ENVIRONMENTAL IMPACT ASSESSMENT

For the Proposed Sewerage System

HDh. Neykurendhoo

Proponent: Global Wings Pvt. Ltd.

Sandcays

January 2012

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1 Introduction

1.1 Introduction

This EIA report has been prepared in order to meet the requirements of Environment Protection and Preservation Act of Maldives (Law No 4/93), in particular Clause 5 of this Act, to assess environmental impacts from proposed sewerage system in HDh. Neykurendhoo. Clause 5 of Environmental Protection and Preservation Act (Law No. 4/93) of the Maldives states that an Environmental Impact Assessment (EIA) study need to be carried out before implementing any development project which may have potential impacts on the environment. Additionally, under Clause 1 of this Act (Law No 4/93) it is very clear that the natural environment and its resources are a national heritage that needs to be protected and preserved for the benefit of future generations. Hence protection and preservation of these resources of this country including land, fresh water, flora and fauna, beaches, reefs, lagoons and all natural habitats are important for the sustainable development of the country.

This report will identify the potential impacts of the proposed project and will recommend mitigation measures to minimize such impacts during construction and operation phase. This report will also look at the justifications for undertaking the proposed project components including alternatives to proposed components or activities in terms of location, design and environmental considerations. At the end of the report a mitigation plan and a monitoring programme before, during and after the development work would also be included.

The findings reported in this report are based on qualitative and quantitative assessments undertaken during a site made to HDh. Neykurendhoo in January 2012 and professional judgments. The key limitation similar to other such studies is unavailability of long term site-specific baseline data; hence the impact assessment methodology has been restricted to field data collected, experience and professional judgment on similar settings across Maldives and elsewhere. Long term data relevant to this report on specific aspects such as meteorology and climate were collected from global databases through secondary sources and published reports on Maldives.

This EIA report has been produced in accordance with the EIA Regulations 2007, published by Ministry of Environment, Energy and Water which at present is enforced by Environment Protection Agency (EPA) of the Maldives under Ministry of Housing and Environment (MHE).

1.2 Aims and Objectives of the EIA

This report addresses the environmental concerns of the proposed sewerage system development project at hDh. Neykurendhoo. It helps to achieve the following key objectives.

- Allow better project planning through identification of key impacts and measures for mitigating these impacts
- Ensure efficient resource use, minimize serious and irreversible damage to environment
- Ensure and allow informed and environmentally sound decision making
- To demonstrate the commitment by the proponent on the importance of environmental protection and preservation.

1.3 Methodologies

Established and widely accepted methods have been applied in this EIA study. This study was based mainly on data collected during a field investigation visit made to HDh. Neykurendhoo by a team of surveyors from Sandcays Pvt.Ltd in January 2012 and published literature on similar settings. Sandcays Pvt. Ltd is an environmental consultancy firm registered in the Maldives. The data collection methods are described in detail under Section 5.

1.4 EIA Implementation

This EIA has been prepared by Ahmed Zahid who is also the lead EIA consultant of the proposed project. He has over 15 years of experience in the field of Environmental Impact Assessment in the Maldives. Zahid has been involved in several small island coastal, harbour, land reclamation, water/sewerage project and resort development project EIA's undertaken in the Maldives.

Once the EIA has been submitted it is expected that the review process will not take more than 4 weeks. The review process may result in the requisition of additional information. This EIA has been prepared based on an approved term of reference (TOR) given in Appendix 1.

2 Project Setting

The proposed project takes place in the Maldives environment. Therefore, the extent to which the project conforms to existing plans, policies, guidelines, regulations and laws of the Maldives needs to be considered. Under EIA regulation 2007, all prescribed activities in Schedule D of EIA regulation 2007 are required to carry out a detailed EIA study to obtain environmental clearance before commencing any physical work on the project. Water supply (desalination) and sewerage system development is a prescribed activity under Schedule D of Maldives EIA Regulations 2007 formulated under the umbrella law of Maldives Environment Protection and Conservation Act (Law No.4/93). Hence, this section will look at the context in which the project activities take place and the legal/policy aspects relevant to activities anticipated in the proposed project.

2.1 Applicable Policies, Laws and Regulations

2.1.1 Environmental Protection and Preservation Act

The Articles of the Environmental Protection and Preservation Act (Law No. 4/93) addresses the following aspects of environmental management, which are relevant, understood and adhered to in the proposed project.

- An EIA shall be submitted to EPA before implementing any developing project that may have a potential impact to the environment.
- Project that has any undesirable impact on the environment can be terminated without compensation.
- Disposal of waste, oil, poisonous substances and other harmful substances within the territory of the Maldives is prohibited. Waste shall be disposed only in the areas designated for the purpose by the government.
- The Penalty for Breaking the Law and Damaging the Environment are specified in the Law.
- 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.

2.1.2 Land Act

The land Act of Maldives (Law No. 1/02), formulated in 2002, makes legal provisions for releasing of lands for different needs, releasing of public land for housing and the conditions that govern the owning, selling, renting and transfer of ownership of public and private land. This Act may have some relevance to the project, especially with reference to components such as treatment plant.

2.1.3 Third National Environment Action Plan

The Third National Environment Action Plan or NEAP 3 published in 2009 was divided into principles, results and goals to achieve the results. The NEAP 3, 2009 is founded on ten fundamental principles. Principle 1 states that environmental protection is a responsibility of every individual. Some of the fundamental principles prescribed in NEAP 3, which have been incorporated into this environmental impact assessment exercise include informed decision making, continuous learning and improvement and most importantly the complementing role of environmental protection in socio-economic development.

2.1.4 National Biodiversity Strategy and Action Plan

The goals of the National Biodiversity Strategy and Action Plan are:

- Conserve biological diversity and sustainably utilize biological resources.
- Build capacity for biodiversity conservation through a strong governance framework, and improved knowledge and understanding.
- Foster community participation, ownership and support for biodiversity conservation.

In implementing the proposed project activities care need to be taken to ensure that the national biodiversity strategies are adhered to.

2.1.5 Consultation and Public Participation Laws

In the Maldives public participation has been limited to the review stages of the EIS until recently. However with the EIA Regulation 2007, which considers public consultation as an important and integral part of the EIA process, public consultation is a requirement for all EIA reports. Hence, this EIA has also taken public views into consideration. In fact, public consultation was conducted in order to take public opinion, views and expectations into the project and not simply to fulfil the obligations under the EIA Regulation.

2.1.6 Regulation on Cutting Trees

The Regulation on cutting down, uprooting, digging out and export of trees and palms from one island to another was issued by the Ministry of Environment in 2006. Clause 5 (a) of the Regulation states that prior to the commencement of any project(s) that would require the indiscriminate removal and export of trees/palms from one island to another for the purpose of agriculture, development/redevelopment, construction or any other purpose, it is mandatory under the Regulation to prepare an Environmental Impact Assessment report.

Article 8 (a) requires permission be obtained from Ministry of Environment, if more than 10 coconut palms that are of a six of 15 ft (from base of the palm to the tip of the palm frond) are cut, uprooted or relocated to another island. The regulation also ensures the replacement of the vegetation that is lost by imposing the planting of two palms for every palm tree that is cut or uprooted (Article 2 (d)). Logging on inhabited islands must be done under supervision of the islands chief or an official appointed by the island chief (now Island Council) (Article 8 (c)).

The proposed sewerage project in Neykurendhoo involves some clearing of land for infrastructure development, especially at pumping station locations. No major trees are expected to be felled under the project.

2.1.7 Regulation on Environmental Liability

The Environmental Liability Regulation (Regulation 2011/R-9) came into force on 17 February 2011 covers a wide range of issues which enable to charge penalties and compensation due to environmental pollution and environmental damages. Apparently, the key objective of the environmental liability regulation is to practice polluter pay principles in the Maldives.

2.2 International conventions, treaties and protocols

Some of the international conventions, treaties and protocols of relevance to the proposed project may be identified as follows:

- United Nations Convention on Climate Change (UNFCCC) and the Kyoto Protocol which aims at minimising greenhouse gases to reduce or combat potential impacts of global climate change, global warming and associated effects such as sea level rise, which are thought to have devastating impacts on the Maldives, a fragile small island nation. The aspects of the proposed project that apply to this convention are the importation and transport of raw material to site using diesel based vessels, use of excavators and other machinery in the construction phase, especially their emissions as well as the use of pumps which consume electricity from diesel generators emitting greenhouse gases. These are unavoidable impacts; however, efforts should be made to minimize all such impacts. These are discussed in the impacts mitigation section.
- United Nations Convention on Biological Diversity (UNCBD) with the objective of "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding". Maldives was one of the first nations to ratify UNCBD. Maldives has developed the National Biodiversity Strategy and Action Plan (NBSAP) in 2002. Formulation of NBSAP was through wide consultation and extensive stakeholder participation. As mentioned earlier, there has been extensive consultation and environmental surveys undertaken to ensure that biological diversity is not affected due to the implementation of this project.

2.3 Water and Wastewater Regulations, Policies, Standards and Guidelines

In the past decade or so, as regulator of water and wastewater, Maldives Water and Sanitation Authority (MWSA) has mainly focused on regulating the service provider, Malé Water and Sewerage Company, MWSC and environmental controls have not been given adequate emphasis. With the functions MWSA incorporated into the functions of Environment Protection Agency formed in early 2009, it is believed that much will be done in improving the regulatory framework for water and sewage disposal.

Although several attempts have been made to introduce regulations and standards, they are still at a draft stage. Consequently, upon increasing requests from donors under the tsunami relief assistance programmes, the Maldives Water and Sanitation Authority drafted the General Guidelines for Domestic Wastewater Disposal in the Maldives in March 2006. This document was developed by the staff of MWSA at the time. The document was later revised by a technical team from South Africa and disclosed for internal use and comments in January 2007 as National Wastewater quality Guidelines. These guidelines were publicized on MEEW website in 2008 along with a Water and Sanitation Policy Statement but were later removed and never used and made public. Later in May 2010, EPA discussed with stakeholders draft documents developed with technical assistance from JICA. These are

- Guideline of Sewerage Concept Design and Design Review (Draft)
- Standard Procedure of Sewerage concept Design
- Standard Check-list of Outsourced Design (Draft)

Despite the draft of several documents relating to wastewater and sewerage system design the only document made publicly available is the General Guidelines for Domestic Wastewater Disposal. Therefore, this document has been discussed in detail in this EIA report.

The Maldives adheres to WHO guidelines for its drinking water standards. However, due to the small size of the islands and the time water remains within the waterworks, free chlorine levels have been set below WHO guideline values. This adjustment has been made mainly due to public complaints of chlorine levels in their drinking water but has not been technically justified. Therefore, this has been recently revised.

Currently, there are no surface water quality standards for the Maldives, but this issue has been addressed in the "Guidelines for Domestic Wastewater Disposal" in the Maldives. The pristine nature of the Maldivian waters requires high standards to be met. Given the existing concerns of raw sewage disposal and wastewater disposal within the coastal zone, there should be surface water quality standards that ensure that the pristine state of the coastal waters of the country as a whole is not affected. There are also standards set by the Ministry of Tourism for the tourist resorts. These are derived from stringent international standards.

Effluent quality standards are also non-existent in the Maldives. Some standards were recently drafted by a South African team. These were disclosed for internal use and comments in January 2007 as National Wastewater quality Guidelines. These guidelines were publicized on MEEW website in 2008 along with a Water and Sanitation Policy Statement but were later removed and never used and made public. Later in May 2010, EPA discussed with stakeholders draft documents developed with technical assistance from JICA in which some effluent quality standards were laid down. However, none of these documents have been finalized and made available to the public. Therefore, for reference, the standards given in Table 2-1 are suggested. These effluent quality standards are based on standards of some developed countries and, especially WHO standards.

Table 2-1: Recommended effluent quality standards

Parameter	Description	Standard
Temperature	An important determinant because of its effects on chemical reaction, reaction rates, aquatic life and suitability for beneficial uses	$<40\,^{o}$C
pH	Hydrogen ion concentration is an important quality parameter of both natural water and wastewater. Concentration range suitable for the existence of most biological life is quite narrow and critical	5-9
BOD_5	Most widely used parameter of organic pollution applied to both wastewater and surface water is the 5-day biochemical oxygen demand (BOD_5). Treated effluents should usually meet this criterion.	20-60 mg/l
COD	Chemical oxygen demand (COD) test is used to measure the contents of organic matter of both wastewater and industrial water. This test is also used to measure organic matter in wastewater that contains compounds that are toxic to biological life. COD of wastewater is in general higher than BOD, because more compounds can be chemically oxidized than can be biologically oxidized.	120 mg/l
Total Suspended Solid (TSS)	This is also one of the most important contaminants of concern in wastewater treatment. Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the environment.	150 mg/l

2.3.1 General guidelines for domestic wastewater disposal

"General Guidelines for Domestic Wastewater Disposal 2006" was a result of a series of questions raised by donors following the tsunami of December 2004 due to the absence of any regulations or guidelines to follow in the design of sewerage systems. Although the Guidelines were the first public document demanding the application for a permit and subsequent approval before installation of a sewerage system in the Maldives, the guidelines lack legal backing. The guidelines require all wastewater management systems to meet prescribed criteria for the use of groundwater, design for easy access for maintenance and durability and undertake monitoring and provide facilities for sampling final effluent. Monitoring requirements have been set for monthly monitoring and annual monitoring of groundwater quality.

It is evident from the guidelines that the guidelines have been set for domestic wastewater since it is stated that industrial effluents require special permits from the Authority. Also, the guidelines have been set specifically for wastewater disposal into the groundwater aquifer as receiving water quality objectives have been set only for groundwater and analysis schedule is also for groundwater. The guidelines also focus mainly on on-site wastewater disposal systems, with specific reference to septic tanks. However, it is stated that:

> "Where a sea outfall is used it should be placed away from areas such as commercial harbours or areas designated for recreational purposes. The sea outfall must be placed in such a way that the effluent will be flushed out into the deep sea, where it can be diluted and dispersed so that the impact on the marine environment is reduced. Untreated wastewater shall not be disposed into the near shore lagoon."

The Guidelines also provides for Environmental Impact Assessment for sewerage project and states that:

> "All sewerage projects have to undertake the Environmental Impact Assessment (EIA) as required by Ministry of Environment, Energy and Water (now Ministry of Transport, Housing and Environment) and then submit the EIA

> Decision Note to the Authority. The EIA must in particular assess the impact of the proposed project upon the island's water resources and receiving waters, including an assessment of the groundwater sustainable yield, quality and anticipated impacts/changes resulting from the project."

The Guidelines were a good starting point but needs to be reviewed in view of existing concerns, especially with regard to legitimacy and authority. The recent developments including the South African and JICA documents are very much improved and would be useful if they can be publicised.

2.3.2 Design Criteria for Sewerage Systems

In early 2007, MWSA prepared design criteria for sewerage systems. These include design standards, testing requirements, submittals and drawing standards, impact analysis procedures and service fee requirements. Some important considerations are that:

- All buildings shall be connected to sewer lines
- Storm water drainage can be deviated to sewers with special permission
- Sewerage system design shall allow for sewage resulting from future landuse and new reclamation
- Sewerage systems shall be designed with a single outfall. If multiple outfalls are required, pumping stations shall be provided
- All systems shall have a bypass sea outfall
- An operation and maintenance manual shall be furnished for all sewerage projects

These design criteria has been taken into consideration in finalizing the design for the proposed sewerage system in Neykurendhoo. Since its implementation, the Design Criteria has been used by engineers in designing sewerage systems for the islands of the Maldives. However, as indicated in the water and sanitation policy statement, there is a need to increase awareness about the Design Criteria and further discussion with engineers and other technical personnel working in the sector to address current concerns is important. It is believed that the Design Criteria has been subject to some criticism especially with regard to specific references to water consumption and pipe diameters. Such issues are being given further consideration by the Water Section of the EPA.

2.3.3 Design Requirements under CSR Projects

Design requirements for sewerage under CSR projects have been provided to all Proponents under CSR scheme. These requirements specify the type of system (gravity system with the least number of force mains and potential for treatment in five years), type of sizes of pipes for the different pipelines, design period and other design criteria. These have been taken into consideration in developing the preliminary design that goes with the EIA report. Detailed design will further elaborate on those requirements.

2.4 Other Developments

As has been indicated earlier, there are several shortcomings in the water and sanitation sector, which needs to be addressed soon. The new administration is trying to address the shortcomings of this very important sector by formulating policies and strategies which are discussed in the recently published Strategic Action Plan, "Aneh Dhivehiraajje". In this strategic plan, water and sanitation is recognized as a basic human right and universal access without prejudice is the key target and strategy. The goals of the sector highlighted in the Action Plan includes protection and preservation of freshwater resources, private sector involvement for service provision regulated by the Government, renewable energy use for water supply and sanitation and groundwater protection. Some of the important policies outlined in the Action Plan include improving accessibility, prioritize water and sanitation in development planning and implementation, establish effective maintenance procedures, facilitate private sector investment, strengthening legal and institutional framework, water resource management for environmental preservation and water safety for public health.

