REPORT

Assessment of the Infrastructure for Improved Wastewater Management in Soufriere

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Acronyms and Abbreviations

AMEP	CEP Programme on Assessment and Management of Marine Pollution
BASAL	Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
BONN	Convention on the Conservation of Migratory Species (CMS)
BVI	British Virgin Islands
CBD	Convention on Biological Diversity
CBWMP	Caribbean Basin Water Management Programme
CEP	Caribbean Environment Programme
CEPPOL	UNEP-CEP Programme for Marine Pollution Assessment and Control in the Wider Caribbean Region
CEHI	Caribbean Environmental Health Institute
CITES	Convention of International Trade in Endemic Species
CZM	Coastal Zone Management
DoF	Department of Fisheries
ECLAC	Economic Commission for Latin America and the Caribbean
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency of the United States
ESDU	Environment and Sustainable Development Unit of the OECS
EST	Environmentally Sound Technologies
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Pollution
GoSL	Government of St. Lucia
IOC	International Oceanographic Commission
LBS	Protocol on Land-Based Sources of Marine Pollution
MAFF	Ministry of Agriculture Forestry and Fisheries
MARPOL	International Convention for the Prevention of Pollution from Ships
MPDEH	Ministry of Physical Development Environment and Housing
MEA	Mulitlateral Environmental Agreement
NCA	National Conservation Authority
NCPDI	NOAA's National Coastal Pollution Discharge Inventory Programme
NOAA	United States National Oceanographic and Atmospheric Administration
NWSU	National Water and Sewage Utilities
OC	Organochlorine Pesticides
OECS	Organisation of Eastern Caribbean States
OSH	Occupational Safety and Health
PAHO	Pan American Health Organisation
PCB	Polychlorobiphenyl
PMA	Piton Management Area
RAC	CEP Regional Activity Centres
RAMSAR	The Convention on Wetlands of International Importance especially as Waterfowl Habitat
RAN	CEP Regional Activity Network

SGD	St. Georges Declaration of Principles of Environmental Sustainability in the OECS
SIDS	Small Island Developing States
SLAS	St. Lucia Archaeological Society
SLNT	St Lucia National Trust
SMMA	Soufriere Marine Management Authority
SPAW	Protocol on Specially Protected Areas and Wildlife
STP	Sewage Treatment Plant
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Environment Scientific and Cultural Organisation
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WASCO	Water and Sewerage Company of St. Lucia
WCR	Wider Caribbean Region
WHO	World Health Organisation
XCD	Eastern Caribbean Dollars

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
Ppm	Parts Per Million
ppt	Parts Per Thousand
SS	Suspended Solids
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
$\eta g\ l^{-1}$	Nanogram Per Litre
$\mu g\ l^{-1}$	Microgram Per Litre

Executive Summary

The people of the Caribbean are closely bonded to the marine environment and depend on the sea for food, transportation, and recreation. This dependence has led to the evolution of towns and villages along the coastline of all the Caribbean States and Soufriere in St. Lucia is no exception. Rich in natural and cultural resources the area of Soufriere and the Pitons is the most symbolic region of St. Lucia and was declared a World Heritage Site in 2005 and continue to attract most of the visitors to the island.

Inherent issues with the settlement of people in small areas include degradation of natural resources and waste management. The stress on the marine resources of Soufriere was deemed critical and the Soufriere Marine Management Authority (SMMA) was formed to address the problems experienced and promoted the conservation and co-management of the existing natural resources. The Soufriere Regional Development Foundation (SRDF) was formed to promote and enhance the natural and cultural assets for economic, cultural and social development for the benefit of the community of Soufriere. All these initiatives are geared towards sustainable development and use of the marine and terrestrial resources of the area.

Sustainable development initiatives must involve the management of waste of which solid and liquid wastes are chronic problems plaguing Soufriere from the early days of settlement. Development of the solid waste management system in St. Lucia has assisted with ameliorating some of the solid waste problems and although emphasis has been placed in this area, there is much more to be desired. Liquid waste management in Soufriere poses an extreme challenge and is influenced by a number of factors including: point sources, non-point sources, hydrogeology, social, economic, political, legal, education and awareness.

In accessing the infrastructure for improved liquid waste management in Soufriere within the legislative framework existing within St. Lucia, the Caribbean Environmental Health Institute (CEHI) opted to undertake key components such as: Literature review of the national, regional and international laws governing liquid waste management, surveys of point source of pollution, surveys of non-point sources of pollution, sampling and laboratory analyses. Hence, this provided information required for the determination of the level of compliance for liquid waste management in Soufriere within the legal, administrative and regulatory framework for St. Lucia and allow for the formulation of recommendations to achieve compliance. Training is an important component of liquid waste management and can be used to improve the design, construction and operation of the systems while at the same time reducing the need for enforcement in obtaining compliance to the regulatory framework. Recommendations for reducing the possible impact of liquid waste management on the marine environment also evolved from the surveys, water sampling and laboratory analyses that were components of the Project.

The Water and Sewage Act No. 14 of 2005, Public Health (Sewage and Disposal of Sewage and Liquid Industrial Waste Works) Regulations (No 22 1978) and Public Health (Disposal of Offensive Matter) Regulations (1978) are the main legal instruments

governing the sewage and liquid waste in St. Lucia. Additionally, the Cartagena Convention and its LBS Protocol is an important instrument for the protection of the marine environment from sewage and liquid waste. The legal instruments although containing shortcoming such as addressing the issue of 'grey water' which is of concern, are difficult to enforce within the socio-economic and political environments. This is compounded by the existence of less fortunate localities within the community such as Barons Drive where there is a general feeling of marginalisation and discontent.

Various initiatives to protect the natural resources and enhance the community of Soufriere were taken such as the SMMA and SRDF. With specific reference to the marine environment, the conservation of the resources through mechanisms such as conflict resolution, creation of reserves and user specified zones has to be complemented by measures geared towards the prevention of pollution by liquid waste from land-based sources. Such measures include: 'Grey water' management, 'Black water' management, appropriate disposal of effluent from household sewage disposal systems, appropriate disposal of sewage from the commercial, tourism and institutional sectors and enhancing the socio-economic status of the less fortunate residents of Soufriere.

The following are recommended for attaining compliance for liquid waste treatment and disposal within the legal, administrative and regulatory framework:

- Mandatory site visits by the Environment Health Department (EHD) of the Ministry of Health prior to approval and before the completion of the sewage treatment and disposal system for buildings and homes. At such visits technical advice and directions should be provided by Environmental Health Officers (EHOs) for the proper construction of the systems to ensure compliance;

- Conduct biannual inspections of individual sewage treatment systems to ensure that measures required for the proper functioning of such systems are enfoirced;

- Develop a ckecklist for self-inspection and assessment for household and commercial sewage treatment and disposal systems and implement a system for self-inspection and assessment by householders and managers of commercial sewage treatment and disposal systems;

- Conduct house to house inspection throughout Soufriere concentrating on specific less fortunate localities such as Barons Drive, to obtain data required for the formulation of a plan to manage sewage and excreta;

- Identify all households without appropriate and approved excreta and sewage disposal systems and assess the measures necessary to obtain compliance on an individual basis;

- Formulate and implement a plan and strategy for attaining compliance within the framework of the legal instruments covering sewage and excreta disposal at the level of the household; The development and implementation of the strategy and

plan should involved governmental and non-governmental resource management organisations, development and social services agencies such as the SRDF, Town Council, SMMA, Ministry of Social Services, Ministry of Agriculture, Ministries of Works, Health, the Environment and Tourism among others.

