters relating to health, safety and environmental protection and conservation. Periodic monitoring of performance is also recommended. Monitoring environmental performance of the powerhouse and desalination facilities would not only demonstrate environmental compliance but also help minimize costs in the medium to long term. It is even better and worthwhile to undertake a corporate environmental monitoring programme incorporating all aspects of the operations so that cost of monitoring and subsequent operational costs are minimized.

9 References

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10 Appendices

- Terms of Reference