In terms of strengthening the legal framework, the Strategic Action Plan refers to the existence of a draft National Water Act, and stresses the need for a separate Sanitation Act. While there is ample research and strategic planning throughout the world to integrate water and sanitation, it is questionable why the Maldives is opting to two different pieces of legislation for Water and Sanitation. The Action Plan also identified that there would be a legal framework for the establishment and management of provincial utilities companies, which have been formed recently with the objective of managing water supply, sewerage and electricity services in the islands. The Proponent, Upper North Utilities Ltd. is amongst those companies.

In addition to the Act(s) or legislative aspects, some of the important strategies that have been highlighted include (1) seeking the most appropriate sewerage systems for the Maldives, (2) establishing mechanism for wastewater research in the country, (3) seeking immediate measures to stop groundwater pollution, (4) integrating water resource planning into landuse planning, (5) establishing effective water resource monitoring programmes, (6) preparing an inventory of natural catchments and (7) developing water safety plans and water quality monitoring capacity at island level.

2.5 Environmental Permits required for the Project

2.5.1 EIA Decision Statement

The most important environmental permit to initiate the proposed sewerage system in Neykurendhoo would be a decision regarding this EIA from the Environmental Protection Agency (EPA). The EIA Decision Statement, as it is referred to, shall govern the manner in which the project activities must be undertaken. This EIA report assists decision makers in understanding the existing environment and potential impacts of the project. Therefore, the

Decision Statement may only be given to the Proponent after a review of this document following which the EPA may request for further information or provide a decision if further information is not required. In some cases, where there are no major environmental impacts associated with the project, the EPA may provide the Decision Statement while at the same time requesting for further information.

3 Project Description

3.1 General context of the study

In the Maldives, water and sewerage infrastructure development and institutional reforms process, until 2004 tsunami was at a very slow pace - the sector, apparently, was ignored. Similar to other developing regions across the globe particularly in small islands states, sanitation and sewerage infrastructure projects in Maldives have been less favoured by politicians. The 2004 tsunami disaster which hit part of Maldives is considered to be the benchmark of beginning water supply and sewerage infrastructure development work across Maldives, particularly in outer islands outside Male'. Nearly 4.5% islands across Maldives until 2004 tsunami were developed with sewerage systems on various system designs including simplified shallow small bore gravity sewers, shallow gravity sewers with household septic tanks and gravity lagoon outfalls', with gravity sewers with household catch pit to beach wells and conventional deep gravity sewers etc. Still the progress in bringing the development of sanitation sector is slow apparently due to lack of good will and commitment. According to government sources by end of 2010 improved island wide sewerage systems have been established 11% islands.

The project as per the concept design available to consultant at the time this report was compiled has been designed to cover the entire community. The system has been proposed to develop with gravity main sewers, lift stations, road manholes, main sumps and forced sea outfalls.

This EIA study will help to identify and assess environmental impacts (positive and negative) and to recommend mitigation measures for minimizing or eliminating the negative impacts during construction and operation phase. This study will also cover the socio-economic aspects of the community and their perception towards implementing the proposed sewerage project.

Similar to other such projects, this project also will have direct and indirect impacts to the environment including loss of vegetation, impacts to terrestrial and aquatic species and contamination of soil, impacts to groundwater aquifer and marine environment etc. The impacts depending on the intensity, duration and type will be of short and long term, reversible and irreversible. Therefore, measures to mitigate and alternatives have been suggested that may either eliminate or minimize impacts to environment.

3.2 Project Scheme

The project is one of the sewerage projects that have been formulated under CSR (Corporate Social Responsibility) scheme. CSR is a concept where business establishments integrate social and environmental concerns in their business operations or commitments given by such business establishments to contribute to sustainable economic development through improved livelihood. Providing access to improved sewerage facilities in island communities across Maldives have been one of the priorities of government. The concept has not been widely practiced among the business communities in Maldives perhaps due to absence appropriate government policies.

3.3 The Proponent

The proponent of the proposed sewerage project in HDh. Neykurendhoo is Global Wings Pvt. Ltd., a company registered in Maldives under the laws and regulation of Maldives.

3.4 Project Location and Study Area

Neykurendhoo is a medium to large sized Island located in Haa Dhaalu Atoll at 72.979807ºN and 6.542908ºE. It has an area of about 169hectares with 2.7hectares of marshy wetland area. Located at about 10km from Kulhudhuffushi, the capital of HDh. Atoll, it can be easily reached by air and sea. The island's population lives at the northwest corner of the island leaving ample green space on the rest of the island. Hence, agriculture is well practiced with betel, coconuts, bananas, chillies and breadfruit being the dominant agricultural produce. Fishing is the main economic activity while involvement in the tourism sector by the youth is on the increase.

The proposed study area comprises the island and lagoon and reef areas at proposed and potential outfall locations around the island.

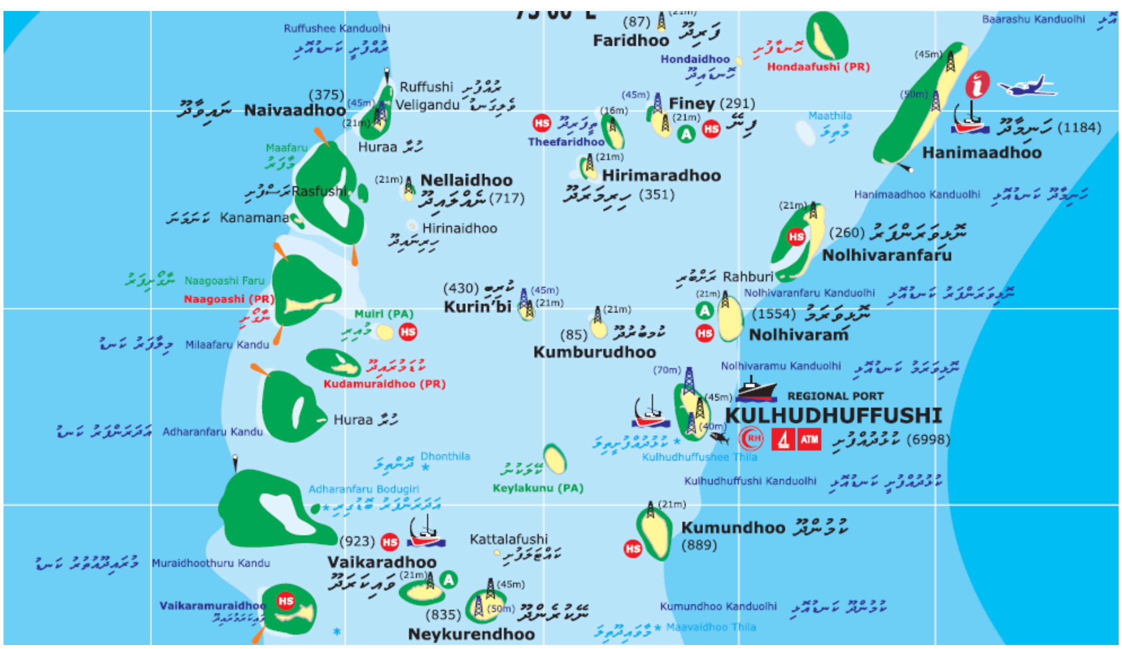


Figure 3-1: Neykurendhoo located at about 10km southwest of the capital of Haa Dhaalu Atoll

3.5 The Project

The proposed project involves the design and installation of a sewerage system in Neykurendhoo, Haa Dhaalu Atoll, Maldives. The proposed sewerage system is a small flow sewerage system conveying sewage and wastewater through gravity sewers, rising mains and pumping stations, treatment plant at a second phase and ultimately disposed off beyond the reef.

The scope of the project involves hydraulic studies, environmental impact assessment, socio economical assessment and other studies to assess the problems that would satisfactorily help to achieve the project objectives to install a technically sound and environmentally sustainable as well as socially acceptable sewerage system. Therefore, a conceptual layout for a sewerage system was developed based on the findings of the above mentioned studies. It is proposed for Neykurendhoo to have a comprehensive sewerage network with a single outfall. In the initial design finalized in 2009, a vacuum sewerage system has been proposed. A preliminary design was therefore developed based on the initial survey but completely abandoning the design proposed earlier for a vacuum system as it is required under the CSR project that a gravity system with pumping stations has to be proposed. It is also required that the maximum depth of excavation should be 2.5m below the ground surface, therefore lift stations had to be provided. Taking this into consideration and in lieu of minimizing the electricity demand for the proposed sewerage system, the Engineer has proposed minimal number of lift stations in the preliminary design. Further analysis to minimize the number of lifting stations would be made during the detailed design stage. The proposed preliminary design for sewerage system is given in Figure 3-2.

3.5.1 Brief Description of the Proposed Concepts

The appropriate locations for the sewage outfall and pumping station was determined in consultation with the engineer and the EIA team based on proposed concept as well as Landuse Plans given by the Ministry of Housing and Environment. These locations were later communicated with the Island Council during the field surveys. Potential locations were also identified as alternatives as it may be possible that these locations could change during the detailed design stage depending on further consultations and design requirements. Reasons why EIA was undertaken at concept stage is that it will give the EIA consultant the opportunity to directly communicate environmental issues and concerns with the proposed sewerage system design engineers and project clients which in turn will save cost, time and avoid mistakes which may cause serious environmental problems. In fact, EIA is a project planning tool that aids in the design of the project to avoid environmental impacts to the greatest possible extent. Therefore, this report will discuss the general components involved in the sewerage project. These components are discussed below.

Key components included in the sewerage system proposed for HDh. Neykurendhoo are as follows

1. Sewer Network: Island wide sewer network has been proposed to covers all existing households and potential developments for a period of 30 years.
2. Household catchpits: A catchpit will be constructed for each lateral connection.
3. Laterals: Lateral connections from main sewers will be provided to households in which wastewater generated within the household shall flow via a catch pit to main sewer.
4. Road Manholes: Manholes will be developed at defined intervals along the main sewers, particularly at each road junctions and road crossings
5. Lift Stations: Lift stations (LS) or intermediate pump stations (IPS) have been proposed to be developed in the system. Lift stations may be required in the event required gravity slope is not attained to reach the flow into the main pump station (PS). Design with minimal no. of lift stations would be proposed.
6. Pump Station: A single main pump station has been proposed. This means all wastewater generated in households will be divided and passed into the main pump stations for discharge via sea outfall.
7. Sea Outfall: A single sea outfall has been proposed. The location of the proposed outfall is given in Figure 3-2.

3.5.2 Project Duration

Sewerage projects are usually built in twelve months from the date of signing the agreement. However, this project formulated under CSR is given a deadline of 6 months to implement the project which may not be sufficient due to logistical difficulties. Project duration depends on the location, weather, and availability of materials, project management team and availability of funds. The actual work schedule has not been made available to consultant at the time this report was prepared.

3.5.3 Environmental Design Consideration

In terms of design the most important and pressing issues to consider are

- Technical and financial sustainability
- Community acceptability
- Protection and improvement of groundwater and
- Protection of the fragile marine environment in the lagoon and around the reef.

The characteristics of groundwater aquifer, effluent quality, influent quality and marine water quality have been considered and further consideration will be given in setting the final design.

3.5.4 Effluent Collection and Disposal

The estimated daily volume of wastewater generated in the island for a population of 1637 people (Census, 2006) is at 196 m^3. Wastewater generated in houses flow into a house catch pit under gravity which then flow into main sewers via lateral connections into main sewers and collection sump or main pump stations. The wastewater that enters into main sewer lines will be lifted with the help of intermediate lift stations positioned in places where the levels are below the designed depth. Wastewater which flows into main sumps will be pumped into sea via sea outfalls. In other word the wastewater effluent will be discharged into sea (receiving water body) for disposal through further dilution and dispersion.

3.5.5 Proposed Sea Outfall Locations

As indicated in **Error! Reference source not found.** one effluent sea outfall has been proposed on the southwest side of the island. The location has been chosen based on the landuse plan given by the Ministry. This location appears to be appropriate considering the potential growth of the island over the 30 year design period. However, for current needs, it may be less costly and effective if an alternative location closer to the area in which people live (northwest or north) have been chosen.

3.5.6 Process and Materials

The process will be similar to that of other such developments in Maldives. All raw materials required for development have to be transported to the island by sea transport. These activities will be processed on a work schedule which is not made available to consultant at the time this report was prepared.

3.5.7 Construction Materials

Construction materials will include PVC pipes, cement, electrical cables, circuit boards, main circuit boards, reinforcing steel bars, river sand, aggregates, PVC conduits, diesel, petrol, tar, PVC adhesive, timber etc. These are the basic materials that are used for such developments.

3.6 Implementation Schedule

The implementation of the proposed sewerage system is expected to be started as soon as the approval including EIA has been obtained from concerned government authorities. The project is expected to be completed in 6 months from the date of getting the final design approved from EPA. This project similar to other CSR sewerage projects is supposed to complete according to the process flow chart made available to proponent as part of the agreement made between proponents and government. A detailed schedule has not been made available at this stage. Copies of the detailed schedule will be submitted to the Environmental Protection Agency before construction begins.

3.7 Implementation Phase Activities

In the construction phase key activities includes, site preparation for development which includes clearing of vegetation where necessary for pump stations, land surveys for proper levelling, excavations for sewer and water network lines, mobilization of materials and equipment, material transport, power generation facilities, sewer outfall and staff mobilization

3.7.1 Site Preparations

Site preparation considered to be one of the key elements of any such projects which include fixing of secure place (house) for material storage and administrative work or build a site office attached to material storage facility in an appropriate location. Other important preparation work include

1. Identification of exact locations for lift stations, pump stations, manholes, and sewer outfalls, water meter locations

2. Carry out ground level surveys and build a level profile on each section of the proposed networks

3. Appoint staff for site management and material stock control

4. Clear vegetations and make access to areas where work will be carried out (e.g. locations for pump stations)

3.7.2 Mobilization of Equipment and Materials

Site mobilization involves mobilization of workforce, machineries/equipment and construction materials to Neykurendhoo to begin physical work. Materials, equipment/machineries and all other related items will be transported to the island by sea.

3.7.3 Workforce and Services

This is one of the key components that need appropriate management on site during the construction phase. In the proposed sewerage system in Neykurendhoo an estimated 100 staff including labourers, engineers and supervisors will be sited on the island. The exact number is not known at this stage

3.7.4 Material Transport

All materials that are required for the implementation of the proposed project need to be transported to the island. The transportation will mainly be on *Dhoni*. Transportation of materials is considered to be one of the key activities that cause impact to environment mainly due to accidental spills and direct/indirect physical damage to coral reefs due to careless boating activities and emission of greenhouse gases which will be further discussed under impact analysis.

3.7.5 Waste Management

A considerable site waste will be generated including organic refuse (vegetations) during site clearing. These leafy and biodegradable organic materials (e.g. leafs, shoots etc) and other off site waste will be disposed through municipal solid waste stream.

3.7.6 Pollution Control and Waste Minimization

No doubt that pollution control/waste minimization going to be some of the key aspects of any developments. Cleaner production through appropriate waste minimization and pollution control measures have been on the agenda of many development projects in other parts of the world. However, this has not been given attention in development projects such as water supply and sewerage in Maldives, although it is written in our development agendas.

3.7.7 Health and Safety

Workers health and safety is also an important aspect that needs careful consideration during the implementation from beginning till end. Protection of employees from likely adverse effects will be one of the core duties of the proponent or contractor. All machineries and equipment must be operated by trained and experienced personals wearing necessary safety gears. In the event, if there is any need an employee to work on a different work site, he/she must be given appropriate training before the work. These elements fully will be applied on workers.

3.8 Operational Phase Activities

Key activities identified throughout the operation of the proposed sewerage system would be sewage effluent disposal, brine reject disposal, sludge disposal (if sludge separated through STP) and operation of pump stations/lift stations

3.8.1 Effluent Disposal

Wastewater including black and grey water generated in the island will be collected into sewage treatment plant or pump station. If STP is not in place, sewage effluent will be discharged into the ocean via sea outfall on condition that an STP will be installed within 5years period from the date of commissioning the system. This has been discussed during the scoping meeting held at EPA on 27 December 2011. In case if STP is in place effluent either will be discharged into the ocean or applied on land for groundwater recharge if the effluent quality meets BOD of effluent at 5mg/l or less (wastewater disposal guideline of MWSA, 2007). As per the information provided by the proponent the sewage system proposed for Neykurendhoo is with treatment. However the type of treatment is not decided at the time this report was compiled. Sewage generated in households flow into main sewer via catch pits and laterals which then flow into pump stations with the help of intermediate lift stations for final disposal.

3.8.2 Sewage Treatment

Sewage treatment as discussed in Section 3.8.1 will be undertaken if it is required. The scoping meeting held on 27 December 2011 at EPA clearly indicates treatment is required before effluent is disposed to environment. However, the timing of putting STP in place is made flexible as discussed in Section 3.8.1 due to high cost anticipated. As per the wastewater disposal guideline of MWSA, 2007 the BOD of effluent shall be less than 40mg/l which is quite stringent.