- Assess the possibility of relocating residents in the congested low–income localities and provide where necessary assistance in obtaining better housing and suitable sewage disposal systems for these residents;

- Implement a programme to gain commitment and support from the political directorate to enhance the standard of living and general residential environment of the town of Soufriere with special emphasis on the less fortunate localities;

- Ensure that the SLCGA, the largest manufacturing plants in Soufriere, in addition to treating its sewage also treat its 'grey water' to the tertiary level before discharge into the environment;

- Conduct a feasibility study for the installation of a sewage treatment and disposal plant that will produce high quality effluent within the national standards and the stipulations of the LBS Protocol for the community of Soufriere.

Obtaining compliance to regulations or any instrument governing liquid waste disposal may not necessarily be obtained through enforcement. The element of voluntary compliance obtained through education, awareness building and training is always a feasible and sustaining alternative that tends to foster buy-in. If the public is not aware of what is required, not trained and educated in the technical aspects for obtaining compliance and not convinced of the need to be compliant, then enforcing the regulations will be extremely difficult.

With respect to training the following are recommended:

- Provide training for the construction and building sectors in the design, erection and functioning of the septic tanks, filtering systems, absorption pits and alternatives for attaining appropriateness (A Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquid and Hazardous Waste for SIDS in the Caribbean Region (UNEP/CEHI, 2004) provides much needed information in this regard);

- Develop a manual for the design, construction and operation of sewage treatment and disposal systems that are appropriate for use in the Soufriere community;

- Promote good liquid waste management practices among the businesses of Soufriere to build awareness and generate a sense of responsibility for protecting the environment from pollution as a result of liquid waste;

- Provide training and awareness building to the management and operators of hotels and institutions in alternative waste treatment and disposal methods and the choice of appropriate systems;

- Provide training to the technicians responsible for the operation and maintenance of the sewage treatment plants in accordance with the Sewage Treatment Operators Manual for the Caribbean Region (USAID/UNEP/CEHI, 1996);

- Provide training to the EHD in the design, construction, operation, maintenance and management of on-site and communal sewage disposal systems;

- Provide training to the EHD in the design, construction, operation, maintenance and management of package treatment plants.

Reducing the potential impact of liquid waste on the marine environment warrants measures to be taken from two fronts;

- Reducing the quantity of liquid waste from point and non-point sources;

- Improving the quality of the waste reaching the marine environment from land-based sources.

In the case of Soufriere the combination of both measures are necessary to improve and sustain marine water quality to minimise the threat to the environment and public health. A comprehensive system for sewage and liquid waste management in Soufriere should consider a policy, plan and strategy for improvement that covers all sectors generating such waste together with and the socio-economic and political aspects of the community.

The results of the survey indicated that residents without adequate sanitary facilities were aware that their current methods of excreta disposal have the potential to impact negatively on public health and the environment. Most householders and businesses with septic tanks and soakaway systems were of the opinion that their systems were appropriate and the potential negative impact of their liquid waste was negligible even where large volumes of 'grey water' were discharged directly into the environment. At the level of the institution where septic tanks were used to treat the 'black water' and 'grey water' entered the public drain or natural watercourse without tertiary treatment this was deemed to be appropriate.

The residents and businesses surveyed felt that solid waste issues were the most critical in Soufriere. The greater awareness of the solid waste malaise existing and the relatively easier discernment of the problem compared to the more latent liquid waste pollution problem can be attributed for should a perception. This therefore suggests that more awareness raising and education building programmes for liquid waste management targeting all sectors of the community is necessary. This can be incorporate in the policy, plan and strategy for improving liquid waste management in Soufriere.

The following are recommended to reduce the potential impact of liquid waste on the marine environment:

'Grey Water' Management. The threats from the significant quantities of grey water entering the marine environment are great. Subjected to no form of treatment the 'grey water', loaded with inorganic nutrients is deposited in open drains and natural watercourses and ultimately reaches the sea. Some end of pipe sampling and analysis results shows nitrates as high as 70 mg/l and phosphates 40 mg/l. The ambient standard for the protection of coral reefs are 2.48 µg/l for phosphate and 9.8 µg/l for nitrate.

For household constructed with individual sewage treatment systems, it should be mandatory that all wastewater be subjected to primary and secondary treatment in a septic tank. Hence, the design and construction of septic tanks should take into consideration the necessity for a grease traps, increased associated wastewater flow rates and a tanks of suitable dimensions and capacity.

'Black Water' Management. The measures necessary for attaining compliance to the Public Health Regulations should be adhered to in the granting of approval for the construction and operation of a septic tank. The design of all individual sewage disposal system should be approved and the construction of all such systems should be monitored to ensure adherence to the approved design. This will allow for the efficient functioning of the system and obtaining the appropriate retention time necessary for the treatment process to be effective. This will allow at least secondary treatment of the sewage before final discharge to the environment.

Individual sewage disposal systems, consisting of mainly of septic tanks and soakaway pits, were the most common in Soufriere. These may constitute a direct point source of pollution when the system malfunction and overflows in cases of properties located close to the shoreline or water courses. Even when such systems function efficiently they may still pose a non-point source of pollution if the are located near to the shoreline or water courses since there is percolation of the effluent into the soil which can get into the watercourses and coastal waters. Overflowing system allows the pollutants to reach the marine environment during direct washout or via natural water courses. In this case the raw untreated or partially treated liquid waste is dumped into the sea.

Percolation into the soil by the effluent of the treatment systems allow for some measure of natural treatment, attenuation, absorption by plants, adhesion to soil particles, dilution and dispersion before entering the marine environment. In this case the less concentrated pollutant may have lower impact or reduced degrading effect due to lower potency. However, the continuous influx of this low concentration pollutant can have a more delayed impact which may be realised in the longer term.

Ensuring the pollutants reaching the marine environment has minimal negative impact and consequently of the highest quality, measures should be taken to obtain the maximum treatment possible. Due consideration should therefore be given to:

- Distance from and gradient to the nearest natural watercourse or the sea;

- The hydrogeology of the area containing the treatment and disposal systems;

- The level of treatment that can be requested or stipulated within the socio-economic and political climate;

- Ratifying and enforcing the requirement of the LBS Protocol to meet its international obligations for the protection of the marine environment from land-based sources of pollution;

- Declaration of the marine space of Soufriere up to the 200 meter bathymetric contour as Class I waters under the LBS Protocol and enforcing discharge standards for the effluent entering this receiving environment;

- Application of root zone treatment to attain tertiary level treated effluent migrating within the substratum by the use of appropriate vegetation to aid in the extraction of inorganic nutrients;

- Where soil is unsuitable to allow required percolation needed for the proper functioning of the absorption pit or where the water table is high, tertiary treatment of the effluent should be requested and enforced.

Appropriate disposal of sewage from the commercial, tourism and institutional Sectors is also needed for Soufriere. The commercial sector in Soufriere refers to businesses such as stores, restaurants, bars, and shops; the tourism sector refers to visitor reception and recreational facilities while the institutional sector refers to schools, places of worship and medical facilities. The Public Health Regulations governing liquid waste require that all such premises provide for sufficient, suitable and adequate sanitary facilities and sewage treatment and disposal systems. These places are of particular interest to any plan and strategy for the management of sewage and liquid waste since they concentrate people in confined areas and hence generate relatively larger volumes of sewage. Some of these sewage treatment systems have their biologically treated effluent entering natural water courses and all of their ‘grey water’ entering either the public drain or a natural watercourse.