3.8.3 Sludge Handling

As the sewerage system is with treatment there it will generate sludge which needs to be disposed carefully. The quantity of sludge as per the small size of population (860) of Neykurendhoo will be small hence it can be pumped into a sludge drying bed where water can be drained back to the STP.

3.9 Project Inputs and Outputs

The project has inputs in terms of human resources, and natural resources and machinery. The main output of the project is island wide community sewerage system implemented in Neykurendhoo. The inputs and outputs are summarised in Table 3-1 and Table 3-2.

Table 3-1: Matrix of key inputs

Input resource(s)	How to obtain resources
Construction workers	Contractor's responsibility
Management and maintenance staff	Appointed by proponent
Construction materials:- timber, cement, electrical cables, circuit boards, main circuit boards, reinforcing steel bars, river sand, aggregates, PVC pipes, diesel, petrol, tar etc	Import and purchased where locally available at competitive prices – Contractor's responsibility
Water (during construction)	Rainwater harvested
Electricity/Energy (during construction)	Diesel-based electricity
Machinery and equipment	Contractor's responsibility
Sulphate resistant cement	Imported or locally purchased
Fuel (e.g. diesel, petrol)	Locally purchased
PVC Adhesives	Imported or purchased locally

Table 3-2: Matrix of major outputs

Products and waste materials	Anticipated quantities	Method of disposal
Waste oils from machinery	Minute	Re-used to other applications
Cleared green waste	Minor	natural decompose
Wastewater effluent	major	Disposed into sea where dilution and dispersion happens
Timber, cardboard, gunny bags and scrap metals (construction site waste)	Moderate	Recovered, reused , recycled
Used oil (waste oil), grease	minute	Reused
Solid waste (kitchen waste, waste from accommodation blocks)	Major/moderate	Taken for disposal through island SW system

3.10 Need and Justification

The proposed sewerage project is one of the most important development projects to be undertaken in the island, which has been in the pipeline for quite some time. The island community has great expectations towards the project. It has become the main priority of the island community given that their main water supply, i.e. the groundwater lens, is being contaminated from inappropriate sewage disposal practices at household level. The proposed system is expected to improve the biological quality of the groundwater lens and have several positive health and socio-economic impacts. Water supply is met through harvested rainwater on roof top which in principle is not appropriate for drinking without treatment. Dependence on rainfall also carried the risk of water scarcity during the dry season.

In addition to the improvements in environmental quality which itself has economic benefits, there are several other socio-economic benefits of proper water supply and sewage and wastewater disposal. These include:

- Protection of the groundwater aquifer, which is the main source of water for the communities as well as the plants. This in turn helps in reducing morbidity and mortality due to water-borne diseases.
- Health benefits due to improvements in environmental health
- Increased standard of living and suitability of the island for economic activities such as tourism

The proposed project targets at further achieving some of these and attempting to achieve a long-term solution to the above mentioned issues of aesthetic quality of the beaches and coastal waters and nuisance caused by seagrass. In short, the project aims to achieve the following objectives:

- Addressing the water and wastewater situation in the island
- Increase the economic value of the island.
- Provide a sustainable means of wastewater disposal
- Improve the overall public health of the island

The proposed system of simplified sewerage with sea outfall(s) has been chosen for the following reasons.

- Groundwater aquifer is the primary water resource for the people of the Maldives. Even in Malé, the capital, where the aquifer is highly contaminated and salty, most people depend on the groundwater aquifer to meet their non-potable water demands. Therefore, people of Neykurendhoo cannot afford to keep on disposing their sewage and wastewater into the aquifer. The aquifer needs to be protected from faecal matter for its longterm sustainability.
- White sandy beaches and clear azure blue lagoon are important natural assets for the islands of the Maldives, and the quality of the beaches and the lagoonal waters needs to be protected and preserved for the benefit of present and future generations. Therefore, the proposed system has deep sea outfalls

disposing into good mixing and dispersing zones ensuring that the faecal coliforms do not reach the nearshore environment.

- The deep sea outfalls are not possible with gravity flow sewers laid in some islands in the past. Therefore, sewage pump stations are necessary and have been incorporated in the design of the proposed system. In order to minimize the depth of excavation, lift stations are proposed that will pump the effluent to the pumping station at the end of the network.

Septic tanks have been purposely avoided in the proposed design because of the high cost involved. It is important to avoid septic tanks if possible since septic tanks take a great proportion of the project cost. Also, there has been ownership problems associated with septic tanks and sometimes catchpits for that matter when household plots get divided. Furthermore, septic tanks only remove less than 50% of the BOD and therefore still require deep sea outfalls, which will be achieved with pumping stations. Additionally, people do not like to have a system in which they may have to do the work of emptying the septic tanks since most of the householders cannot do it themselves.

The proposed system will improve the biological quality of the groundwater resource to a great extent including the potential smell in the water which is a result of faecal matter being disposed into the groundwater lens. This results in high levels of nitrates and phosphates in the water in addition to faecal contamination. The system is expected to improve this situation dramatically. Although it will take some time for the system to get back to acceptable levels in terms of biological contamination and subsequent increase in nutrients in the water, the rate at which this is achieved would be high. Malé would be a good example to consider when discussing about the impacts of improper sewage disposal. When Malé was without a sewerage system, all faecal matter was disposed into the ground. With the rapid increase in population, the groundwater became smelly and almost unusable in areas where the pressure on the groundwater aquifer was high. The smell was initially from ammonia. Later with sewage in catchpits and other areas becoming septic, hydrogen sulphide gas became a major problem. Since a proper sewerage system would be installed in Neykurendhoo at a time when the groundwater is still in good condition, the system will help to alleviate most of these problems which became evident in Malé.

In terms of salinisation of the groundwater lens, the constructional impact would be small, related to some amount of dewatering, especially with the proposed revision to incorporate lift stations. However, the main impact would be felt during the operational phase when the groundwater would be used for toilet flushing. However, it has been seen in many islands, including larger islands such as L. Gan, L. Fonadhoo and even FuahMulah, where there are no sewerage systems, that the main contributor to groundwater salinisation is the use of pumps and high pumping rates. In fact, it is known that in most of the islands, there are no sewered connections. Yet with high pumping rates and increasing population, the groundwater lens is becoming more saline in addition to the deterioration in chemical and biological quality. Therefore, it can safely be argued that an increase in salinisation of the groundwater lens would become apparent in most of the islands, whether a sewerage system exists or not. Even in places where the sewerage system pumps all water out to the lagoon such as K. Gulhi, Lh. Hinnavaru and Lh. Naifaru, there is no data to suggest that the groundwater has become more saline due to the sewerage system. Some of these islands have groundwater of a quality similar to other similar islands where there is no sewerage system.

Recharge of groundwater aquifer with treated effluent has not been considered to help in anyway except further pollute the groundwater aquifer given that tertiary treatment to achieve very low levels of BOD or COD is not possible within the framework of the proposed project. According to the USGCRP team (Carter et al 2001), “the size of the groundwater lens is directly related to the size of the island… (and) also related to the normal amount and type of precipitation (e.g., heavy downpours recharge lenses, while light rain generally does not)”. Therefore, the type of rainfall that occurs in the Maldives with high intensity-high duration-low frequency rainfall is useful for the development of groundwater lenses in low-lying islands. It is also important to note that the aquifer (like a rainwater tank) has its own capacity and not every drop of rainwater will percolate to contribute to the freshwater lens. This argument also supports the belief held by the consultants that aquifer recharge is not easily possible by grey water recharge.

Figure 3-2: Proposed sewerage system

4 Project Alternatives

This section looks at alternative ways of undertaking the proposed project. There are two basic options: (1) leave the problem as it is (no project option), or (2) take measures to resolve the problem (undertake the project options). If the project were to continue, it would be necessary to take economic, ecological and social aspects of the project into consideration and ensure that these concerns exist within a delicate balance. Neither the economic benefits nor the social and ecological concerns can be avoided. Therefore, it is important to consider all options and ensure that the best available option(s) is/are chosen to solve the issues/problems.

The alternatives discussed in this report have been considered based mainly on community consultations and field visit findings. The community has mainly proposed alternatives in terms of the size and location of the harbour and some of the design considerations. See discussions from the community consultation meeting given in Section 7 for details on the concepts or alternatives proposed by community representatives.

Alternatives have been considered only for the sewerage system as alternatives for the water supply system is not considered appropriate. However, alternative location for the water and sewerage facilities have been highlighted in Figure 4-1.

4.1 No project option

It should be noted that the "no project" option cannot be excluded without proper evaluation. In this report this alternative was considered as the baseline against which to evaluate the other options. The no project option takes the following into consideration:

- Existing setup is sufficient for the present time
- Existing safety and other socio-economic impacts will remain or may continue to worsen
- Existing public frustration will continue to worsen causing greater political and social issues.

The main advantages and disadvantages of the no-project option are given in Table 4-1.

Table 4-1: Advantages and disadvantages of the no project option

Strategy	Advantages	Disadvantages
Allow groundwater contamination to continue	Costs related to improving the situation may be avoided in the short term	Burden of diseases due to poor sanitation may increase Long term socio-political problems may arise Greater long term costs An important water resource will eventually be lost and alternatives sources sought
Try to improve the situation by providing appropriate guidelines (soft interventions such as minimize use of pumps, improved septic tank quality, etc.)	May minimize groundwater contamination Short term costs may be avoided	Contamination of groundwater will continue although at a slower rate Will not address current concerns adequately

4.2 Alternative Sewerage Systems

For the islands of the Maldives, it is preferable to adopt simple and environmentally sound technologies that require minimum maintenance. Therefore, the following options which may be adopted for Neykurendhoo have been selected after careful consideration of socio-economic, technical and environmental aspects. As per *Design Criteria*, there are certain elements that would be considered common, whatever the system is employed. For instance, even if treatment plant is considered, an overflow pipe for raw sewage/wastewater shall be provided, with outfall discharging to offshore, high current location outside the reef edge using submersible pumps located or housed in a pumping station. So, alternatives for the outfall or overflow pipe would not be discussed.

There are three main alternative considerations. They are alternatives for sewage conveyance (sewer line), alternatives for sewage treatment and alternatives for final disposal. The basic alternatives for each, which have been tried or are under trial in the Maldives are discussed in the following subheadings.

4.2.1 *Sewage collection and conveyance*

There are three different options for the collection or conveyance of sewage in a sewer network. These are the gravity system, pressure system and the vacuum system. Of these options, the most practicable option for the Maldives due to several advantages as enlisted in

Table 4-2 is the vacuum system. The vacuum system has been implemented in four inhabited islands as a trial project undertaken by UNICEF. It has been seen from the experience of these projects that the vacuum system gives the community a big electricity bill as a result of which it may not be considered appropriate for small island communities. Therefore, gravity, which comes for free, is considered more appropriate although a few lifting stations may be required.

4.2.1.1 Gravity system

The existing system in Neykurendhoo is a combination of on-site septic tanks and gravity flow sewers. Gravity sewers convey the sewage with the help of gravity and without the use of pumps or mechanical pressure systems. The advantage of gravity system is that there would not be a need for electrical components. However, adequate gradients in sewer network has to be met, as a result of which trenching or excavation for laying pipes would be deep and outfalls would be quite short and several outfalls have to be used. Gravity systems are often referred to in the Maldives as small bore sewerage systems.

4.2.1.2 Pressure system

A pressure system is a gravity flow system up to a certain depth, after which lifting stations are used to pump the wastewater to a final pumping station that pumps the final effluent from all lift stations directly to an offshore location at the proposed outfall. In this system, the collection system is designed to minimize the multiple outfalls with small bore sewers or gravity sewers. These systems are often referred to as conventional sewerage systems. This is what is being proposed for Neykurendhoo.

4.2.1.3 Vacuum system

A vacuum system conveys sewage and wastewater by sucking the wastewater by creating a vacuum inside the system. In a vacuum system, five or six homes can be connected to one interface valve unit. The vacuum pipeline conveys the sewage to the ejector pump station that creates the vacuum and delivers the influent to the pumping station or treatment works. The ejector pump stations would be similar to lifting stations in the proposed pressure system.

4.2.2 Sewage treatment

Sewage treatment is a requirement for the proposed project in Neykurendhoo and it is important to look at the different options for sewage treatment. The systems that have been proposed and tried in the Maldives are discussed here.

4.2.2.1 Individual septic tanks

The existing system in Neykurendhoo has household septic tanks disposing to the ground via soakpits. This arrangement contaminates the groundwater and also households find difficult to clean or maintain the septic tanks regularly. Also, individual septic tanks would drastically increase the cost of the project. Furthermore, the use of septic tanks improves the quality of the effluent disposed to ground or via multiple outfalls into the lagoon, however, does not minimize the number of outfalls nor does it help to increase the length of the outfalls. Also, the problem of backflow during high tide would be a cause for concern.

Advantages and disadvantages that have been identified include:

- May recharge groundwater but deteriorate groundwater quality since septic tanks only remove less than 50% of the BOD.
- High cost of septic tank and soakage pit and land availability need to be checked.
- Requires sludge removal by house holders.

4.2.2.2 Communal septic tanks

Communal septic tanks work on the same principle as individual septic tanks. However, communal septic tanks require more single space than individual septic tanks. However, communal septic tanks may be more acceptable if their maintenance fall with the system operator rather than individual households.

4.2.2.3 Packaged treatment plants

Packaged treatment plants capable of secondary treatment to reduce BOD and nutrients to acceptable limits have been used in several resorts. However, these are small treatment units, which are costly. Some of the systems proposed under tsunami assistance have been designed with packaged treatment plants, mainly activated sludge treatment systems. The vacuum systems proposed initially for Neykurendhoo consider such treatment plants. Project for Th. Vilufushi considered a RBC (Rotating Biological Contactors) unit as the treatment system. The more recent sewerage projects in Muli, Eydhafushi and Funadhoo have also been constructed with packaged treatment plants.

4.2.2.4 Reed beds or leaching fields

Furthermore, treatment beds or filtration beds have been tried in the Maldives in Kulhudhuffushi under the Regional Development Project Phase I in 2003 as a pilot project, the results of which were not so promising. Later in 2006, a project in Isdhoo-Kalaidhoo by the Japanese Government also considered reed beds, which had yet to be evaluated. The system in Isdhoo-Kalaidhoo is also quite expensive that further consideration would be given for replicating the system elsewhere in the Maldives. These systems are also suitable for larger islands like Isdhoo-Kalaidhoo due to space requirements and it may be considered suitable for Neykurendhoo too.

4.2.2.5 Natural treatment

Most of the treatment units discussed above treat sewage by natural means, by allowing aerobic or anaerobic bacteria to decompose the sewage thereby reducing its BOD. However, these systems require confined spaces which are hard to be found in the small islands of the Maldives. So, given the small population of almost every island in the Maldives except Malé and that only residential wastewater effluent would be discharged, it has been shown that if the effluent was disposed directly into the abundant sea, it would provide adequate mixing, dilution and treatment. Therefore, the consultant believes that Neykurendhoo would not require sewage treatment if the wastewater from the current population can be disposed at an appropriate location and depth. In fact, it has been shown that for a population less than 10,000 adequate dilution would be provided even under worst case scenario if untreated wastewater were to be disposed off in an appropriate location (Johnson et al, 2007; WS and LHI, 2006).

4.2.3 Disposal

There are three basic mechanisms considered for wastewater disposal in the Maldives. They are: (1) disposal to ground, (2) disposal to lagoon, and (3) disposal to sea. Disposal to ground and lagoon can only be considered if secondary level of treatment can be provided. However, disposal to sea at appropriate locations and depths may be considered even without treatment if it can be demonstrated that adequate mixing and dilution would be achieved at the given location.

4.2.3.1 Disposal to Ground

This is the common practice in the Maldives due to its cost-effectiveness. In most islands, poorly constructed septic tanks or solid separation chambers are directly connected to an infiltration bed made of coral rubble. Some people have two or more chambers in their septic tank system. However, the level of treatment provided by such septic tanks is not adequate for disposing the effluent to the ground. Due to the superficial nature of the groundwater lens, the water lens gets easily contaminated with faecal coliforms, nitrates and phosphates mainly.

Recently, the vacuum systems proposed by UNICEF do not have any marine outfalls but treated effluent is proposed to be used for gardening and discharged into ground for groundwater recharge. The EIA for Ungoofaaru specifically states that there would not be much benefit from the proposed recharge but it would increase the nutrient levels of the groundwater thereby making it smelly and making people to refrain from using it (Water Solutions 2007). Yet, recharge was incorporated and the result was that recharge was not acceptable to local people due to smell in the treated water and outfalls were constructed recently.

4.2.3.2 Disposal to lagoon

In islands, where small gravity flow systems have been designed for reasons of cost-effectiveness, disposal has been primarily via lagoon outfalls. The first few sewerage systems constructed in places such as Hinnavaru, Naifaru, Thulhaadhoo, Kandholhudhoo, Komandoo, Gulhi and Thinadhoo in the past have failed to achieve the objectives primarily because wastewater effluent is disposed to lagoon or nearshore environment. However, some of these systems with septic tanks have been seen to be working effectively in some places such as Gulhi. Yet, according to the island chief of Gulhi, during a site visit under a previous project, they have made requests to the government to provide pumping stations and pump the effluent away from the clear lagoon areas purely for aesthetic reasons.

4.2.3.3 Disposal to sea

Disposal to sea has been considered by the Government as the most practicable method of disposal. For this reason, emergency by-pass outfalls have been proposed for all systems (with or without treatment) under the *Design Criteria*. Disposal to sea means disposal to an appropriate location off the reef edge and at a suitable depth that mixing and dilution ensures that sewage is diluted before it reaches the surface and also does not directly dispose onto the seabed or reef. Disposal to sea is naturally a suitable option due to its dilution potential and its characteristics such as adequate flow and salinity which ensure that faecal coliforms would not survive for longer periods and distances as in groundwater and lagoon water. However, disposal to sea would be more expensive than disposal to ground or lagoon, yet have clear long term benefits that would over-ride the cost implications. Disposal to sea has economic advantages over other treatment options too.

4.3 Preferred Alternative Sewerage Systems

4.3.1 First Preference

The first preference would to consider a design with a single pumping station and without any lift stations or with a single lift station, if necessary. However, based on experience in Dhidhoo and Felidhoo, the Government has made it mandatory to reduce excavation depth to below 2.5m. While there would be advantages of minimized excavation and resultant reduction in dewatering, the disadvantages of implementing the system with several lift stations is that the operation cost will increase which in turn will have to be borne by the community. Therefore, if excavation technologies can be improved and hydro-fusion or similar technologies can be utilized, this alternative of using a single pumping station and outfall would be the most practicable option not entailing excessive costs.

4.3.2 Second preference

The second preference would be to consider the proposed system without treatment but with two outfalls. Having two outfalls will minimize the volume of the disposed sewage and therefore the impact would be less. Both outfalls will discharge at a depth of 12-15m below the reef edge since there will be no treatment and both outfalls are expected to create appropriate conditions for dilution as well as economic considerations. This option is preferable for the following reasons:

- Environmental impacts of disposing untreated sewage to the open ocean via ocean outfalls discharging at appropriate depths have very low health and environmental impacts
- Capital and operational costs as well as odour and physical space issue related to the sewage treatment plant can be avoided
- Since emergency overflow outfalls are required for pumping stations (as per the Guidelines for Wastewater Disposal), all pumping stations would require a sea outfalls for emergency use.

4.3.3 Third Preference

The preferred third alternative is the vacuum system with sea outfalls as has been proposed for Neykurendhoo in 2009. Since vacuum system has been proposed for the island earlier, details of the vacuum system has not been considered in this report.

Table 4-2: Comparison of pressure system (gravity system with pumps) and vacuum system

Gravity system with pumps	Vacuum System
The island being flat where depth is limited due to high water table would require lift pumps and lift stations	The vacuum system allows shallow trenching to be used resulting in substantial excavation cost savings and reduced installation time.
The island has high water table and excavation will expensive, time consuming and will require trenching stabilization to avoid trenches from collapsing on the workers or destabilizing houses	The vacuum system on the island will minimize dewatering and eliminate the need for trench stabilization
The wide and deep trenches required for the gravity systems will play havoc with the roads and narrow lanes on the islands	Small diameter mains allow for shallow and narrow trenching thereby minimizing construction time and environment disturbances
With gravity systems it is possible for exfiltration to occur with contamination of the fresh water lens. It is also possible for infiltration to occur which can lead to over loading at the treatment plant. To detect where exfiltration or infiltration is occurring is almost impossible to detect.	With a vacuum system – infiltration can occur if a main pipe is broken and this will be detected. Exfiltration does not occur due to the nature of the system.
Unforeseen obstructions such as rocks can cause expensive rerouting of pipes	The vacuum system can easily be laid around an obstruction
200 up to 400 mm diameter concrete pipe and vitrified clay pipe sewer main are typical with material and heavy transport costs and unit labor costs	90 up to 200 mm diameter PVC or HDPE vacuum sewer mains are typical. The cost of installing vacuum piping is much lower than gravity pipes.

4.3.4 Other Alternatives

4.3.4.1 Greywater separation

A system which separates grey and black water is also suitable and will enable some recharging of the groundwater (mainly during the dry period) if grey water is recycled back in to the aquifer. However, such a system will require additional reticulation system for grey water separation and ultimate discharge. Although grey water is relatively free from contaminants, it has several harmful substances such as phosphates from soap and detergents. These chemicals can be harmful if they are allowed to enter water bodies. Therefore though grey water disposal is an option, it has also to be treated to some stage prior to disposal. These factors make it unattractive as such a system will increase the capital costs of the project. Furthermore, maintenance is also going to be a significant challenge. Last but not least, the limited space available in the island will be a limiting factor for a complex system.

It is often believed that greywater recharge would help improve groundwater, however, the fact is that greywater recharge would contribute very little to slow down salinisation of the groundwater aquifer and would not be economically feasible given the cost implications of greywater recycling. In fact, the Maldives receives well over 2000mm of rainfall, which would be more than sufficient to recharge the aquifer. Yet, the aquifer, similar to a rainwater tank, has its maximum capacity limits and cannot overgrow the impact imposed by high rates of abstraction. It has been shown that the rate of groundwater pumping is the main factor contributing to salinisation of the lens. Therefore, sustainable rates of pumping can only ensure sustainable management of the aquifer, as has been discussed earlier.

It has been observed from data collected even in the late 90's for Malé that the freshwater aquifer is of good quality in areas where the abstraction is small and quite saline in areas where there is high abstraction. Even wells in the vicinity of a well with freshwater may have more brackish water. Therefore, it is known that freshwater exists in pockets. Where the drawn down effect is high, due to the size of pumps and rate of pumping, there is a tendency for the water lens to become more saline at the location where the drawdown is greater. According to the Ghyben-Hertzberg principle for every feet of groundwater drawn from the surface of the water lens, salt water from below the lens pushes the water lens or the freshwater-seawater transition zone by 40feet (Freeze and Cherry, 1979), thereby making the freshwater at a particular location more saline than other areas. This draw down or lowering of the water table at the point of abstraction, sometimes referred to as the "coning effect" for the freshwater lens, can only be avoided with the use of appropriate technology such as skimming wells and infiltration galleries. High rates of pumping are the main contributor to salinisation. This is the case in many islands, where the aquifer has become salty, even when there is no sewerage system. Therefore, as long as pumps continue to be used for groundwater abstraction, no amount of recharge would guarantee a freshwater aquifer.

It is not necessarily true that the interval of rainfall (frequency) is important in considering the recharge potential of precipitation. However, the amount of rainfall (intensity) is more important. According to the USGCRP team (Carter et al 2001), "the size of the groundwater lens is directly related to the size of the island… (and) also related to the normal amount and type of precipitation (e.g., heavy downpours recharge lenses, while light rain generally does not)". Therefore, the type of rainfall that occurs in the Maldives with high intensity-high duration-low frequency rainfall is useful for the development of groundwater lenses in low-lying islands. It is also important to note that the aquifer (like a rainwater tank) has its own capacity and not every drop of rainwater will percolate to contribute to the freshwater lens. This argument also supports the belief held by the consultants that aquifer recharge is not easily possible by grey water recharge.

4.3.4.2 Deep disposal wells

There is also an appropriate technology that can be applied to reduce risks of marine pollution. This method involves the disposal of effluent in to deep disposal wells in to the salt water strata, below the upper fresh water zone. The well is designed and constructed so as to isolate the upper zone from any risk of contamination from the effluent being disposed of. The depth of well is approximately likely to be 20 to 40 meter, depending on the hydro-geological situation.

The benefits of disposing sewage effluent to the lower zone are a much-reduced environmental impact and health risk because of the following.

- Dispersion and dilution in to a large body of underground water that is very unlikely to come in to contact with man or the near shore environment
- Possibility of anaerobic treatment taking place over a significant period of travel time, killing off most of the dangerous contaminants and substantial gentrification before the water flows to the open sea
- In islands with large reef systems, the construction of the outfall may require damage to the reef and sometime blasting of hard coral. In such instances, deep disposal wells may be extremely practical though the initial investment may be higher.
- Outfalls may be aesthetically unappealing
- Likelihood that if the groundwater does flow to the open sea, then the depths encountered probably mean that it would not enter the open sea until far out from land. This will mean that elevated nutrient levels caused by disposal of sewage to near shore environment will not occur, preventing the marine damage that is evident from the existing systems.

The well can be located at the edge of the island where fresh groundwater is unlikely to exist, and reducing risks even further as the groundwater flow will always be from the centre of the island towards the sea. However, this technology has yet to be tested in the Maldives and has, therefore, not been considered appropriate for Neykurendhoo.

Figure 4-1: Alternative locations

5 Methodology

This section covers methodologies used to collect data on the existing environment. The key environmental components of the project considered were terrestrial, coastal environment and marine environment. In order to study the existing environment of the island, a field visit was made to Neykurendhoo early January 2012.

5.1 General Data Collection Methodologies

Existing environment of the study area were analysed using appropriate scientific methods. Field surveys were undertaken to get further understanding of the existing environment of the island. Field surveys were carried out during a field visit made to the island on January 2012 to collect baseline data. The following components of the existing environment were assessed.

- Terrestrial Environment
  - Terrestrial vegetation, groundwater quality, estimation of groundwater aquifer, estimation of aerial extent of groundwater aquifer, terrestrial fauna.
- Marine Environment
  - Coastal environment, shoreline, back reef, fore reef, reef flat, marine water quality, fishes, protected species, endangered species etc.

5.1.1 Groundwater and marine water quality

Groundwater quality was measured in several locations around the island to provide a representative sample. Similarly, marine water quality was tested at all potential outfall locations. Water quality was measured in situ using YSI potable water quality loggers. Parameters tested include temperature, electrical conductivity, salinity, total dissolved solids, dissolved oxygen and pH.

Samples were brought to Malé for testing in one of the laboratories, National Health Laboratory or MWSC lab. These samples are currently under testing and the results will be sent to the EPA as soon as they are available.

5.1.2 Ocean Currents

Ocean and lagoon current was measured by conducting drogue tests on selected locations around the island. A purpose built drogue with a GPS (Trimble Juno) was made to create spaghetti diagrams of the ocean currents.

5.1.3 *Condition of the House Reef*

Marine environment was surveyed to assess and obtain baseline data of the existing marine environmental conditions. Both quantitative and qualitative methods were used to assess the benthic substrate at the survey sites including Manta Tow survey, quadrants and visual assessments were used to quantify benthic types. .

This study was complemented with extensive underwater photographs of the areas in question. Methodologies adopted for these surveys are internationally accepted (English et al. 1997) and are widely used to assess the status of coral reefs in the Maldives as well.

5.1.3.1 Quadrats Survey

Quadrats surveys were carried out to assess the benthic types and coral species at the survey sites. It was carried on five different sites around the reef line including proposed outfall locations. It is one of the survey technique widely applied for ecological sampling.

Quantitative percent cover data of morphological characteristics of the reef community is obtained using this method and it can be repeated over time to obtain temporal changes. In this EIA study during the field visit made on January 2012, a square shape quadrat 1m x 1m was used for reef flat sampling.

6 Existing Environment

This section covers the existing environmental of proposed work site. In this case the work site is Neykurendhoo island where and island wide sewerage system will be developed. The key environmental components of the project under consideration are described below.

- Vegetation of the island
- Coral reef systems – status and health of coral reef system
- Groundwater aquifer – quality and quantity
- Marine and coastal environment – oceanography, marine water quality and oceanic currents
- Meteorological conditions – local wind, current, rainfall and tides
- Socio economic – public perceptions, the status, health and wellbeing of the community

6.1 General meteorological conditions

The Maldives, in general, has a warm and humid tropical climate with average temperatures ranging between 25°C to 30°C (MHAHE, 2001) and relative humidity ranging from 73 per cent to 85 per cent. The country receives an annual average rainfall of 1,948.4mm. Table 6-1 provides a summary of key meteorological findings recorded for Maldives.

Monsoons of Indian Ocean govern the climatology of the Maldives. Monsoon wind reversal plays a significant role in weather patterns. Two monsoon seasons are observed: the Northeast (*Iruvai*) and the Southwest (*Hulhangu*) monsoon. Monsoons can be best characterized by wind and rainfall patterns. These are discussed in more detail in the following subsections. The southwest monsoon is the rainy season which lasts from May to September and the northeast monsoon is the dry season that occurs from December to February. The transition period of southwest monsoon occurs between March and April while that of northeast monsoon occurs from October to November. However, according to Elliot *et al,* 2003 due to proximity to the equator, the monsoon seasons in Maldives are not as well defined as they are in Sri Lanka. The monsoons in Maldives are best defined in the northern part of the country where a distinct monsoon seasons including the strong southwest monsoon from June through September and a noticeable northeast monsoon from December through February occurs

Table 6-1 Key meteorological information in Maldives

Parameter	Data
Average Rainfall	9.1mm/day in May, November 1.1mm/day in February 1900mm annual average
Maximum Rainfall	184.5 mm/day in October 1994
Average air temperature	30.0 ^{0}C in November 1973 31.7 ^{0}C in April

Parameter	Data
Extreme Air Temperature	34.1 ^{0}C in April 1973 17.2 ^{0}C in April 1978
Average wind speed	3.7 m/s in March 5.7 m/s in January, June
Maximum wind speed	W 31.9 m/s in November 1978
Average air pressure	1012 mb in December 1010 mb in April

The climate of the Maldives varies slightly from South to North of the country. As pointed out by Elliot *et al,* 2003 the monsoon in north region is more pronounced and distinct. In Maldives, meteorological data are not recorded in all islands across Maldives. It has been recorded regional airports. General meteorological conditions prevailing in the region based on meteorological data for Hulhulé and Hanimaadhoo has been used to understand climatic factors affecting Neykurendhoo. Table 6-2 below shows summary of four seasons in Maldives.

Table 6-2 Summary of seasons in the Maldives

Season	Months
North East-Monsoon (Iruvai moosun)	December
	January
	February
Transition Period - 1 (Hulhangu Halha)	March
	April
South West-Monsoon (Hulhangu moosun)	May
	June
	July
	August
	September
Transition Period - 2 (Iruvai Halha)	October
	November

6.1.1 Wind

Wind has been shown to be an important indirect process affecting formation, development and seasonal dynamics of the islands in the Maldives. Winds often help to regenerate waves that have been weakened by travelling across the reef and they also cause locally generated waves in lagoons. Therefore winds are important here, as being the dominant influence on the hydrodynamics around the island (waves and currents). With the reversal of winds in the Maldives, NE monsoon period from December to March and a SW monsoon from April to November, over the year, the accompanying wave and current processes respond accordingly too.

The two monsoon seasons have a dominant influence on winds experienced across Maldives. These monsoons are relatively mild due to the country's location close to the equator and strong winds and gales are infrequent. However, storms and line squalls can occur, usually in the period May to July; gusts of up to 60 knots have been recorded at Male' during such storms.

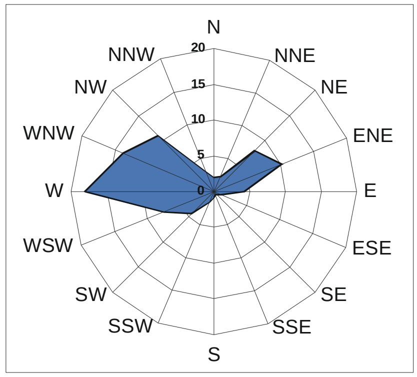


Figure 6-1: General wind rose diagram for the Maldives (source MEEW 2005)

Changes in wind directions need to be taken into consideration in determining the most favourable time period of proposed work. The development work will disturb the floor sediments to some extent and form sediment suspension which depending on the wind speed, direction and ocean current will move until naturally settles down.

The extreme northern part of the region experience wind climate with a strong southwest monsoon from May through August and a moderate northeast monsoon from December through February. The Maldives experience strong ocean wind at speed of 6m/s to 7.5m/s at a height of 10m during June, July and August (Elliott *et al*, 2003).

6.1.2 Rainfall

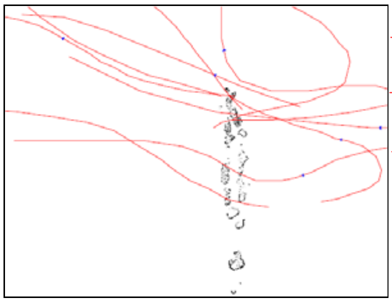
The northeast monsoon is known as the dry season with average monthly rainfall of 50-75 mm. The intensity of rainfall is a concern in the Maldives since intensity is high with low frequency. It is sometimes believed that the interval of rainfall (frequency) is important in considering the groundwater recharge potential from precipitation.