With specific reference to the commercial, tourism and institutional sectors the following are recommended:

- Conduct an assessment of the sewage treatment and disposal facilities ;

- Identify areas for improvement and retrofitting to enhance the level of treatment required, including cost effective alternatives where necessary;

- Working with all these premises, develop a programme to enhance the quality of the liquid waste through a simple tertiary treatment system such as a sand or charcoal filter;

- Develop an operations manual for the sewage treatment and disposal systems and educate the operators in the use of the manual;

- Develop inspection forms for specified periods as deemed necessary and have them issued and checked by the EHD;

- Ensure that all 'grey water' from these premises are subjected to treatment prior to final disposal;

- Develop and implement a programme for voluntary improvements in the sewage treatment and disposal systems with emphasis placed on ensuring that the Government operated institutions adhere to the same guidelines;

- Heightened vigilance by the EHD and SDEU in monitoring the level of voluntary enhancement in sewage treatment and disposal and determine the necessity for the amendment of the Public Health Regulations to reflect what is required;

- Ensuring that enterprises such as the Fishing Complex and abattoir which generate large volumes of 'grey water' are fitted with simple means of tertiary liquid waste treatment systems to generate a highly polished effluent before final disposal.

Enhancing the socio-economic status of the less fortunate residents of Soufriere is a critical element for the reduction of pollution from liquid waste. Integrating the human element in the management and conservation of the coastal and marine resources was not adequately considered in the Management Plan of the SMMA or the Management Plan for the Pitons Management Area. This is a critical element to ensure that the financial gains from the non-extractive use of natural resources trickle to the grass-roots residents of the area either directly or through the multiplier effect. This will reduce the feeling of marginalisation among the residents by the agencies and investors, who market, sell and generate significant revenue from the natural resources that are of symbolic value to St. Lucia and to which they have a birth right.

- Improving the socio-economic status of the residents of Barons Drive so that they can improve their standard of living at the household level and manage their liquid waste on an individual basis in the long-term;

- In the short-term, refurbish the communal sanitary facility existing within Barons Drive and establish a management and operation system to prevent the abuse and vandalisation of the premises;

- Integrate the human element into the development and management plans for Soufriere and ensure that the improvements in the facilities provided for visitors and enhancement in the infrastructure to facilitate the ever increasing tourist arrivals are paralleled with the socio-economic advancement of the less fortunate residents;

- Promote alternate forms of livelihood to that of extraction of the natural resources among the less fortunate residents of Soufriere so that they can benefit from the royalties obtained from the marketing and promotion of Soufriere as a premier visitors' attraction;

- The custodians of natural resources of the area who are entrusted with the management should allocate a small percentage of the revenue generated to be pumped back into the community at the level of the household;

- Interagency collaboration between the Governmental and Non-Governmental Organisations and the residents themselves should be promoted for the development of a policy, plan and strategy for the advancement of the less fortunate residents of Soufriere.

1.0 Introduction

An inextricable link exists between the people of the Caribbean and the marine environment. The dependence on the sea for extractive and non-extractive resource uses such as food, transportation, recreation, livelihood, performing cultural rites and even final disposal is well known. The unsustainable use, abuse and exploitation of this wealth of marine resources is well documented and many efforts were made to retard, mitigate and reverse the myriad negative impacts on and degradation of the region's most important resource. Additionally, two of the Caribbean's major economic activities (tourism and fisheries) are heavily dependent on the marine environment, which is degrading at an alarming rate (UENP-CEP/RCU, 2005). In fact, the 1999 report of the World Travel and Tourism Council highlights that tourism accounts for 20.6% of the region's gross domestic product ($5,722.0 million US), 15.8% of employment and 25.7% of capital investment. The Council estimates that significant growth in the Caribbean's tourism and travel sectors will continue. Specifically, the GDP, employment and capital investment are projected to grow by 5.5, 1.9, and 5.3 percent respectively up to 2010.

Despite the dependence and projected increase reliance on marine resources for growth and development, further degradation is likely if unsustainable practices such as over-fishing, unplanned coastal developments, poor land use practices and pollution from inappropriate methods of waste disposal persist. This holds true for St. Lucia like the many other states of the region and though in the infancy stage and limitations of various kinds leave much to be desired, efforts are made through regional and national initiatives, to protect and conserve the marine environment.

Once such initiative for the protection of the marine environment in Soufriere is the sub-project for the Assessment of the Infrastructure for Liquid Waste Management in Soufriere. This project originated out of the need to address the liquid waste treatment and disposal issues in Soufriere which is critical for the maintenance of water quality and environmental sustainability as a whole. This project is funded by United States National Oceanographic and Atmospheric Administration (NOAA) and implemented by the Organisation of Eastern Caribbean States Environment and Sustainable Development Unit (OECS-ESDU) and the Soufriere Marine management Authority (SMMA).

1.1 Background

In St. Lucia, the town of Soufriere is the best example epitomising the link between the coastal and marine resources. The affinity for and dependence on the sea was the impetus for the first formal human settlement in this coastal village in 1746 (**Figure 1.1.1**). Furthermore, the passage of time and the modernisation of society have concretised this historical bond between the residents of the area and the marine environment.

Designated a World Heritage Site in 2005 by United Nations Environment Scientific and Cultural Organisation (UNESCO) the Pitons and the environmental sustainability of the town of Soufriere is critical to its success as a premier tourist destination and to sustain the visitor arrival. Management measures giving due consideration to the built and

natural environments and the development goals nationally and locally is the most important element for the long-term sustainability of Soufriere. The need to manage the marine and coastal resources and the ensuing user conflict for extractive and non-extractive uses was realised years ago and the Soufriere Marine Management Authority (SMMA) was established in 1995 as a response to this concern.

The impacts of land-based sources of pollution on the marine environment and resources therein are threatening the sustainability of the environment in Soufriere and the revenue generated from the use of these resources. Improper solid waste management practices including indiscriminate dumping in watercourses is evident in the sea and along the coastline as a result of washout after heavy rains. Additionally, the management of liquid waste poses a significant challenge in Soufriere due to socio-economic and geological factors. All liquid waste disposed whether directly in the sea, in a watercourse or by means of sub-surface absorption and percolation, ultimately influences the marine water quality. It is the potential for degradation of the vital coastal and marine resource that has triggered the SMMA and OECS-ESDU to seek funding from NOAA to commission the Wastewater Assessment Study for Soufriere.

Figure 1.1.1: Location of Soufriere

The liquid waste assessment assignment (proposal and TOR in **Appendix 1**) which includes a legislative, policy and literature review had the following deliverables:

- Assessment report on liquid waste management in Soufriere;
- Determination of the level of compliance for liquid waste disposal within the Soufriere watershed;
- Recommendations for compliance within the legal, administrative and regulatory framework;
- Recommendations for training in obtaining compliance;
- Recommendations to reduce the potential impact of liquid waste on the marine environment.
- Recommendations for possible amendment of the SMMA's monitoring activities (e.g. monthly GPS coordinates of green algae *Chaetomorpha aerea*).

1.2 Sewage Management in St. Lucia

The management of sewage in St. Lucia has been an issue and an area of much debate and concern for many years. The sewer system serving the town of Castries has been responsible for the pollution of the Castries Harbour from raw sewage. In villages along the coast, the influx of pollutants from natural watercourses or the direct discharge of excreta and sewage into the sea pervaded human settlement in these areas. Resource degradation due to inappropriate liquid waste management practices occurred and continued at an accelerated rate as population increased.

The commissioning of the Eastern Caribbean Dollars (XCD) 25 Million, Alliance Franciase De Developpment (AFD) funded Rodney Bay Sewage Treatment Plant in 1994 serving the northern districts of St. Lucia amounting to 1/3 of the population was a step in the right direction. The coastal and marine resources along the entire northwest coast of St. Lucia was under threat from developments as a result of expansion of residential areas and the infrastructure to support the growing tourism industry. This plant currently provided secondary level treatment to approximately 300,000 gallons of wastewater per day. The final discharge of the treated effluent is at the Trou Sallee River which traverses marshlands before final exist to the sea on the eastern seaboard where the oceanographic conditions and the assimilative capacity of the environment are adequate to minimise environmental impacts.