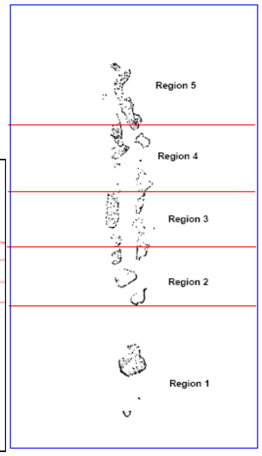
6.2 Natural Hazard Vulnerability

An island's natural vulnerability depends on geographic and geomorphologic characteristics of the island. These include geographic features of the island and location of the island with respect to the country, the formation of the island, location of the island respect to the atoll, orientation of the island, region of the country where island is located, level of protection to the island from the reefs and other islands; area of the inland lake found on the island, width of the island's house reef, coastal defence structures on the island, shape of the island and the area of the island. Although Maldives is generally considered to have moderate risk to natural hazards or disasters, islands across Maldives experience varying degree and magnitude of natural disasters.

Referring to Suffir-Simpson Scale, Neykurendhoo is considered at high vulnerable zone when cyclonic winds and storm surges over the Maldives are concerned and also low risk when tsunamis and earthquakes are concerned.

The island fall hazard zone 5 at Suffir-Simpson Scale 2, the maximum probable wind speed expected to be at 96.8 knots as shown in the following figures. Sea level rise due to climate change has uniform hazard throughout the country (RMSI/UNDP 2005).





Hazard Zone	Probable Maximum Wind Speed (knots)	Saffir-Simpson Scale
1	0.0	0
2	55.9	0
3	69.6	1
4	84.2	2
5	96.8	3

The stormy weathers around the world are affecting coral reef systems directly and indirectly due to global climatic changes. Intense storms can wipe out the natural coral "recruitment" process (Daily Science, April 29, 2008) as a direct effect of climatic change. Healthy coral reef systems are vital assets to many economies around the world on which large numbers of island communities depend on range of fisheries activities including Maldives. In Maldives for instance according to NAPA (2006) local demand on reef fishery has increased in recent years. Therefore, the concern of natural hazard vulnerability on corals reefs in Maldives is very high, which needs a solution through local and global effort.

6.3 Existing Coastal and Marine Environment

The island oriented north south direction is formed with small lagoon portion in the western side of the island. Along the eastern side beginning from southern tip to north end the long stretch is rocky shoreline. It absents lagoon along the stretch. The eastern side is continuously subjected to strong swells and wave actions. The reef system around the island is not live in other word there is no healthy reef system. There are some patch corals in the western side lagoon at outer rim of the lagoon (branching coral formation)

6.4 Oceanography

6.4.1 Waves

Wave energy also plays a key role in the movement and settlement of sediments and suspended solids, and is also a crucial factor controlling coral growth and reef development. Studies by Lanka Hydraulics (1988a & 1998b) on Malé reef indicated that two major types of waves in Maldives coasts: wave generated by local monsoon wind and swells generated by distance storms. The local monsoon predominantly generates wind waves which are typically strongest during May-July in the south-west monsoon period. During this season, swells generated north of the equator with heights of 2-3 m with periods of 18-20 seconds have been reported in the region. Local wave periods are generally in the range 2-4 seconds and are easily distinguished from the swell waves.

Distant cyclones and low pressure systems originating from the intense South Indian Ocean storms are reported to generate long distance swells that occasionally cause flooding in Maldives (Goda, 1988). The swell waves that reached Malé and Hulhule in 1987, thought to have originated from a low pressure system of west coast of Australia, had significant wave heights in the order of 3 metres.

6.4.2 Water Currents

Studies on current flow within a reef flat in Male' Atoll suggests that wave over wash and tides generate currents across the reef platforms, which are also capable of transporting sediments (Binnie Black & Veatch, 2000). However, available information suggests that tidal currents are not strong due to small tidal range.

Generally current flow through the Maldives is driven by the dominating two-monsoon season winds. Westwardly flowing currents are dominated from January to March and eastwardly from May to November. The change in currents flow pattern occurs in April and December. In April the westward currents flow are weak and eastward currents flow will slowly take place. Similarly in December eastward currents flows are weak and westward currents will take over slowly.

Studies on current flow process within a coral atoll have shown that waves and tides generate currents across the reef flats, which are capable of transporting sediments on them. Currents, like waves are also modified by reef morphology. Under low-input wave conditions (0.5m heights) strong lagoonward surge currents (>60cm/sec) are created by waves breaking at the crest. Studies on current flow across reef platforms have shown that long-period oscillations in water level cause transportation of fine-grained sediments out of the reef-lagoon system, while strong, short duration surge currents (<5sec.) transport coarse sediments from the breaker zone to seaward margin of the back reef lagoon. Always sediment accumulates at the lee of high-speed current zones. Generally zones of high current speed (jets or rips, 50-80cm/sec) are systematically located around islands.

6.5 Marine Environment

Key marine environmental components identified of relevance to the proposed study are ocean current, marine water quality and reef ecology. Focus was given to elements which is relevance to the proposed sewerage system in Neykurendhoo in particular of the ocean outfalls associated to the proposed system.

6.5.1 Currents

Study of current around the island identified to be one of the key aspects relevance to the proposed sewerage system in Neykurendhoo. Flow of water current would play a key role in assessing the pattern of sewage dispersion. In order to assess the current around the island in particular of the proposed out fall locations drogue tests were conducted.

Figure 6-2: Location of drogue tests conducted around Neykurendhoo

6.5.2 The Reef System and Reef Aesthetic

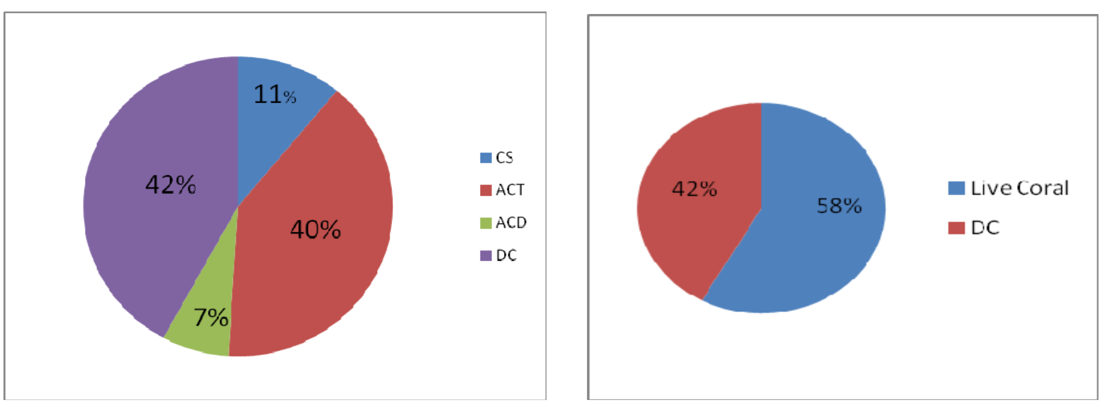
There is well developed healthy reef system around the island. Large branching corals are dominated species along with young isolated tabular and massive corals were observed as indicated in Figure 6.3. The reef system is aesthetically appealing. The reef survey carried out at five reef sites shows that reef system around the island appealing and rich in biological diversity. The live corals indicated the reef ecological system around the island is rich.

6.5.3 *Reef Survey*

Reef survey was conducted at three locations from Q1 to Q3 on reef flat as indicated in Figure 6-3. The results of these surveys are given below.

Figure 6-3: Quadrat sampling locations

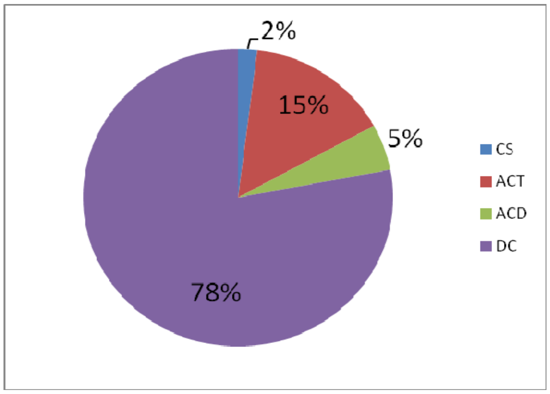
Figure 6-4: Benthic cover at Site 01



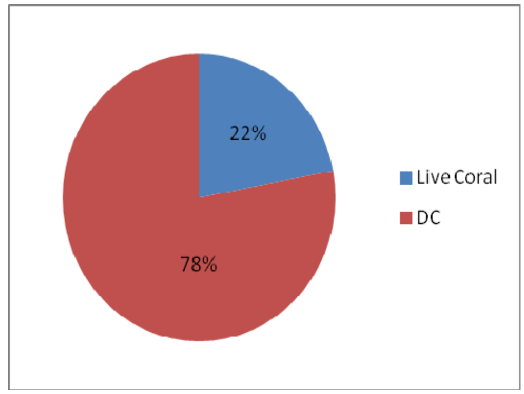
Benthic Cover

Live and Dead Coral Percentage

Figure 6-5: Benthic cover at Site 02

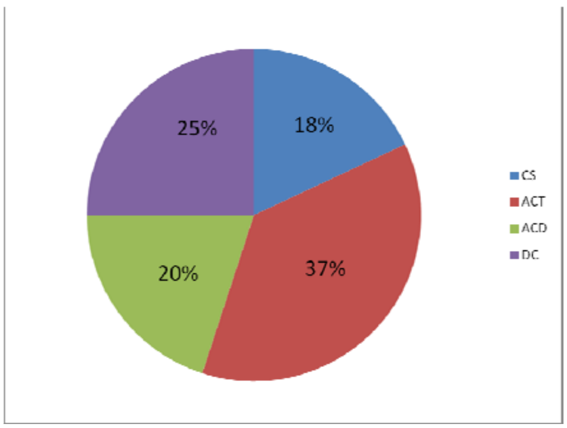


Benthic Cover

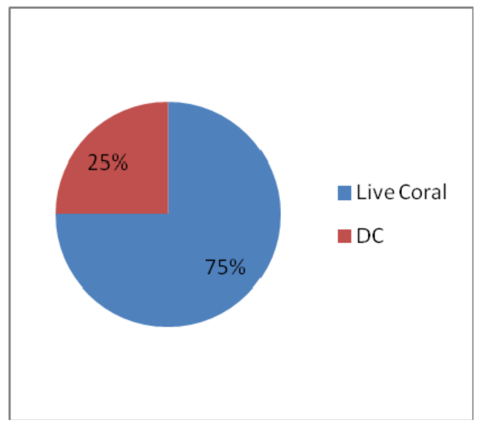


Live and Dead Coral Percentage

Figure 6-6: Benthic cover at Site 03



Benthic Cover



Live and Dead Coral Percentage

6.5.4 Marine Water Quality

Seawater samples collected from four different locations where survey was conducted, parameters such as Electrical Conductivity, Total Dissolved Solids, Dissolved Oxygen and pH were tested in-situ as shown below. These results show that water quality is good at the time of survey.

Table 6-3: Water quality results

	Units	WQ1	WQ2	WQ3
GPS Location	WGS84	N 724311.820 E 276023.708	N 723207.013 E 275574.220	N 722822.781 E 276354.760
Temperature	°C	28.39	28.21	28.38
E. Conductivity	mS/cm	53.09	53.01	52.6
TDS	g/l	34.51	34.46	34.19
Salinity	%	34.93	34.87	34.56
DO	mg/l	6.12	4.13	4.08
pH	NA	-33.7	7.96	8.06

6.6 Terrestrial Environment

The terrestrial environment is similar to other inhabited islands across Maldives. The island is wide and elongated in the north east to south west orientation. However, the unique feature noted in the island is that along all main roads trees are planted on centre of the road.

6.6.1 Geological Settings and Hydrogeology

In general the islands in Maldives are small, low lying and flat with common type of vegetation. There are two lakes on the island- one at the north end and the other in the southern end. However these types of freshwater lakes so far are not considered with any environmental value. The natural freshwater resource available in the island is groundwater. The fresh groundwater aquifers generally are formed as freshwater lenses floating on salt water which depends on island width, recharge rate and the ease of transmission of freshwater through soil (Falkland *et al*, 2007, cited in Mustafa, 2010). According to the USGCRP team (Carter et al 2001), "the size of the groundwater lens is directly related to the size of the island also related to the normal amount and type of precipitation (e.g., heavy downpours recharge lenses, while light rain generally does not)". Therefore, the type of rainfall that occurs in the Maldives with high intensity-high duration-low frequency rainfall is useful for the development of groundwater lenses in low-lying islands. This argument also supports the belief held by the consultants that aquifer recharge is not easily possible by grey water recharge.

6.6.1.1 Size of Groundwater Lens

The size of groundwater lens depends on several factors. Key factors which are considered in measuring the size of the groundwater aquifers in small islands are size of the island, width of the island, rainfall pattern and extraction of groundwater. Assuming estimated average ratio of groundwater lens area (ha) and area of island (ha) at 0.45 using data collected from northern islands in Maldives (Falkland, 2001, Southern and Northern Regional Development Project)

The estimated aerial extension of groundwater lens (ha) = 0.45 x 169ha = 76ha.

6.6.1.2 Groundwater Quality

Groundwater quality from existing open wells was tested from four different houses as shown in

Table 6-4. The idea was to make an estimation of the quality of water particularly in terms of salinity and bacterial contamination from onsite sewage disposal systems.

Table 6-4: Groundwater quality results

No.	House	Temp	E-Cond	TDS	Sal	Do	pH
		°C	ms/cm	g/l	ppt	mg/l	
1	Uraha	27.26	0.816	0.53	0.4	3.21	8.17
2	Gulfaamge	27.57	0.65	0.422	0.31	2.13	7.77
3	Karankaage	27.57	1.167	0.759	0.58	1.24	7.55
4	Scenaryge	27	1.177	0.765	0.58	5.58	7.63
5	Kaamineege	27.42	0.725	0.472	0.35	6.46	7.76
6	Robins	28.7	0.651	0.423	0.31	6.15	7.78
7	Dhoogas	27.69	0.622	0.404	0.3	3.89	7.73
8	Fiya	27.1	0.595	0.387	0.29	3.02	7.57
9	Powerhouse	28.56	0.637	0.414	0.31	1.21	

6.6.2 Current Sewage Disposal Practices

Sewage effluent generated at houses is discharged into the ground via soak pits and filter wells. It is the similar practice widely practiced across Maldives. There are advantageous and disadvantageous from disposing effluents into the ground within house plots. The key advantage is that avoids rapid salinization. The key disadvantage is that it continuously pollutes the aquifer with domestic sewage which deteriorates the aquifer in terms chemical and biological contamination.

7 Stakeholder Consultations

The key stakeholders involved in the project includes Ministry of Housing and Environment, Environmental Protection Agency, Global Wings Pvt Ltd, Atoll and Island Council.

7.1 Scoping Meeting

The scoping has been held at EPA on 27 December 2011. Key issues discussed in the scoping meetings include the designs including the sewer and water network, pump stations, and lift stations, sea outfalls and user fee pays.

7.2 Consultations with the Proponent

Consultations were held with the proponent, in order to find out further information about the detailed design of the proposed sewerage systems. As mentioned earlier that the project is under CSR where Global Wings Pvt. Ltd as the developer gives commitment towards the development of sewerage infrastructure in Neykurendhoo in return government leases an island to Global Wings for resort development.

7.3 Community Consultation

A lengthy community consultation meeting was held with island councillors and members selected from the community. held in Neykurendhoo 12th January 2012. Information regarding the proposed sewerage system was given by survey team members represented from Sandcays Pvt.Ltd.

- Explanation of the proposed concept design - household catch pit, main sewer, lift stations, manholes, pump stations and sea outfalls
- Why the community need an island wide sewerage system
- The importance of EIA for the project
- Why lift stations are proposed
- Sea outfalls, its locations, the disadvantage of sea outfall proposed on eastern side of the island
- Impacts to groundwater after the sewerage system developed - the elevation of salinity would depend on the rate of extraction and recharge.
- Sewerage user tariff system – explained a fee will be charged for operation, maintenance and management of the system

8 Impacts and Mitigation Measures

This section covers potential environmental impacts identified and measures to mitigate these impacts due to the proposed sewerage system in Neykurendhoo. The potential environmental impacts during implementation and operational phases of the proposed project components and appropriate mitigation measures are elaborated in the following sections.

8.1 Impact Identification

Impacts on the environment from various activities of the proposed development have been identified through:

- A consultative process within the EIA team, the Project Engineer and the Proponent
- Purpose-built checklists
- Existing literature and reports on similar developments in small island environments and other research data specific to the context of the Maldives
- Baseline environmental conditions
- Consultants experience of projects of similar nature and similar settings

Possible negative impacts on the environment have been considered in worst-case scenario to recommend mitigation measures in the best possible ways so that these impacts would be minimized and perhaps eliminated in the implementation phase.

Impacts on the environment were identified and described according to their location/attribute, extent (magnitude) and characteristics (such as short-term or long term, direct or indirect, reversible or irreversible) and assessed in terms of their significance according to the following categories:

1. **Negligible** – the impact is too small to be of any significance;
2. **Minor adverse** – the impact is undesirable but accepted;
3. **Moderate adverse** – the impact give rise to some concern but is likely to be tolerable in short-term (e.g. sediment suspension during dredging) or will require a value judgement as to its acceptability;
4. **Major adverse** – the impact is large scale giving rise to great concern; it should be considered unacceptable and requires significant change or halting of the project.
5. **Beneficial impact-** the impact represents a positive outcome in terms of either improving the existing quality of environment.

6. **Significant beneficial impact** – the impact represents highly desirable outcome in terms of improving the existing environment.

8.2 Identifying Mitigation Measures

Where an identified impact can be mitigated, mitigation measures are identified and discussed along with the identification of the impact. The mitigation measures proposed will help to alleviate or eliminate environmental problems before they occur. Mitigation measures are important because if identified impacts are significant and/or important, it would be necessary to identify and implement mitigation measures. Mitigation measures are selected to reduce or eliminate the severity of any predicted adverse environmental effects and improve the overall environmental performance and acceptability of the project. Where mitigation is deemed appropriate, the proponent should strive to act upon effects, in the following **order of priority**, to:

1. Eliminate or avoid adverse effects, where reasonably achievable.
2. Reduce adverse effects to the lowest reasonably achievable level.
3. Regulate adverse effects to an acceptable level, or to an acceptable time period.
4. Create other beneficial effects to partially or fully substitute for, or counter-balance, adverse effects.

8.2.1 Mitigation Options

Possible mitigation options include:

- Design alterations (e.g. recharge treated effluent into ground etc.) - operational
- Work method alterations (e.g. changes in construction scheduling etc.)
- Provision of environmental protection and health and safety equipment (e.g., provision of first aid and personnel protection gears such as helmets, safety shoes etc)
- Changes in management practices (e.g., contractor's awareness on environmental issues, keeping work areas clean, provide key environment information to workers)
- Changes in operation (e.g. operational procedures, specific responsibilities for clean up and maintenance).
- Environmental monitoring during civil works and operational phase

8.3 Existing Environmental Concerns

8.3.1 Natural Hazard Vulnerability

Although Maldives is not considered in a zone of hurricane and cyclones, Maldives is subjected to some of the climatic and non climatic natural hazards. The climatic natural hazards include prolonged dry period, flooding and storm surges and that of non climatic natural hazards include the impact of seismic activities. A clear example is the recent devastating tsunami occurred close to Sumatra, Indonesia in December 2004 killing more than a million people in the region including 26 deaths in Maldives.

8.4 Constructional Impacts

Construction is often a stage where the environmental impacts are underestimated, but in fact is very real and can be damaging. As construction requires lot of processes that typically impact the location by bringing about physical modifications, environmental impacts are felt almost in every aspect. Very often if these impacts are not mitigated, they may result in more significant long term environmental problems which may be more difficult to rectify. The purpose of this section therefore is to summarize the measures that can be undertaken during the construction stage to mitigate the impact on environment during the construction stage. These recommendations may seem exhaustive; nevertheless they must be followed if impacts are to be mitigated. In most instances, these recommendations only require little effort which only needs to be considered during construction stage. These measures reflect the general aspects of the construction phase that involves both land and marine based development activities.

8.4.1 Civil works

8.4.1.1 Impacts

The proposed sewerage network development in Neykurendhoo involves multiple tasks and use of machinery and other construction processes that will have its related impacts on the environment. The impact from civil works in the construction phase will have some degree of direct shot-term impacts on the island's terrestrial and marine environment. These impacts will result from the following activities.

- Excavation and laying of the outfall of the sewerage network
- Possible dewatering for pipe laying and construction of manholes and pump stations
- Possibility of sedimentation from excavated soil in case of rain
- Excavating on the reef for laying part of the outfall including removal of large coral boulders.
- Noise impacts during construction period.

Most of these activities are considered to have minor adverse environmental impacts. Impacts of constructional noise would not be considerable and the possibility of sedimentation from excavated soil is also inconsiderable given the topography of Neykurendhoo. There will also be negligible impact on the flora and fauna of the island as there are no significant habitats. Excavation of trenches to lay the sewers/pipes is also considered to have minor, short term impact on the groundwater aquifer and does not require detailed analysis. However, the impacts of dewatering and excavation in the lagoon and reef flat would have moderate negative impacts and are discussed in detail.

Dewatering to lay the sewers and construct manholes, lift stations and pump stations

During the construction stage, excavation will occur to lay the sewer networks. However, in some areas, especially where the main sewer lines are laid, the pipes will be laid below the groundwater aquifer. Hence, the project will involve some dewatering of groundwater for laying of the sewer networks. An estimation of the numbers of sewer lines requiring dewatering and the possible extent of dewatering indicates that roughly 10-15% of the sewer laying works would require dewatering. The impacts of dewatering to lay the pipes and construct manholes in these sections would be felt on the groundwater aquifer. However, the impact will be small since dewatering will occur in sections as described in the mitigation section.

The pump stations have been located on the periphery of the island in the 50m boundary which is not considered to fall into the areal extent of the fresh groundwater lens of the island. Also, these locations are at a considerable distance from neighbouring household wells. However, lift stations would be near household wells and would have some minor negative impact on household wells during the dewatering process. Yet, the impacts of small scale dewatering for the construction of manholes, lift stations and pump stations would be inconsiderable and would not negatively influence the neighbouring wells. The impact would also be short-term allowing the aquifer to return to "normal" after rainfall.

Excavating reef areas at outfall locations

According to the Final Design Report, the outfall pipes will be laid in a trench wherever possible and anchored with concrete blocks and backfilled using excavated material. Such protection is necessary to protect the pipeline from wave action during rough weather. Given that the outfalls are located on the atoll-ward lagoon side, the impact of waves would be small.

About 10-15% of the entire length of the outfall falls on the coral reef areas, the status of which has been described earlier. The impact on the reef would be minimal given that there would be no excavation although there would be some short term siltation during the installation as a result of wading and use of machinery for the placement of concrete blocks and so on. There may be removal of few small corals on the reef flat, slope and edge during the anchoring of the pipeline in these areas. This impact is considered to be minimal given that the percentage of live corals is small and that any live corals removed would be transplanted in the same area or any other area.

8.4.1.2 Mitigation Measures

General construction impact management

The following measures to minimize general impacts of construction will help to reduce or mitigate the impacts.

- During the construction stage all activities should be properly supervised to ensure that construction is according to the required specification or standards and that no threat or damage to the environment other than that at the specific location occurs.
- Appropriate waste handling, transportation and disposal methods for all waste generated during the construction works including parts of the existing system should be implemented to ensure that construction wastes do not pollute the environment.
- Ensure that no leaks and accidental spillages of oil occur from vehicles and that they are maintained adequately.
- Careful control should be exercised to ensure that no materials and machinery fuels enter the marine environment and cause contamination

Specific measures to mitigate dewatering and excavation impacts

The following measures will help to reduce or mitigate the specific impacts related to dewatering to lay the pipes and construction of manholes and pump stations as well as reduce impacts related to excavation of the reef flat.

- No dewatering would be done for making good pipes joints underwater. In such circumstances, underwater fusion of pipes may be considered or pipes may be jointed ex-situ.
- Dewatering would be undertaken only for the construction of manholes, lift stations and final pumping station, where necessary. In these areas, work may be restricted to low tides, etc. so that less dewatering would be required.
- Outfall pipe would be buried only in the lagoon areas in order to protect the pipes from vessel and anchor damage. The reef section would be anchored to the seabed, thereby minimizing damage to coral.
- Anchors would be placed on the reef areas by using manual methods and machinery would not be used on the reef areas.

8.5 Operational Impacts

8.5.1 Groundwater

8.5.1.1 Impacts

There are two types of impacts on groundwater quality; one is a positive impact and the other considered as a potential negative impact. The positive impact is the potential improvement in the biological and chemical quality of the groundwater resource and the negative impact would be the potential negative impact would be the potential to cause increased salinization of the groundwater aquifer due to increased flushing as a result of improved sanitation facilities. However, this is not necessarily a direct result of the sewerage system but a cumulative impact caused due to increasing population and human needs and quality or standard of life. These two impacts are discussed in more detail in the following sections.

Improved quality of the groundwater lens

The groundwater aquifer of Neykurendhoo has been contaminated as a result of direct disposal into the groundwater aquifer of untreated sewage and wastewater emanating from current sewage disposal system. Currently, there is concern over the smelly groundwater in many households as a result of pollution from disposal of septic tank effluent. The proposed system will completely eliminate the need to dispose sewage and wastewater effluent into the ground or groundwater, thereby helping the aquifer to recover over a short period of time given that other polluting factors are minimal or non-existent. The only possibility of groundwater contamination is due to a failure of the wastewater system or a possible leakage from sewer pipes, which could occur if the system is not maintained properly. Groundwater contamination could also occur as a result of poor construction. The proposed system is expected to have improved materials and construction standards that would ensure that sulphuric compounds produced in the sewage would not cause catchpits and manholes to corrode. In Malé, corroded or damaged catchpits has been the main cause for groundwater contamination resulting in increased levels of hydrogen suphide (sewer gas) in the groundwater aquifer. This gas has taken away lives including one death and few cases of poisoning in the late 90s and a recent incident in which five lives have been claimed. Therefore, further improvements to the system and subsequent positive impacts on groundwater quality expected from the proposed system would eliminate the potential for such incidents in the future.

Potential to aggravate the rate of salinisation of the groundwater aquifer

The most severe impact of a comprehensive sewerage system on the island is increased abstraction of groundwater from the aquifer. This will cause greater salinisation of the groundwater lens due to increased flushing. When the population of Neykurendhoo increases above 5,000 or the water demand of the existing population increases, this impact would be exacerbated by the fact that the sustainable yield per capita is lower than the net water demand per capita. However, as mentioned earlier, this impact is not directly related to the sewerage system but adds to the stress on the aquifer of increasing population and water demand.

It has been seen in many islands, including larger islands such as L. Gan, L. Fonadhoo and even FuahMulah, where there are no sewerage systems, that the main contributor to groundwater salinisation is the use of pumps and high pumping rates. With high pumping rates and increasing population, the groundwater lens is becoming more saline in addition to the deterioration in chemical and biological quality. Therefore, it can safely be argued that an increase in salinisation of the groundwater lens would become apparent in most of the islands, whether a sewerage system exists or not. Even in places where the sewerage system pumps all water out to the lagoon such as K. Gulhi, Lh. Naifaru and Lh. Hinnavaru, there is no data to suggest that the groundwater has become more saline due to the sewerage system. Some of these islands have groundwater of a quality similar to other similar islands where there is no sewerage system.

It has been observed that freshwater exists in pockets. Where the drawn down effect is high, due to the size of pumps and rate of pumping, there is a tendency for the water lens to become more saline at the location where the drawdown is greater. According to the Ghyben-Hertzberg principle for every feet of groundwater drawn from the surface of the water lens, salt water from below the lens pushes the water lens or the freshwater-seawater transition zone by 40feet (Freeze and Cherry, 1979), thereby making the freshwater at a particular location more saline than other areas. This draw down or lowering of the water table at the point of abstraction, sometimes referred to as the “coning effect” for the freshwater lens, can only be avoided with the use of appropriate technology such as skimming wells and infiltration galleries. High rates of pumping are the main contributor to salinisation. This is the case in many islands, where the aquifer has become salty, even when there is no sewerage system. Therefore, as long as pumps continue to be used for groundwater abstraction, groundwater would become saline and no amount of recharge would guarantee a freshwater aquifer.

At present, salinisation of the water lens also occurs as a result of low gradients which aid seawater entering the system at high tide. However, the proposed sewer outfall is not expected to cause such backflow during high tide. Even if it does, the saltwater will not enter the groundwater aquifer unless it backflows from the pump station sump.

8.5.1.2 Mitigation Measures

The main environmental impact would be the potential for increased abstraction of the groundwater. This would enhance the potential for salinisation of the aquifer. Therefore, island sewerage systems development should go hand in hand or integrated with water resource management planning. Population planning would also be an integral part.

The main factors in determining the potential for salinisation of the water lens and how they can be effectively controlled would be:

- <u>Construction controls</u>. Construction material and workmanship would be carefully supervised by project engineers to ensure that sulphur resistant cement and other appropriate materials are used.
- <u>The use of pumps and flush tanks.</u> Pumping has already been evidently causing severe salinisation of the groundwater aquifer in many islands of Maldives. Awareness is low on these issues. Therefore, creating awareness would play an important role in reducing water use. Cistern flush is common place but more people are going for dual flush tanks. So, increasing awareness on dual flush systems and other water conservation measures need to be considered in order to mitigate the impact of salinisation of the groundwater lens. Flushing volumes can be reduced by placing bricks, etc. in the cistern or by

promoting dual flush units. Even more important is controlling the size of pumps in household wells. If pumps were to be used, skimming wells which will draw water from a larger area than a single point would also help to alleviate the problem of salinisation. Such technologies need to be tried in all islands of the Maldives for sustainability of the groundwater aquifer.

- Safe or sustainable yield vs population. Ensuring population does not outgrow safe or sustainable rates of groundwater abstraction is important. The safe yield for Neykurendhoo has been determined based on assumptions of recharge from rainfall and freshwater lens area given by Falkland (2001). The estimates for different population sizes for Neykurendhoo are given in **Error! Reference source not found.**. Note that the sustainable yield varies with the size of the population. The estimates show that for Neykurendhoo, the current population can sustainably draw a daily volume of about 95litres per person on average. The best estimates for Neykurendhoo gives a sustainable yield of 513m^3/day for the current population. This is assuming skimming wells or similar techniques/technologies were adopted.

8.5.2 Lagoon and seawater quality

8.5.2.1 Impacts

Marine water quality is not likely to be impacted from wastewater from the current population or even the predicted population as wastewater will be disposed in to the deep sea beyond the reef at a location that is considered to have strong currents moving parallel to the island and not towards the island most of the time. The appropriate locations have been determined during the initial study using Mike21 modelling techniques. Considering the large dilution potential in combination with the effect from saltwater, most pathogens and nutrients will be dispersed and diluted, though one might assume long term impact, but not with huge impacts on the marine biota. Given that there will be secondary treatment for the sewage effluent that would be disposed at the proposed outfall, the impact would be almost negligible.

8.5.2.2 Mitigation Measures

In order to avoid conflicting scenarios with any cumulative impacts of solid waste management, it is important that solid waste is managed properly and its impact on the island's shore and lagoon are minimized. Only then, would it be possible to directly associate any negative impacts on the environment with the sewerage system.

8.5.3 Coral Reef and Marine Biodiversity

8.5.3.1 Impacts

Discharges of sewage to the marine environment have the potential to cause:

- *Eutrophication* of coastal waters due to chronic inputs of nutrients and organic matter;

- Impacts associated with the accumulation of toxicants such as heavy metals in marine organisms and sediments;
- Changes to the species composition of marine communities to higher abundances of species that are tolerant to pollution; and
- Long-term degradation of sensitive environments such as coral communities and seagrass meadows by chronic exposure to sewage effluent.

The environmental impacts of sewage disposal on coral reefs depend on several factors including the quantity and characteristics of the effluent, level of pollutants, duration and timing of the peak discharges, diffusion efficiency of the outfalls, depth and location of outfalls, the oceanographic and hydrological conditions and the tolerance of marine organisms.

In the Maldives, there are very few studies that have attempted to collate information on the status of the coral reefs and response of reef fauna to sewage discharges. A study by Binnie Black and Veatch showed detrimental impacts of high sedimentation on coral growth and survival. However, the general concentration levels of total suspended solids in municipal sewage discharges have been found to be much below the levels that are generally considered to be lethal for corals. Studies carried out in the Maldives have also shown that:

- Generally, the amount of nutrients that might lead to eutrophication was found to be very low in coastal waters
- No effect on the level of temperature, salinity or dissolved oxygen were recorded
- In many outfall locations in Male, the currents were quite strong that sewage concentrations were found to be diluted quickly and were not seen to affect general quality of the receiving waters
- In Naifaru and Hinnavaru, studies have indicated that nearshore outfalls can cause nearshore bathing waters to get dirty in colour and increased nutrient levels thereby promoting seagrass.

Pastorak and Bilyard (1985) had indicated that although a wide range of impacts from sewage on coral reefs have been reported, little or no impact has been observed in well flushed waters, as is the case in the proposed design for Neykurendhoo.

Human population pressures and resultant developments are the greatest threat to coral ecosystems. Studies have concluded that eutrophication and sedimentation from effluent outflows are one of the most damaging anthropogenic activities to coral reefs and reef fisheries (Brown and Ogden, 1993). Effluent outflows from waste treatment plants or septic tanks generally increase the level of sediment and nutrients around its outlet and in shallow reef areas sewage outflows can diminish light penetration and increase algal growth; inevitably leading to coral bleaching and death (Brown and Ogden, 1993). In Maldives, fishermen have noticed a decline in the abundance of coral reef fishes and have also noticed a dramatic increase in algal growth amongst shallow reef areas. Many have attributed these changes to environmental degradation. As previously discussed however, in most of the densely populated islands, sea outfall have been installed using on gravity flow capability, consequently, the short outfall pipes have been located near the shoreline and shallower reef beds (Marine Research Centre, 2003).