Many factors including financial, cost benefits, political will, topography and affluence of the communities are responsible for the absence of communal sewage treatment systems in the various communities. Hence, individual traditional methods of sewage treatment and disposal such as the pit privy and septic tank with soakaway pits continue to be the most common. Besides the fact that they provide minimum primary and secondary treatment, they continue to be a main source of direct or indirect pollution of the marine environment as a result of design and construction flaws.

1.3 Overview of the SMMA and Marine Resource use in Soufriere

In recent years, Soufriere has witnessed radical changes and infrastructural growth to adapt to the influx of increased tourist arrival in this picturesque west coast town. The coast also plays a central part in the life and economy of Soufriere, developments are located near the shore and the beaches are extensively used for recreation. Over the past two decades, tourism has grown significantly, with two large resorts, four smaller hotels, and a number of guesthouses and restaurants, many of them focusing on the diving and the yachting sectors. Additionally, there are approximately 150 registered fishers, from which two-thirds fish on a full-time basis using gears such as nets, lines and pots. Maritime transportation remains important and an increasing number of day charter boats and water taxis bring large volumes of visitors to the town.

According to SMMA (2006) in the late 1980s and early 1990s, the multiplicity of uses and growing demand for scarce and fragile resources generated critical impacts and conflicts.

The main environmental problems prior to the establishment of the SMMA can be summarized as follows:

- Degradation of coastal water quality, with direct implications for human health and for the protection of the reef ecosystem;
- Depletion of near-shore fisheries resources;
- Loss of the economic, scientific and recreational potential of coral reefs, particularly in the context of diving tourism;
- Degradation of landscapes and general environment quality, notably on or near beaches,
- Pollution generated by solid waste disposal in ravines or directly in the sea.

Problems of resource management in turn manifested themselves in growing conflicts among users of the resource, particularly the following:

- Conflicts between commercial dive operators and fishermen over the use of, and the perception of impact on, the coral reefs;
- Conflicts between yachts and fishermen because of anchoring in fishing areas;
- Conflicts between the local community and hoteliers over the access to beaches;
- Conflicts between fishermen and authorities at both the local and national levels over the location of a jetty in a fishing priority area;
- Conflicts between fishermen and hoteliers over the use of the beaches for commercial fishing or recreational, tourism oriented activities.

It is against this background that a conflict resolution process was initiated to attempt to address the many issues affecting users of marine and coastal resources in Soufriere. These issues were considered severe, because they resulted in a rapid degradation of the natural resource base, and because they affected resource users in several ways. Through the work of a number of agencies such as the St. Lucia National Trust, Department of Fisheries (DoF), Soufriere Regional Development Foundation (SRDF), Ministry of Agriculture (MOA), Ministry of Planning, Caribbean Natural Resources Institute

(CANARI) and St. Lucia Diving Association (Anbaglo) an agreement forming the Soufriere Marine Management Authority (SMMA) was reaslised. The agreement contained details of a proposed Zoning Agreement (and included maps showing the extent of proposed marine reserves, fishing priority areas, multiple use areas, recreational areas, and yacht mooring sites), legal provisions needed to manage individual activities such as fishing, diving, yachting, marine transportation, demarcation requirements, materials for user information, and training needs.

After a submission to the Ministers of Cabinet, the SMMA became a legal entity in 1995 and has been on a steady road of success as a world famous Marine Protected Area exemplifying the importance of applying co-management to natural resources.

Today the success of the SMMA is not only seen in the published literature containing the case study and the desire for other States to replicate the system of marine and coastal resource management employed in Soufriere but in the hard statistics. The revenue generated from the sale of dive permits (both daily and annual) doubled between 1998 and 2005 (**Figure 1.3.1**). Additionally, the revenue generated from snorkeling has increased 10 fold between 2001 and 2005 (from XCD 6,000 to XCD 77,000 respectively). **Figure 1.3.2** shows the number of yachts visiting for the years since the establishment of the SMMA and revenue generated for the corresponding periods.

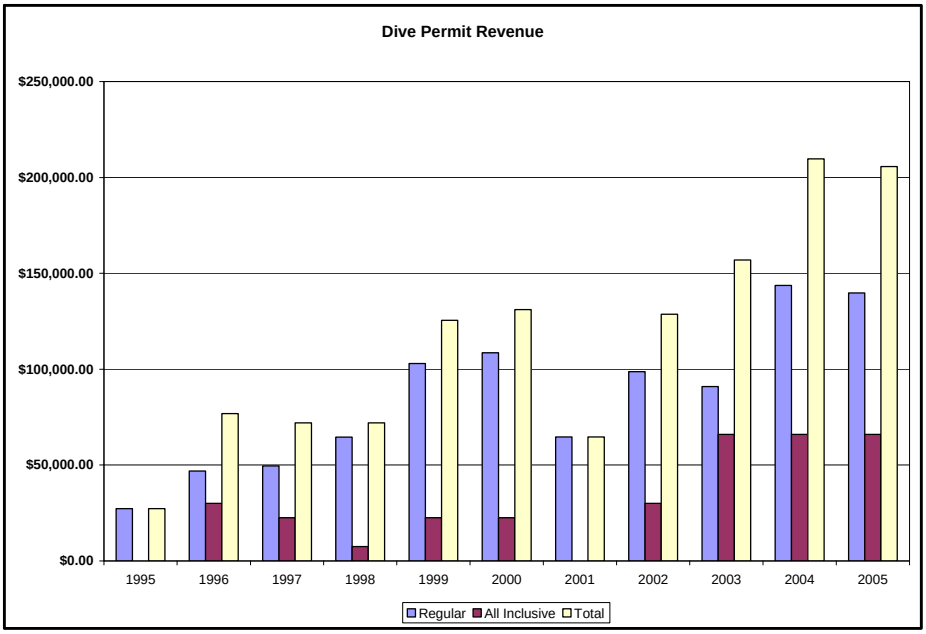

Figure 1.3.1: Revenue Generated From Recreational Diving in Soufriere

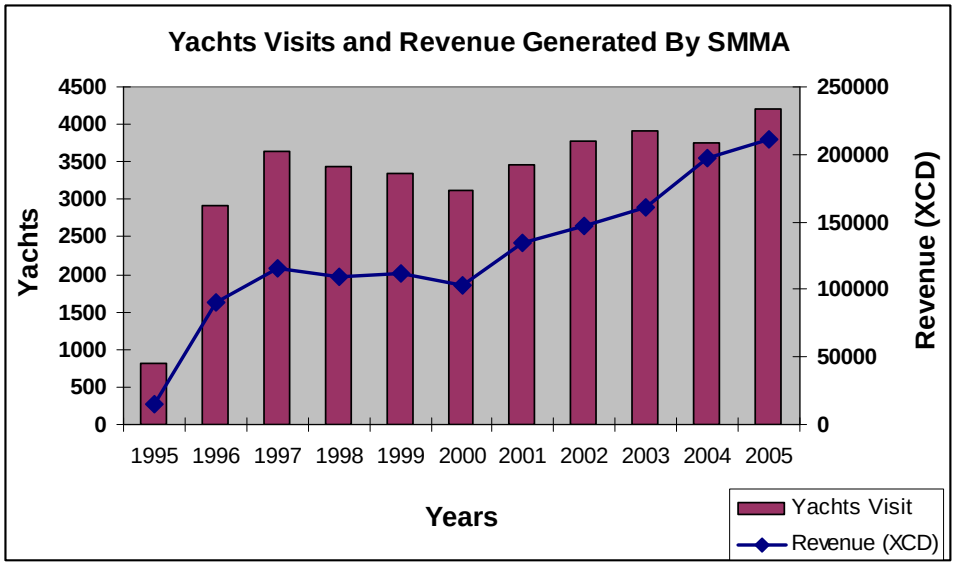

Figure 1.3.2: Revenue Generated by SMMA through Yachts Visits

It is evident that the struggles and the dedication of those who laboured on the efforts to have the SMMA established and functional were not futile. The fruits are discerned by the statistics and the many elements that are not yet measured. The establishment of the marine reserves and the behavioural ecology of the reef fish mean that the fishermen began to realise that an increase in catch per unit effort in adjacent areas had increased. The generation of income from alternative non-extractive livelihoods all in the name of sustainable development is key to the conservation of natural resources.