However, this is not the case for the proposed system in Neykurendhoo. The outfall location has been considered to be close to a well flushed channel, where strong currents would exist during both monsoons. However, for the outfall on the north, the effect will be less than that on the south as there would be some degree of movement of solids towards the shore for this particular outfall during the northeast monsoon. However, the impact would be minimal given the distance from shore or lagoon areas that would be used for swimming.

8.5.3.2 Mitigation Measures

Minimising effluent disposal impacts

Based on the United Nations Environment Program the level of impact from sewage pollution on coral reefs is directly related to the level of treatment before discharge and the natural flushing by tides and currents upon discharge (UNEP 2002). Only deep-sloped outfalls can adequately disperse and dilute treated effluent via underwater currents. In Hawaii for example, secondary-tertiary treated sewage displayed no impact on the surrounding coral reef ecosystem because the outlet is at a depth of 35 feet (Dollar and Grigg, 2003).

Similarly, the proposed system in Neykurendhoo would dispose at similar depths and also have a very high level of dilution due to hydrodynamic conditions prevailing at the outfall location. Therefore, the impact of sewage on the reefs or water quality at the outfall location would be almost negligible. Even if the sewage were disposed without treatment, the proposed depth and location is practical for the current or projected population of Neykurendhoo to counteract the effects of outfall pipes on coral reef habitat in Neykurendhoo. It is not anticipated that marine water quality or the reef is to be significantly impacted from the discharge of untreated wastewater due to the oceans large dilution potential in combination with the effect from saltwater. In this environment most pathogens and nutrients will be dispersed and diluted and the resulting impacts on the marine biota should be negligible and limited to the environment in the immediate vicinity of the outfall.

The other mitigation measures are similar to those given in the previous subheading.

8.5.4 Socio-Economic Impacts

The social implications of the proposed sewerage systems have been considered by assessing the projects direct and indirect benefits to the society. The social impacts include improvement of environmental health, increase in property values and additional gain in ecotourism potential. In summary, the social implications of this project are both real and perceived and are discussed below. Following are the potential benefits and other issues outlined by the communities with regard to the new sanitation project that is planned to be implemented

8.5.4.1 Solution to existing problems

One of the potential benefits looked forward by the whole community is a solution to the existing problems that they are experiencing with the current system. In Neykurendhoo the existing problems as outlined earlier includes contamination of groundwater lens, lack of space for household septic tanks and excessive expenses for cleaning and repairing. In addition, contamination of the water is believed to be the cause of diarrhoea and other water borne diseases. All of the respondents are aware of these existing problems and many believe the biggest relief of establishing a suitable sewerage system would be the end of all the existing problems they are encountering at present.

8.5.4.2 Less expensive

It is expensive at the household level to hire workers to clean and repair the septic tanks. The expenses range from Rf200 to Rf2000 and are as frequent as once a month. For some people of the island it is difficult and cannot afford to pay. So the whole community is looking forward for the new system which they believe would be less expensive and hassle free to maintain at the household level. Also, once the utilities company takes over all utilities of the island, sewerage services would not be reflected in the bill as sewerage services but may be integrated as a marginal cost into water tariff or overall utility tariff.

8.5.4.3 Strengthening social cohesion and employment opportunities

Implementation of the sewerage system involves lot of activities and work by the community. Such opportunities of working together will strengthen the community spirit and confidence of the community strengthening social cohesion. The whole community is looking forward for the start of the project.

During the operational stage, there will also be job opportunities for locals as manpower will be required for operation and maintenance once the system is in place. These new job opportunities will stimulate the economy and mobilize potential residents who are unemployed. Once the system is developed, the job opportunities created will also increase knowledge and capacity of staff on water and wastewater, thus increasing their economic potential elsewhere.

8.5.4.4 Willingness to pay

As indicated earlier, levying charges for sewerage services is difficult, and so is penalizing because disconnecting sewerage service is difficult. A disconnection to a sewerage service would mean provision of several public toilets within easy reach. It may be assumed that over 70% of the households would not pay for sanitation directly but it has to come through indirect taxation. Since sanitation is often regarded as a public service that has to be financed through indirect taxation by the government or councils (island communities), discussing measures to cover those who cannot pay and measures to deal with those who would not pay would not be sensible.

8.6 Overall Impact Evaluation

This section provides a summation of the impacts of the project components discussed above. The impacts of the project have been evaluated according to the following criteria:

1. Magnitude (or severity): the amount or scale of change that will result from the impact
2. Significance: importance of the impact. Reversibility is considered part of its significance
3. Duration: the time over which the impact would be felt
4. Extent/spatial distribution: the spatial extent over which the impact would be felt

The scale associated with the above criteria is given in the table below.

Table 8-1: Impact evaluation scale

Criteria	Scale	Attribute
Magnitude *Change caused by impact*	-3	Major adverse
	-2	Moderate adverse
	-1	Minor adverse
	0	Negligible
	1	Minor positive
	2	Moderate positive
	3	Major positive
Significance/Reversibility *Impact implications / Reversibility of impact's effects*	0	Insignificant
	1	Limited implications / easily reversible
	2	Broad implications / reversible with costly intervention
	3	Nationwide or global implications / irreversible
Duration *Duration / Frequency of Impact*	0	Immediate
	1	Short term/construction period only
	2	Medium term (five years of operation)
	3	Longterm/continuous
Extent/Spatial Distribution *Distribution of impact*	0	None/within 1m from point of discharge/no affected party
	1	Immediate vicinity/household level/developer/consumer
	2	Specific areas within the island/atoll/specific parties
	3	Entire island/atoll/nation/all stakeholders

Based on the above scale, an impact matrix was developed for the proposed or recommended option to determine the overall impact of the proposed project. This matrix is given in the table below.

Table 8-2: Impact matrix for the proposed project

	KEY COMPONENTS																	
	Environment								Socio-Economic									
PROJECT ACTIVITIES	Reefs	Seagrass	Live Bait	Erosion/Accretion	Lagoon/seawater	Soil and groundwater	Land/seascape	Air/Noise	Resource allocation	Recreation and aesthetics	Services and Infrastructure	Health and Safety	Employment	Economic Diversification	Property Value	Landuse	Costs to consumer/tax payer	Quality of Life
Construction																		
Removal/modification of existing sewer network	0	0	0	0	3 2 2 3	1 1 1 2	1 1 1 2	-1 0 1 1	0	3 2 3 2	0	3 2 3 2	2 1 1 3	1 1 1 3	2 3 3 2	2 2 3 3	-2 3 1 3	0
Excavation/backfilling for laying pipes	0	0	0	0	0	-1 1 1 2	-1 0 1 2	-1 0 1 1	0	-1 0 1 1	-1 1 1 2	-1 1 1 1	2 1 1 3	1 1 1 3	-1 0 1 1	-1 0 1 1	-2 3 1 3	0
Dewatering for laying pipes	0	0	0	0	0	-2 2 2 2	-1 1 1 1	-1 0 1 1	0	-1 0 1 1	-1 1 1 2	-1 0 1 1	2 1 1 3	1 1 1 3	-1 0 1 1	-1 0 1 1	-2 3 1 3	0
Excavation/backfilling for lift and pump stations	0	0	0	0	0	-1 1 1 1	-1 0 1 1	-1 0 1 1	0	-1 0 1 1	-1 1 1 2	-2 1 1 1	2 1 1 3	1 1 1 3	0	-1 0 1 1	-2 3 1 3	0
Dewatering for lift and pump stations	0	0	0	0	0	-2 2 2 2	-1 1 1 1	-1 0 1 1	0	-1 0 1 1	-1 1 1 2	-1 0 1 1	2 1 1 3	1 1 1 3	0	-1 0 1 1	-2 3 1 3	0
Construction of sea outfalls	-2 1 1 2	-2 0 1 2	-1 1 2 3	0	0		-1 0 1 1	-1 0 1 1	0	-1 0 1 1	-1 1 1 2	-1 0 1 1	2 1 1 3	1 1 1 3	0	-1 0 1 1	-2 3 1 3	0
Machinery, equipment and site installations	-1 0 1 1	0	0	0	-1 0 1 1	-1 1 1 1	-1 0 1 1	-1 1 1 1	-1 0 1 1	-1 1 1 1	-1 1 1 2	-1 0 1 1	1 1 1 3	1 1 1 3	2 1 1 1	-1 0 1 1	-2 3 1 3	0
Workforce management	0	0	0	0	0	0	0	0	0	0	-1 1 1 2	-1 0 1 1	2 1 1 3	1 1 1 3	2 1 1 1	0	2 2 1 3	1 1 1 1
Operation																		
Toilet flushing/groundwater abstration	0	0	0	0	0	-3 1 3 3	0	0	-2 2 3 2	0	0	-2 0 3 3	1 1 3 2	1 1 3 3	1 1 2 1	0	-1 1 3 2	0
Effluent discharge/management	-1 0 3 2	-1 0 3 2	-1 0 3 3	0	-1 0 3 2	2 2 3 3	0	0	1 1 3 2	1 1 3 2	1 1 2 2	2 1 3 2	2 1 3 1	1 1 3 3	1 1 2 1	0	-1 2 3 2	1 1 3 3
Sludge disposal/management	0	0	0	0	0	0	0	0	0	-1 0 3 2	1 1 3 2	-1 0 3 1	2 1 3 1	1 1 3 3	1 1 2 1	-1 0 3 2	-1 0 3 2	1 1 3 3
Oil and grease removal and disposal	-2 0 3 1	0	0	0	-1 1 3 1	-1 1 3 1	0	0	0	-1 0 3 1	0	-1 0 3 1	2 1 3 1	1 1 3 3	1 1 2 1	-1 0 3 2	-1 0 3 2	1 0 3 3
Treatment plant operation and pumping	1 1 3 2	1 1 3 2	1 1 3 2	0	1 1 3 2	0	0	-1 0 3 3	-1 1 3 2	1 1 3 2	0	1 1 3 2	2 1 3 1	1 1 3 3	1 1 2 1	-1 1 3 2	-1 2 3 2	-1 1 3 3
Admin and finance (Tariffs/fee collection)	0	0	0	0	0	0	0	0	0	0	1 1 3 1	0	2 1 3 1	1 1 3 3	1 1 2 1	0	-1 0 3 3	0
System maintenance and repairs (technical)	0	0	0	0	0	-1 0 3 1	0	0	0	0	1 1 3 1	1 1 3 1	2 1 3 1	1 1 3 3	1 1 2 1	0	-1 0 3 1	1 1 3 3

M S / D E — M = Magnitude, S = Significance, D = Duration, E = Extent (spatial distribution)

An impact potential index was then developed from the above table. The impact potential index table below represents a product of the magnitude (M), significance (S), duration (D) and extent/spatial distribution (E) given in the above table. The sum of all key component specific indexes for one activity (i.e. sum by rows) provides the Activity Potential Impact Index (API) and the sum of all activity specific indexes for one key component (i.e. sum by column) provides the Component Potential Vulnerability Index (CPVI) which gives an indication of the vulnerability of each key component to activity related impacts. The table below represent the impact potential indices for the proposed project.

Table 8-3: Impact potential indices for the proposed project

	KEY COMPONENTS																		
	Environment								Socio-Economic										
PROJECT ACTIVITIES	Reefs	Seagrass	Live Bait	Erosion/Accretion	Lagoon/seawater	Soil and groundwater	Land/seascape	Air/Noise	Resource allocation	Recreation and aesthetics	Services and Infrastructure	Health and Safety	Employment	Economic Diversification	Property Value	Landuse	Costs to consumer/tax payer	Quality of Life	TOTAL API
Construction																			
Removal of existing sewer network	0	0	0	0	0.44	0.02	0.02	0	0	0.44	0	0.44	0.07	0.04	0.44	0.44	-0.22	0	2.13
Excavation/backfilling for laying pipes	0	0	0	0	0	-0.02	0	0	0	0	-0.02	-0.01	0.07	0.04	0	0	-0.22	0	-0.16
Dewatering for laying pipes	0	0	0	0	0	-0.2	-0.01	0	0	0	-0.02	0	0.07	0.04	0	0	-0.22	0	-0.34
Excavation/backfilling for lift and pump stations	0	0	0	0	0	-0.01	0	0	0	0	-0.02	-0.02	0.07	0.04	0	0	-0.22	0	-0.16
Dewatering for lift and pump stations	0	0	0	0	0	-0.2	-0.01	0	0	0	-0.02	0	0.07	0.04	0	0	-0.22	0	-0.34
Construction of sea outfalls	-0.05	0	-0.07	0	0	0	0	0	0	0	-0.02	0	0.07	0.04	0	0	-0.22	0	-0.25
Machinery, equipment and site installations	0	0	0	0	0	-0.01	0	-0.01	0	-0.01	-0.02	0	0.04	0.04	0.02	0	-0.22	0	-0.17
Workforce management	0	0	0	0	0	0	0	0	0	0	-0.02	0	0.07	0.04	0.02	0	0.15	0.01	0.27
Operation																			
Toilet flushing/groundwater abstration	0	0	0	0	0	-0.33	0	0	-0.3	0	0	0	0.07	0.11	0.02	0	-0.07	0	-0.5
Effluent discharge/management	0	0	0	0	0	0.44	0	0	0.07	0.07	0.05	0.15	0.07	0.11	0.02	0	-0.15	0.11	0.94
Sludge disposal/management	0	0	0	0	0	0	0	0	0	0	0.07	0	0.07	0.11	0.02	0	0	0.11	0.38
Oil and grease removal and disposal	0	0	0	0	-0.04	-0.04	0	0	0	0	0	0	0.07	0.11	0.02	0	0	0	0.12
Treatment plant operation and pumping	0.07	0.07	0.07	0	0.07	0	0	0	-0.07	0.07	0	0.07	0.07	0.11	0.02	-0.07	-0.15	-0.11	0.22
Admin and finance (Tariffs/fee collection)	0	0	0	0	0	0	0	0	0	0	0.04	0	0.07	0.11	0.02	0	0	0	0.24
System maintenance and repairs (technical)	0	0	0	0	0	0	0	0	0	0	0.04	0.04	0.07	0.11	0.02	0	0	0.11	0.39
TOTAL CPVI	0.02	0.07	0	0	0.47	-0.35	0	-0.01	-0.3	0.57	0.06	0.67	1.02	1.09	0.62	0.37	-1.76	0.23	2.77

API = Activity Potential Impact Index

CPVI = Component Potential Vulnerability Index

The table above indicates that the project has some negative environmental impacts during the construction phase as well as operational phase, which are not as strong as the positive outcomes of the project, as a result of which the total potential impact index for the project is positive. However, given that the project has high economic burden on the tax payer or government revenue, the results are not as positive when measured against the high social acceptance of the project.

8.7 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 Neykurendhoo may be expected to be low due to the experience of similar projects in similar settings in the Maldives. Nevertheless, it is important to consider that there will be uncertainties and to undertake voluntary monitoring as described in the monitoring programme given in the EIA report.

9 Environmental Monitoring

9.1 Introduction

Neykurendhoo does not have an island-specific monitoring programme. Therefore, it is recommended that the Island Council initiate an integrated, island-wide environmental monitoring programme. There are several benefits in such a programme including:

- Impacts on the island of different projects ongoing including solid waste management, water supply, harbour and sewerage projects can be undertaken in a coordinated manner
- Since all projects impact upon the same environmental resources and aspects, the cumulative impacts of all projects combined is better understood
- A holistics approach to environmental management can be adopted
- Cost of monitoring would be reduced and more parameters can be monitored.

Therefore, it would be useful to undertake such an integrated monitoring programme. In that case, the following environmental components would be useful to monitor.

- Ground water of the island to monitor the improvements
- Waste management aspects
- Island shorelines and vegetation
- Coral reef monitoring for reef health and marine biodiversity around the outfall and a control point
- Surface water at existing outfall locations to monitor improvements in sea water quality especially the lagoon
- Socio-economic aspects

In case of adopting a project-specific monitoring programme, it is perhaps only useful to monitor groundwater and surface water quality at designated locations. This report discusses the monitoring requirements specifically for these parameters. However, monitoring requirements for other parameters such as reef and socio-economic aspects are also included for reference in case an island-wide monitoring programme were to be considered.

The proposed monitoring programme shall be undertaken by environmental consultants during the construction period. The monitoring programme shall continue for a period of at least 5 years in order to understand the impacts and benefits of the system. Annual monitoring reports (summarizing the findings from the annual monitoring) need to be submitted to the EPA at the end of each year including monitoring records and field inspections during the construction phase.

It is important that information and experience gained through the monitoring activities are fed back into the EIA evaluation and analysis system to improve the quality of future assessment studies.

9.2 Monitoring Requirements

9.2.1 Coral Reef Monitoring

Table 7-1 shows the coral reef monitoring programme recommended for short and long-term evaluation of the reef system and ambient marine environment. Depending on the logistics available some of the elements in the above matrix can be omitted, however, it is strongly recommended that these methods are included in the monitoring programme.

Table 9-1: Coral reef system monitoring programme matrix

Methods	Frequency of Monitoring	Purpose
Ambient Environmental Parameters to include Temperature, Salinity, Turbidity/light penetration, Currents	Twice every month during construction phase; once every three months thereafter	Important to the 'health' of living marine resources, reefs and fish populations and other benthos
Manta Tow Technique	Once every year or following a significant natural event e.g. coral bleaching, COT infestation, storm damage etc.	Broad scale qualitative and Semi-quantitative assessment of general status of the reef system / coral and other benthic recruitment
Water quality test	Once every three months	Quantitative assessment of Nitrogen and Phosphorous contents, chlorophyll A and other parameters such as total and faecal coliform and streptococci counts

Research in the Caribbean and in the Great Barrier Reef of Australia has established the critical levels of nitrogen and phosphorous which must not be exceeded if reefs are to remain healthy without being overgrown by weedy algae (Lapointe et al., 1992, 1993, Bell, 1992).These concentrations are:

- Nitrogen: 0.014 ppm N or 0.040 ppm NO_3
- Phosphorous 0.003 ppm P or 0.007 ppm PO_4

9.2.2 Water Quality Monitoring

Table 9-2: Monitoring water quality

Impact Area	Data sought	Min. Frequency	Purpose
Groundwater	pH, E-Conductivity, TDS, total and faecal coliforms, nitrates, nitrites, BOD and phosphorus, H_2S gas	Every three months initially, then every six months	To ensure effectiveness of the proposed systems To base groundwater protection measures
System performance	Inspect and report leaks in sewerage system	Once a year	To ensure appropriate performance
Lagoon	pH, E-Conductivity, TDS, total and faecal coliforms, nitrates, BOD and phosphorus	Every three months initially, then every six months or annually	To ensure effectiveness of the proposed systems
Sea outfall/marine	pH, E-Conductivity, TDS, total and faecal coliforms, nitrates, nitrites, BOD, phosphorus and chlorophyll-A	Every three months initially, then every six months or annually	To ensure effectiveness of the proposed systems

9.2.3 Monitoring dewatering impacts

The water quality and water levels of selected houses would be monitored just before, during and after the project to understand the changes due to dewatering. The parameters to be monitored from each well would be pH, E-Conductivity, total and faecal coliforms, nitrates and tidal water level variations. This impact specific monitoring will be undertaken only during the period of the impact.

9.2.4 Socio-Economic Aspects

One of the key aspects of sustainable sanitation is the contribution that a proper sewerage system makes towards overall health of the population and community development. Therefore, such systems must be able to demonstrate their contribution towards social and community development through economic contributions and awareness creation.

A healthy environment should in turn mean opportunities for improved health and community development for the residents of Neykurendhoo. Another key indicator of system sustainability will be the community's capacity to maintain and operate the system without undue financial or mental stress. A monitoring protocol to review costs associated with operation and maintenance of the system should be a component of the operating manual. In the first year following the implementation of the system, resident concerns should be promptly addressed, noted and resolved. A survey of residents to assess and track their level of satisfaction with system should also be undertaken following the first year of system operation, so that issues might be addressed before they become serious.

Table 9-3: Indicators for monitoring of socio-economic aspects of the project

Indicator	Assessment question	Source of information
1. Access to water No of households using different types of water by purpose E.g. Households using ground water for cooking / drinking/ washing/ bathing/ agricultural purposes. Households using purified water for drinking/washing/bathing/agricultural purpose	What are the changes occurring regarding the access to safe water?	Island Council records Focus Group Discussion
2. Incidence of water borne diseases Diarrhoea Typhoid Cholera	What are the changes occurring regarding the incidence of water borne disease?	Health Center records Focus group discussions
3.Employment Number of direct employment created due to the project	Are jobs and income earning opportunities created due to the project?	Record in the Council Office
4. System performance and satisfaction, e.g. how does the present system compared with previous system, how satisfied are people with the new system on a given scale (Likert)		

9.3 Recommended Monitoring Programme

Outlined here are minimum project specific monitoring requirements that should be considered. This monitoring programme for the proposed project includes at least three monthly monitoring and covers the three stages of the project implementation.

Stage 1: Immediately before starting works

Stage 2: During civil works

Stage 3: Operational stage for two years

The monitoring needs of each stage are discussed in detail below:

<u>Stage 1</u>

- Groundwater quality for pH, Conductivity, TDS, DO, nitrates, phosphates, faecal and total coliforms (to be sampled and tested prior to project implementation)
- Marine water quality – BOD, faecal coliforms, dissolved oxygen and chlorophyll A (to be sampled and tested prior to project implementation)
- Public expectations (covered in this EIA)

<u>Stage 2</u>

- Groundwater quality for pH, Conductivity, TDS, DO, nitrates, phosphates, faecal and total coliforms
- Marine water quality – BOD, faecal coliforms, dissolved oxygen, chlorophyll A
- Public complaints and issues raised

<u>Stage 3</u>

- Groundwater quality for pH, Conductivity, TDS, DO, nitrates, phosphates, faecal and total coliforms
- Marine water quality – BOD, faecal coliforms, dissolved oxygen and chlorophyll A
- Public satisfaction/dissatisfaction of the system

For water quality monitoring, site conditions during monitoring such as smelly groundwater, rainy day or outfall within 5m of sampling location must be identified. Sampling conditions including sampling depth, time and GPS location shall be provided.

9.4 Cost of monitoring

The following table outlines a cost estimate for the monitoring assuming the monitoring will be undertaken by environmental consultants and most of the parameters would be tested in-situ.

Table 9-4: Estimated cost of the proposed monitoring programme (annual)

No	Details	Unit cost (MRF)	Total (MRF)
1	Transport cost	10,000.00	30,000.00
2	Field allowance for 2 staffs for 2 days	1,000.00	4,000.00
3	Accommodation and food and miscellaneous for 2 staffs for 2 days	500.00	2,000.00
4	Monitoring equipment	5,000	30,000.00
5	Water quality testing and analysis	1,500	1,500.00
	Total		67,500.00

Alternatively, samples can be taken by designated person (such as the sewerage system operators) and sent to Malé for testing at the Public Health Laboratory. The costs of this would be much less compared to the costs given above. However, this would be quite impractical as the community may not have a particular need to assess the water quality. However, the Environment Protection Agency and the project consultants who have an obligation to measure the accuracy of the impacts assessed as well as monitor the environmental benefits of the proposed project would have several reasons to undertake adequate monitoring. This is why the commitment of the Proponent to undertake monitoring has been made mandatory under the EIA Regulations. Hence, the commitment statement from the proponent is based on the estimates given in Table 9-4.

9.5 Monitoring Report

A detailed environmental monitoring report is required to be compiled and submitted to the Environment Protection Agency of the Ministry of Transport, Housing and Environment yearly based on the data collected for monitoring the parameters included in the monitoring programme given in this report. EPA may submit the report to the relevant Government agencies in order to demonstrate compliance of the Proponent.

The report will include details of the site, strategy of data collection and analysis, quality control measures, sampling frequency and monitoring analysis and details of methodologies and protocols followed. In addition to this more frequent reporting of environmental monitoring will be communicated among the environmental consultant, project proponent, the contractors and supervisors to ensure possible negative impacts are mitigated appropriately during and after the project works.

10 Declaration of the consultants

This EIA has been prepared according to the EIA Regulations 2007. I certify that the statements in this Environmental Impact Assessment study are true, complete and correct to the best of my knowledge and abilities.

Ahmed Zahid (EIA 08/07)

15 January 2012

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Appendix 1: Terms of Reference

Appendix 2: Commitment letter from the proponent to undertake monitoring


01


02


03


04


05


06


20


PROPOSED ZONES & LAND USES
N
Industrial and slipway
buffer zone
agricultural land
Future housing
Housing units or flat
Stadium
Water suply
Waste site
Park
Secondary School
Police
Health Center
Youth Center
Proposed Mosque
commercial retail mix
Future government Use
HA. Neykurendhoo
Satellite Image, V.16.AB
GIS & Mapping Unit
Spatial Planning Section
Department of National Planning
0 50 100 200 300 500
meters


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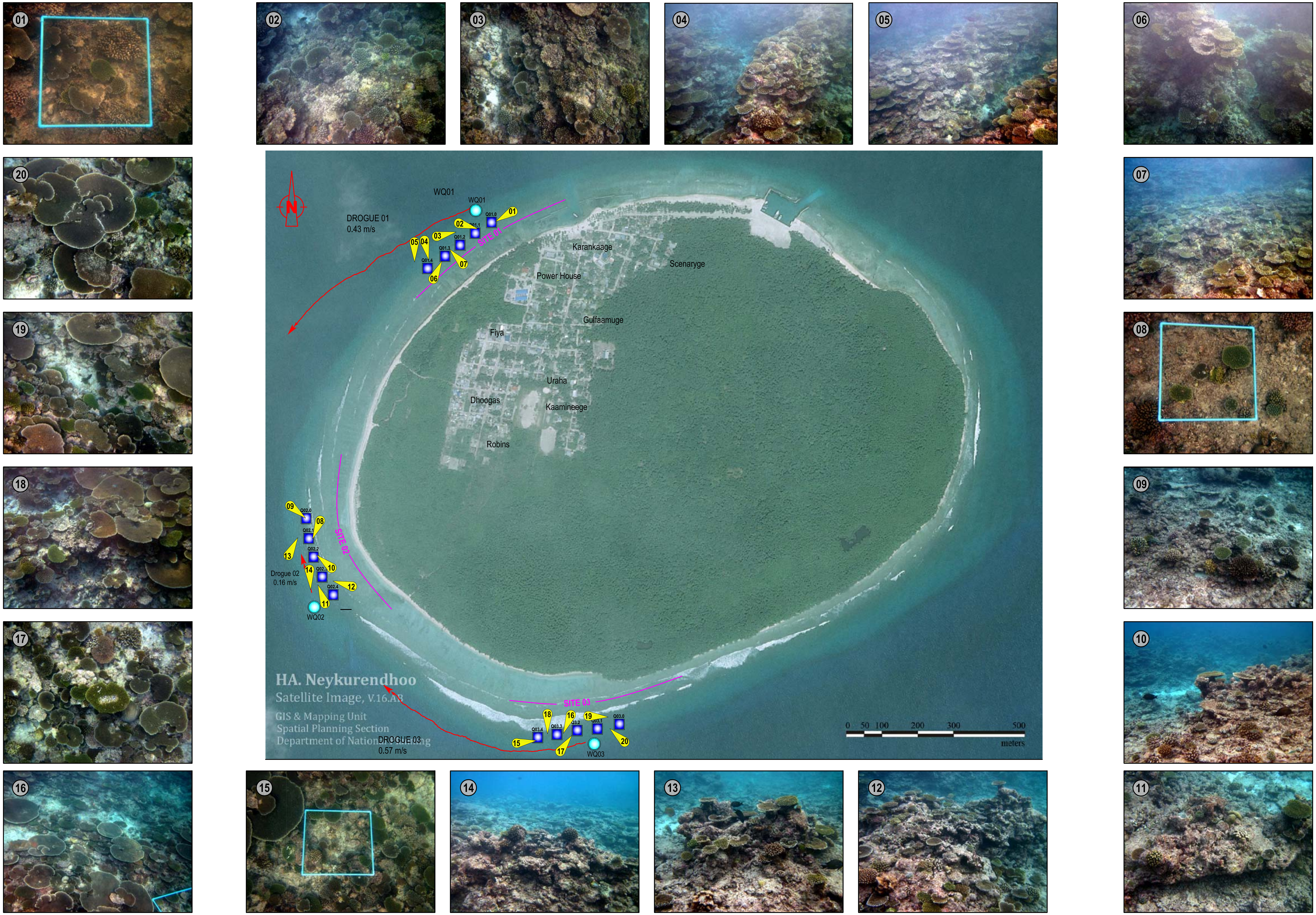
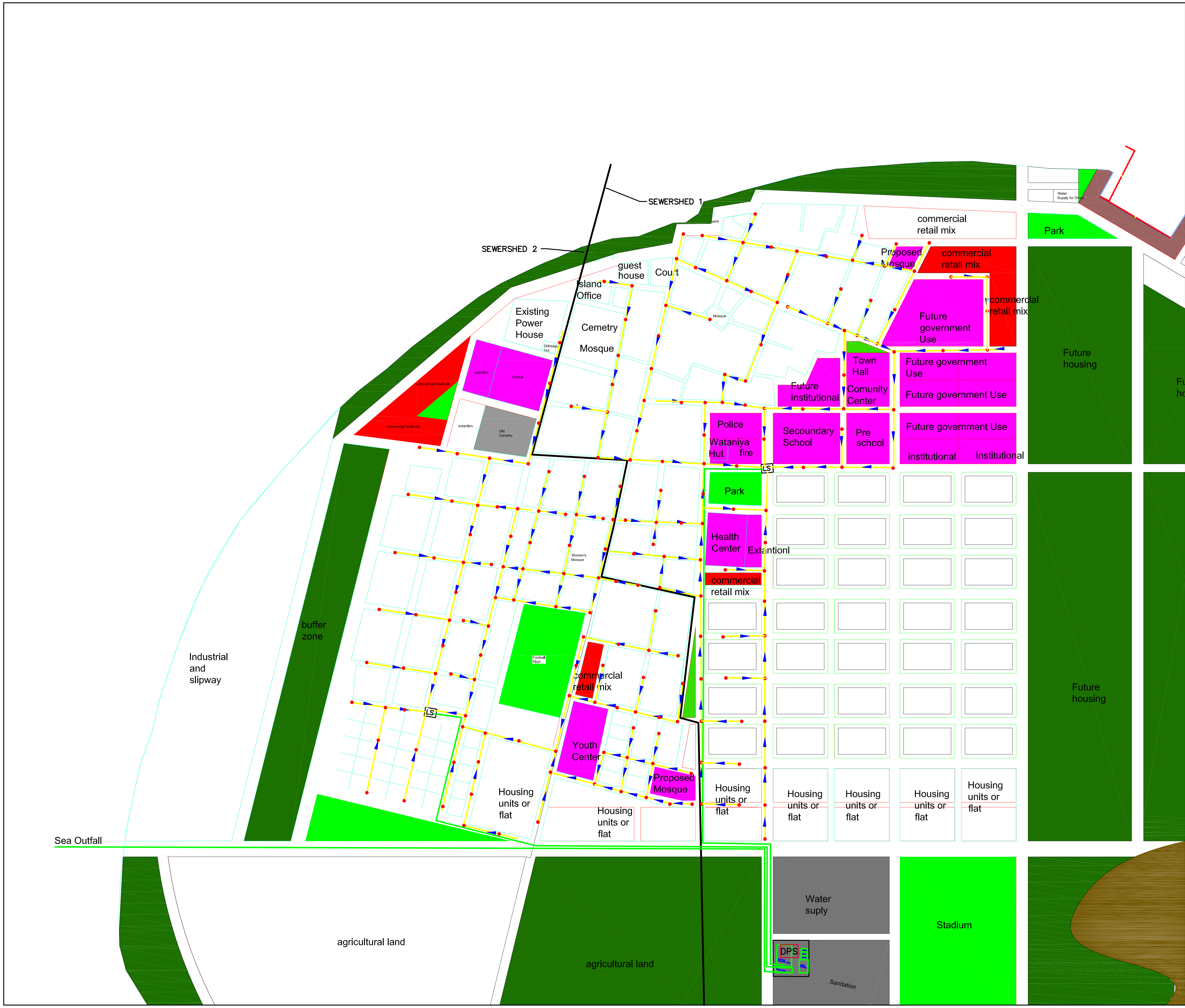


Proponent: Global Wings Pvt. Ltd.
Consultant: Ahmed Zahid (EIA08/07)



LEGEND

(blue line)	GRAVITY SEWER MAIN
(green line)	FORCE MAIN
(black line)	SEWER CATCHMENT BOUNDARY
LS	LIFT STATION
PS	PUMPING STATION
DPS	DISPOSAL PUMPING STATION
(orange dot)	SEWER MANHOLE
(green dot)	CLEANOUTS

HDH. NEYKURENDHOO SEWERAGE CONCEPT 01

ISLAND	NEYKURENDHOO
ATOLL	HAA DHAALU ATOLL
CLIENT	GLOBAL WINGS.PVT.LTD
SCALE	AS GIVEN
SURVEYED DATE	12-13TH JAN 2012
SURVEYED BY	MIZAL, MUHEETH & RIYAZ
DRAWN BY	SHAHEED
DRAWING DATE	14TH JAN 2012

REVISIONS: -

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LEGEND

- GRAVITY SEWER MAIN
- FORCE MAIN
- SEWERSHED BOUNDARY
- LS LIFT STATION
- XXX EXISTING GRADE
- INV. XXX PIPE INVERT

HDH. NEYKURENDHOO SEWERAGE CONCEPT 01

ISLAND	NEYKURENDHOO
ATOLL	HAA DHAALU ATOLL
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SANDCAYS PVT LTD

LEGEND

- GRAVITY SEWER MAIN
- FORCE MAIN
- SEWERSHED BOUNDARY
- LS — LIFT STATION
- PS — PUMPING STATION
- XXX — EXISTING GRADE
- SEWER MANHOLE

HDH. NEYKURENDHOO SEWERAGE CONCEPT 01

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