The SMMA has contributed immensely to the conservation of the resources along the original 12 miles coastal realm over which its mandate covers. Presently there are efforts to add the coastal areas of Canaries (Canaries Marine Management Area, CAMMA) to the area managed by the SMMA so that the successes of the Soufriere story can be replicated there. The designation of the area as one of UNESCO's World Heritage Sites in 2005 and the soon to be implemented Piton Management Area (PMA) will all provide impetus to continue the conservation efforts along the west coast and entire island of St. Lucia. However, this will not be realised if the marine and coastal resources continue to be stressed and degraded by land-based activities and poor watershed management. Waste management particularly solid and sewage are important aspects to be given priority especially in small rural coastal villages. The thrust see by the Government of St. Lucia (GoSL) towards the Cartagena Convention and Protocols in particular the Land-Based Sources of Marine Pollution (LBS) is a step in the right direction exemplifying commitment to protect the marine and coastal resources. Hence, the study on liquid waste management in Soufriere commissioned by the SMMA, OECS-ESDU and NOAA is vital to understanding measures necessary to ensure the long-term sustainability of the existing resources.

1.4 Soufriere Regional Development Foundation

According to the Management Plan for the Piton Management Area (De Beauville-Scott, George, 2003), this non-profit agency is responsible for fostering economic, cultural and social development in a manner that is responsive to the needs and aspirations of the Soufriere community, while preserving and enhancing the natural and cultural assets upon which that development is based. The Foundation provided a coordinating framework for programmes concerning the development of Soufriere and facilitates cooperation between government, private sector, NGOs and community organisations. The foundation is integrally involved in the formulation and implementation of development plans for Soufriere and the establishment of public infrastructure. It seeks to maximise community benefits by facilitating appropriate forms of tourism that are culturally and environmentally sensitive. The agency also engages in community education and capacity building within community groups and organisations.

2.0 International and Regional Agreements and Frameworks

A major component of Wastewater Assessment Study for Soufriere is a thorough literature review of the legislative and policy framework for liquid waste management. This is inclusive of all pertinent Multi Lateral Environmental Agreements (MEAs) at the regional and international levels and laws and policies at the national and local levels.

2.1 International Agreements

St. Lucia is party to a number of international agreements (soft laws) aimed at the protection and conservation of the marine and coastal resources. This include *inter alia*:

- Cartegena Convention and Protocols in particular the LBS Protocol;
- United Nations Convention on Law of the Sea (UNCLOS);
- Convention for the Control of Marine Pollution from Ships (MARPOL);
- Convention on Transboundary Movement of Hazardous Waste (BASAL);
- The Convention on Biological Diversity;
- Convention on Trade in Endemic Species;
- International Convention on Whaling;
- Convention Concerning Protection of World Cultural and Natural Heritage.

A succinct overview of the relevant MEAs are contained below.

2.1.1 The Cartagena Convention, 1983 (The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region)

This Convention discusses issues such as pollution from ships, dumping, land-based sources of pollution, sea-bed activities, airborne pollution, specifically protected areas, cooperation between nations in case of emergencies, and environmental impact assessments.

The Convention is supplemented by three Protocols which addressed specific issues relevant to the marine environment of the Wider Caribbean Region (WCR). These are:

- The LBS Protocol;
- The SPAW Protocol;
- Protocol Concerning Co-operation in Combating Oil Spills in the Wider Caribbean Region.

The LBS Protocol which is the ancillary instrument for attaining the aims of this Convention that pertains to pollution from Land-Based Sources is very relevant to the Soufriere area and rich marine and coastal resources existing there.

2.1.2 Protocol Concerning Pollution from Land-Based Sources and Activities

The LBS protocol was adopted on October 6, 1999 in Aruba and contains 29 articles covering aspects such as General Obligations, Monitoring and Assessment Programmes, Environmental Impact Assessment, Transbounday Pollution, Institutional Mechanism and Ratification. The protocol also contains 4 Annexes which serves as appendages to this tool for the management of LBS of pollution. The LBS Protocol forms the basis for the trust towards the management of liquid waste in the watershed of Soufriere

A synopsis of some of the components of the protocol is provided below.

Annex 1 (A) Source Categories, Activities and Associated Pollutants of Concern

This Annex laid the definition for the purpose of subsequent Annexes:

1. "Point Sources" means sources where the discharge and releases are introduced into the environment from any discernible, confined and discrete conveyance, including but not limited to pipes, channels, ditches, tunnels, conduits or wells from which pollutants are or may be discharged.

2. "Non-Point Sources" means sources, other than point sources, from which substances enter the environment as a result of land run-off, precipitation, atmospheric deposition, drainage, seepage or by hydrologic modification.

Annex 1 (B) Priority Source, Categories and Activities Affecting the Convention Area

The contracting parties shall take into account the following priority source categories and activities when formulating regional and as appropriate, sub-regional plans, programmes and measures for the prevention, reduction and control of pollution of the convention area:

- Domestic Sewage;
- Agricultural Non-Point Sources;
- Chemical Industries;
- Extractive Industries and Mining;
- Manufacture of Liquor and Soft Drinks;
- Oil Refineries;
- Pulp and Paper Factories;
- Sugar Factories and Distilleries;
- Intensive Animal Rearing Operations.

Annex II Factors to be used in determining Effluent and Emission Source Controls and Management Factors

A. When developing regional and sub-regional source specific effluent and emission limitations and management practices contracting parties shall evaluated and consider the following:

1. Characteristics and composition of the waste

- Type and form of the waste;
- Physical state of the waste;
- Quantity and discharge frequency;
- Partial concentration of the constituents;
- Interaction with the receiving environments.

2. Characteristics of the Activity and Source Category

- Performance of the existing technologies and management practices, including indigenous technologies and management practices;
- Age of the facilities;
- Existing economic, social and cultural characteristics.

3. Alternative Production, Waste Treatment Technologies or Management Practices

- Recycling, recovery and reuse opportunities;
- Less hazardous or non-hazardous raw material substitution;
- Economic, social and cultural impacts of alternatives, activities or products;
- Substitution of cleaner alternatives, activities or products;
- Low-waste or totally clean technologies or processes;
- Alternative disposal activities.

Annex III Domestic Wastewater

This Annex is particularly relevant to the Contracting Parties to the Cartagena Convention in the WCR and by extension St. Lucia. The definition contained therein are worthy of noting for the Soufriere Wastewater Assessment Project.

1. Domestic wastewater means all discharges from households, commercial facilities, hotels, septage and any other entity whose discharge includes the following:

- Toilet flushing (black water);
- Discharges from showers, wash basins, kitchens and laundries (grey water);
- Discharges from small industries, provided their composition and quantity are compatible with treatment in a domestic wastewater system.

2. Class I waters means waters in the Convention Area that, due to inherent or unique environmental characteristics or fragile biological or ecological characteristics or human use, are particularly sensitive to the impacts of domestic wastewater. Class I water include but are not limited to:

    - Waters containing coral reefs, seagrass beds or mangroves;
    - Critical breeding, nursery or foraging areas for aquatic and terrestrial life;
    - Areas that provide habitat for species protected under the SPAW Protocol;
    - Protected areas listed in the SPAW Protocol;
    - Waters used for recreation.

3. Class II Waters means waters in the convention area, other than Class I waters, that due to oceanographic, hydrologic, climatic or other factors are less sensitive to the impacts of domestic wastewater and where human or living resources that are likely to be adversely affected by the discharges or are not exposed to such discharges.

B. Discharge of Domestic Wastewater

Each Contracting Party shall:

a. Provide for the regulation of wastewater discharging into, or adversely affecting the Convention Area;

b. To the extent practicable, locate, design and construct domestic wastewater treatment facilities and outfalls such that any adverse effects on, or discharges into, Class I Waters, are minimised;

c. Encourage and promote the reuse of domestic wastewater to minimise the quantity of effluent discharged;

d. Promote the use of cleaner technologies to reduce the discharges to a minimum, or to avoid adverse effects;

e. Develop plans to implement the obligations of the Annex including obtaining financial assistance.

C. Effluent Limitations

1. Discharge into Class II Waters

Each contracting party shall ensure that domestic wastewater that discharge into or adversely affects Class II waters is treated by a new or existing domestic wastewater system whose effluent achieves the following effluent limitations based on a monthly average:

Parameter	Effluent Limit
Total Suspended Solids	150 mg/L*
Biochemical Oxygen Demand (BOD_5)	150 mg/L
pH	5 – 10 pH units
Fats, Oil and Grease	50 mg/L
Floatables	Not visible
* Does not include algae from treatment ponds	

2. Discharge into Class I Waters

Each Contracting Party shall ensure that domestic wastewater that discharges into or adversely affects, Class I waters is treated by a new or existing domestic wastewater system whose effluent achieves the following effluent limitations based on a monthly average:

Parameter	Effluent Limit
Total Suspended Solids	39 mg/L*
Biochemical Oxygen Demand (BOD_5)	30 mg/L
pH	5 – 10 pH units
Fats, Oil and Grease	15 mg/L
Floatables	Not visible
Faecal Coliforms (Parties may meet effluent limitations either for faecal coliform or for E. coli (freshwater) and enterococci (saline water)	Faecal Coliform: 200 mpn/100 ml; or a. E. coli:126 organisms/100 ml b. enterococci: 35 organisms/100ml
* Does not include algae from treatment ponds	

3. Discharges

a. Each contracting party shall take into account the impact that total nitrogen and phosphorus and their compounds may have on the degradation of the convention area and to the extent practicable, take appropriate measures to control or reduce the amount of total nitrogen and phosphorus that is discharged into or may adversely affect the Convention Area.

b. Each party shall ensure that residual chlorine from domestic wastewater treatment systems is not discharged in concentrations or amounts that would be toxic to marine organisms that reside in or migrate to the Convention Area.

E. Households Systems

Each Contracting Party, shall strive to, as expeditiously, economically and technologically feasible, in areas without sewage collection, ensure that household

systems are constructed, operated and maintained to avoid contamination of surface or groundwater that are likely to adversely affect the convention area.

For household systems requiring septage pumpout, each Contracting Party shall strive to ensure that the septage is treated through a domestic wastewater system or appropriate land application.

This Annex is particularly relevant to Soufriere since the wastewater categorised as domestic is the main threat to the marine and coastal resources therein. The profile ranges from direct discharge of night soil into the coastal waters by less fortunate householders in the town areas, pit latrines, septic tanks and package plants for major hotels in the area. The Soufriere and Etang Rivers and the other intermittent water courses that discharge into the Soufriere Bay are also conveyers of domestic liquid waste to the marine environment.

ANNEX IV Agricultural Non-Point Source of Pollution

This annex call for the Contracting Parties to develop programmes, policies, plans and legal mechanisms for the mitigation of pollution from agricultural non-point sources. These include in particular: nutrients (nitrogen and phosphorus), pesticides, sediments, pathogens, solid waste etc.

Plans shall include *inter alia* the following elements:

1. An evaluation and assessment of agricultural non-point sources of pollution that may adversely affect the Convention area, which may include:

    a. estimation of loading;
    b. identification of associated environmental impacts and potential risk to human health;
    c. evaluation of the existing administrative framework to manage agricultural non-point source of pollution;
    d. evaluation of existing best management practices and their effectiveness;
    e. establishment of monitoring programmes.

2. Education training and awareness programmes.

3. The development and promotion of economic and non-economic incentive programmes to increase the use of best management practices to prevent, reduce and control pollution from agricultural non-point sources.

    An assessment and evaluation of legislative and policy measures, including a review of the adequacy of plans, policies and legal mechanisms directed towards the management of agricultural non-point sources and the development of a plan to implement such modifications as may be necessary to achieve best management practices.

2.1.3 SPAW Protocol

The Protocol Concerning Specially Protected Areas and Wildlife (SPAW Protocol) has been internationally recognized as the most comprehensive treaty of its kind. Adopted in Kingston, Jamaica by the member governments of Caribbean Environment Programme (CEP) on 18 January 1990, the SPAW Protocol preceded other international environmental agreements in utilizing an ecosystem approach to conservation. The Protocol acts as a vehicle to assist with regional implementation of the broader and more demanding global Convention on Biological Diversity (CBD). This Protcol is very relevant to the Assessment of the Infrastructure for Improved Wastewater Management in Soufriere, providing a basis and framework for the protection of the marine resources.

The objective of the Protocol is to protect rare and fragile ecosystems and habitats, thereby protecting the endangered and threatened species residing therein. The UNEP-CEP Caribbean Regional Co-ordinating Unit (RCU) pursues this objective by assisting with the establishment and proper management of protected areas, by promoting sustainable management (and use) of species to prevent their endangerment and by providing assistance to the governments of the region in conserving their coastal ecosystems.

The objectives of the SPAW Programme are:

- To significantly increase the number of and improve the management of national protected areas and species in the region, including the development of biosphere reserves, where appropriate.

- To develop a strong regional capability for the co-ordination of information exchange, training and technical assistance in support of national biodiversity conservation efforts.

- To develop specific regional, as well as national management plans developed for endangered, threatened or vulnerable species such as sea turtles, the West Indian manatee, black coral and migratory birds.

- To co-ordinate the development and implementation of the Regional Programme for Specially Protected Areas and Wildlife in the Wider Caribbean, in keeping with the mandate of the SPAW Protocol.

- To coordinate activities with the Secretariat of the Convention on Biological Diversity, as well as other biodiversity-related treaties, such as the Convention of International Trade in Endemic Species (CITES), Ramsar, Bonn and Western Hemisphere Conventions.

2.1.4 Protocol Concerning Co-operation in Combating Oil Spills in the Wider Caribbean Region

This Protocol emanated from the eminent threat that oil transport and refining activities may have on the coastal and marine resources of the Caribbean. This issue is real along the west coast of St. Lucia where a major oil refining operation and other oil storage facilities are located.

The main reasons for the evolution of the Protocol were as a result of:

- Consciousness that oil exploration, production and refining activities, as well as related marine transport, pose a threat of significant oil spills in the wider Caribbean region;
- Awareness that the islands of the region are particularly vulnerable, owing to the fragility of their ecosystems and the economic reliance of certain of them on the continuous utilization of their coastal areas, to damage resulting from significant oil pollution;
- Recognizing that, in the event of an oil spill or the threat thereof, prompt and effective action should be taken initially at the national level, to organize and co-ordinate prevention, mitigation and clean-up activities;
- Recognizing further the importance of sound preparation, co-operation and mutual assistance in responding effectively to oil spills or the threat thereof;
- Determined to avert, through the adoption of measures to prevent and combat pollution resulting from oil spills, damage to the marine environment, including coastal areas, of the Wider Caribbean Region.

The protocol contains 11 Articles which covers *inter alia*:

- General Provisions;
- Information exchange;
- Communication of information concerning and reporting gof iol spill incident;
- Mutual assistance;
- Operation measures;
- Sub-regional agreement;
- Institutional agreement.

2.1.5 MARPOL 73/78 - International Convention for the Prevention of Pollution from Ships

MARPOL is comprised of six Annexes, of which St. Lucia is a signatory to the first five. Annex I regulates oil and oil tankers; Annex II regulates noxious liquid substances; Annex III regulates harmful substances in package form; Annex IV regulate sewage; Annex V regulates garbage on ships; and Annex VI regulates air pollution from ships in the form of nitrogen oxide and sulfur oxide emissions. Each Annex includes several marine locations classified as special areas where heightened marine protection laws apply, including the Antarctic, the Mediterranean Sea, the Baltic Sea, and others.

Annexes I, II, and IV all have revisions in effect from as recently as 2004. The MARPOL agreement also outlines international enforcement measures.

Adherence to the MARPOL Convention does not only speak to international responsibility, but also to sustainability as it ensures that marine resources that forms the basis on which the residents of Soufriere survives are preserved and will continue in the future to be attractive and allow for the continued derivation of a livelihood for all user groups.

2.1.6 Montreal Protocol – Substances that Deplete the Ozone Layer

This protocol addresses the production and consumption of calculated levels of substances categorized as ozone depleting substances including Chlorofluorocarbons (CFCs); Halogens; Halogenated CFCs; Carbon Tetrachloride; 1,1,1-Trichloroethane (Methyl chloroform); Hydrochlorofluorocarbons; Hydrobromofluorocarbons; Methyl bromide; Bromochloromethane and their isomers. Under the Protocol, the levels of sub-groups of these substances either in their pure state or as constituents of other products produced and consumed must be reduced annually. These controlled substances are common constituents of automobile and truck air conditioning units, domestic and commercial refrigeration and air conditioning /heat pump equipment e.g. (refrigerators, freezers, dehumidifiers, water coolers, ice machines, air conditioning and heat pump units), aerosol products (except medical aerosols), insulation boards, panels and pipe covers, and Pre-polymers.

2.1.7 United Nations Convention on Law of the Sea (UNCLOS, 1982)

This convention entered into force in 1994 was the main environmental event since Rio Conference (1990). UNCLOS is the only global agreement that provides comprehensive coverage of all aspects of the various uses, abuses and resource management of the world's oceans. It attempts to balance environmental protection and resource management with free navigation. It provides a rational global framework for the exploitation and conservation of marine resources and the protection of the environment, which can be seen as a system for sustainable development and as a model for the evolution of international environmental law.

It is therefore certainly a Convention which will have great impact on all human activities in the maritime sphere, both for the foreseeable future and in global terms. It was the first major undertaking among states to protect the world's oceans in their entirety against all potentially polluting maritime activities. This convention ensures that the protection of the marine and coastal resources is now a matter of comprehensive legal obligation affecting the marine environment as a whole. Moreover, the marine environment for this

purpose includes rare and fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life (Sunkin et al, 1998).

2.1.8 Basal Convention (1989)

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in Basel (Switzerland) in March 1989 and entered into force in May 1992. This convention is relevant to the protection of the marine environment from hazardous waste and is therefore relevant to the Assessment of the Infrastructure for Improved Wastewater Management in Soufriere.

Some of the aims of the Convention are:

- To reduce transboundary movements of hazardous wastes and other wastes, subject to the Basel Convention, to a minimum consistent with their environmentally sound management.
- To dispose of the hazardous wastes and other wastes generated, as close as possible to their source of generation.
- To minimise generation of hazardous wastes in terms of quantity and hazardousness.
- To ensure strict control over movements of hazardous wastes across borders.
- To assist developing countries and countries with economies in transition in the environmentally sound management of the hazardous and other wastes that they generate.

2.1.9 Convention on Biological Diversity (1992)

At the 1992 Earth Summit in Rio de Janeiro, world leaders agreed on a comprehensive strategy for "sustainable development" -- meeting our needs while ensuring that we leave a healthy and viable world for future generations. One of the key agreements adopted at Rio was the Convention on Biological Diversity. This pact among the vast majority of the world's governments sets out commitments for maintaining the world's ecological underpinnings as we go about the business of economic development. The Convention establishes three main goals: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources.

St. Lucia ratified the CDB in 1993 and this provided the basis for national programmes and projects for biodiversity conservation. The Biodiversity Country Study Report (1998) and the Biodiversity Strategy and Action Plan (2000) were conducted as part of the administration of the convention at the national level.

2.1.10 Convention Concerning Protection of the World Cultural and Natural Heritage

The World Heritage Convention (WHC) was ratified by St. Lucia on October 14, 1991 and the St. Lucia World Heritage Committee was established in 1996 to administer this Convention nationally. This Committee through the process of planning and consultation is responsible for the designation of the Pitons and surrounding as a World Heritage Site. This magnified the Pitons and Soufriere as symbolic of St. Lucia and the influx for visitors to the area as a result of attraction to the natural resources increased.

2.2 Regional Agreements

2.2.1 St. Georges Declaration

In April 2000, The St. George's Declaration (SGD) of Principles for Environmental Sustainability in the Organisation of Eastern Caribbean States (OECS) was formulated to guide the environmental process for Member States. The participating islands persuaded that the effective management of environmental resources at local, national and international levels is an essential component of sustainable social and economic development, including the creation of jobs, a stable society, a buoyant economy and the sustaining of viable natural systems on which all life depends. Hence, the OECS Member States adopted the SGD and the commitments contained herein, which proclaim the principles of sustainable development by which human conduct affecting the environment is to be guided and judged.

The 21 principles contained therein covers aspects such as fostering sustainable improvement in the quality of life, biodiversity conservation and integrating socio-economic and environmental considerations into national development plans and programmes. In this regard, the the Assessment of the Infrastructure for Improved Wastewater Management in Soufriere has to be guided by the principles of this sub-regional agreement and declaration.

2.2.2 OECS Model Physical Planning Bill

In 1994 the OECS Model Physical Planning Bill was prepared to address the need for development of appropriate planning and land use legislation, which will serve to offer some measure of protection to the environment in Member States. This Act endeavours to incorporate EIAs as an integral part of planning (MAFF, 1998) and is used to guide Member States.

Since there is ever increasing population influx into the coastal zone and land-based activities of SIDS impact the marine environment, this Model Bill is important to guide the development practices of States and certainly Soufriere and St. Lucia are no exception.

3.0 National Policy and Legislative Framework

A number of national laws and policies are relevant to the Soufriere Liquid Waste Assessment Project, however, these laws are scattered among the various agencies with responsibility for environmental management in some way or the other.

3.1 Agricultural Small Tenancies Act (1983)

This Act outlines basic regulations for tenancies on small agricultural holdings. It can be important for the promotion of Best Management Practices to reduce the impact of agricultural non-point sources of pollution on the marine environment. Coastal agriculture is practiced in the upland watershed of Soufriere and adjacent areas. The Act includes a description of the responsibilities of the landlord and tenant, including responsibilities for good husbandry. Other issues, such as land boundaries and tree-felling, or plant growing (sections 30 and 31, respectively), are also covered. This is particularly important for Soufriere with respect to the issue of sedimentation and smouldering of reefs. Section 32 states that the Minister of Agriculture has the right to make any regulations he/she sees fit to ensure that good husbandry policies are followed, including the right to terminate contracts in cases where it has been determined that policies are not being adhered to.

3.2 Beach Protection Act (1967)

This Act provides regulations for the protection, control, and preservation of St. Lucian beaches and coastlines. This act prohibits the removal or possession of sand, stone, gravel, and other materials from beaches, seashores, or the seafloor for any purpose without a permit from the Director of Public Works. The Beach Protection Amendment of 1984 increases the penalties for committing an offence and includes more detail to some of the original legislation.

The beaches on the southwest coast of St. Lucia are very important for the protection of the coastline since the area is low lying. The aesthetic and amenity value cannot be overstated and the inherent potential for their use and development as a tourism product is obvious.

3.3 Coastal Zone Management Project and Policy

In 2001, the Government of St. Lucia embarked on an initiative aimed at establishing institutional arrangements to facilitate the sustainable development and management of the coastal resources. As part of the initiative, a Coastal Zone Management Project (CZMP) was established under the Ministry of Agriculture Forestry and Fisheries (MAFF) with the task of preparing coastal zone management related policy and guidelines (Scott, 2004).

According to Scott (2004) some issues in CZM in St. Lucia include:

Natural Resources

- Biodiversity;
- Water resources;
- Forestry and landscape;
- Air quality;
- Sea level rise;

Productive Sectors

- Industry;
- Fishing;
- Tourism;
- Agriculture;
- Aquaculture;
- Mining;

Physical Development

- Built environment;
- Ports and marinas;
- Pollution control and waste management;

Management systems

- Environmental standards
- Protected areas;
- Data collection and management;
- Public awareness and education;
- Environmental law;
- Special area management planning

The CZMP evolved as a product of the Coastal Conservation Study (Atria, 1995) and sought to develop a Coastal Zone Management Policy for St. Lucia. The objectives of the island's Coastal Zone Management policy are to maintain the integrity and productivity of the coastal zone to social and economic development through the sustainable use of resources and the equitable sharing of benefits; and harmonised use of the coastal zone and provide a framework for the management and resolution of resource use conflicts.

The CZM policy is guided by a number of strategies including:

- Equity;
- Stewardship;

- Collaboration and participation;
- Multiple use;
- Enforcement;
- Capacity-building;
- Coordination and integration;
- Public awareness.

Soufriere constitutes an important part of the coastal realm of St. Lucia and integrated management of the coastal resources contained therein is necessary. It is therefore, timely and appropriate that the Soufriere Sewage Assessment Project is executed and will serve to guide the LBS Protocol ratification process by GoSl. Although limited in scope and the fact that the appropriate management of liquid waste in Soufriere is in the infancy stage, issues related to pollution from sewage disposal can be discerned and efforts can be made to address them.

3.4 Crown Lands Ordinance (1946)

This Ordinance provides for an appointment of a Commissioner of Lands who functions as Protector of Crown Lands and has responsibility for serving notice to occupiers who have encroached on said Lands. The Ordinance also allows the state to set rules and regulations for the sale, occupation and allotment or Crown Lands. This will have relevance to the transfer and development of Crown Lands on the coastline.

3.5 Fisheries Act (1984) and Fisheries Regulations (1994)

The Fisheries Act provides regulations on fishing activities within St. Lucian territory. It defines what waters are permitted for fishing purposes, and what different vessels are allowed to fish in which areas with a relevant permit. The Fisheries Minister may declare any area of the fishery waters to be a fishing priority area; likewise, the Minister may declare any marine area (including adjacent land) to be a marine reserve for the purposes of protecting and preserve the nearby land and wildlife. Fishing, removing any animal or natural matter, or harming the environment in any way in a protected reserve constitutes a punishable offence. Other offences and penalties are described throughout the Act. The Minister may also regulate sport fishing, scuba and snorkelling activities, turtle, lobster, and conch protection, fishing safety standards, and other fishery-related matters. Sections of particular interest include sections 8, 20, 21, 22, 24, 39. Part VII of the Fisheries Regulations also dictates a number of Fishery Conservation Measures for the management of marine and coastal resources.

3.6 Forest, Soil, and Water Ordinance (1946)

This ordinance aims to regulate the national forestry and timber industry while providing adequate protection for the forests. This legislation defines and allows for the creation of protected forests and areas, which can be any non-Crown land that the Minister for

Forest, Soil, and Water Conservation declares as such in order to protect against erosion, forest depletion, water and timber depletion, as well as other problems. The boundaries of protected forests and areas must be clearly defined, marked, and maintained. Once an area has been designated as protected, no lands shall be granted, devised, or sold within that area. Sections of interest include sections 6, 7, 18, 19, 20, 21, 22, 32, and 47 (amendment).

3.7 Housing and Urban Development Corporation Act (1971)

The Housing and Urban Development Corporation Act provides legislation creating the Urban Development Corporation. The Corporation may carry out and secure the laying out and development of any designated area. This act also gives the Minister power to develop any land via the Corporation as an urban area if he finds it in the national interest to do so. This act also requires the Corporation to give all local authorities of the relevant areas the necessary details pertaining to the development and construction plans. This act also provides other powers and restrictions of the Corporation, including the power to pave, improve, or modify any roads in deems necessary for an area involved in development plans. This Act is relevant to the development of the coastal zone and is of importance to CZM in St. Lucia. Sections of interest include sections 18, 26, 27, 30, and 32.

3.8 Local Authorities Ordinance (1968)

Section 15 of this Ordinance provides for the establishment of local town and village authorities with the power to develop legislation for the management and control of public cultural institutions and places of public recreation. Lands may be purchased, leased, or acquired otherwise by the Local Authority for the purpose of public utility, particularly as regards waterworks, markets, parks and places of recreation, streets and roads. This has implications for the use of the natural resources within the coastal zone and the public access to these resources.

3.9 Maritime Areas Act (1984)

This Act empowers the Minister of Foreign Affairs with authority over marine scientific research, and the protection and preservation of the marine environment and territorial sea. This Act is relevant to the use and the exploitation of resources within the territorial waters and the Exclusive Economic Zone (EEZ) and will affect the outcome of all activities destined for the coastal zone.

3.10 National Conservation Authority Act (No. 16 of 1999)

This act establishes the National Conservation Authority, whose functions include conserving, protecting, and controlling the development, maintenance of, and access to public areas and beaches. Part III, Section 7 fully details the responsibilities of the Authority. The NCA Act details licensing procedures, offences, and penalties related to actions taken by the Authority and with the approval of the governing Minister. Part VI

details the prohibitions on selling and littering at protected areas. This Act is of importance to the coastal zone since there is a close link between residents and the use of marine and coastal resources. Access to these resources, enhancement and maintenance of use of these coastal resources are elements covered by this Act.

3.11 National Biodiversity Strategy and Action Plan for St. Lucia

St. Lucia was one of the first signatories to the Convention on Biological Diversity (CBD) at the June 1992 "Earth Summit" in Rio de Janeiro. This was ratified in July 1993. Under the Convention, signatories agree to develop national action plans and strategies for biological conservation and sustainable management of biological resources.

St. Lucia has gone forward with this step and has produced such a document with the following objectives:

- Conservation of the country's diversity of ecosystems, species and genetic resources;
- Promotion of the sustainable use of these resources to support human life;
- Encouragement of the equitable distribution of the benefits derived from the use of biodiversity;
- Facilitation of the participation of people and institutions in the management of biodiversity.

Towards these broad objectives, a strategy and action plan has been developed with more specific objectives:

- Provision of a mandate and a set of policy directions to management authorities, developers and policy-makers;
- Provision of a reference point for stakeholder, governmental, NGO, CBO groups etc. towards the development of programmes and actions related to biodiversity;
- Assisting with the build-up of support for the implementation of projects related to biodiversity.

3.12 Plant Protection Act (1988)

This Act regulates the importation, exportation, and removal of plants and plant material in St. Lucia. The control of plant pests is also described, together with some enforcement measures to ensure compliance with the Act. The Act also establishes a Plant Protection Board that is appointed by the Minister of Agriculture and states the responsibilities and powers of the Board and the Minister in regard to plant protection. This legislation complements some of the provisions of the National Biodiversity Strategy and Action Plan, as it relates to plants. It is relevant to the protection of the natural flora and fauna and the coastal vegetation especially in cases where negative impacts can occur due to the importation of exotic species.

3.13 Pesticides and Toxic Chemicals Control Act (2001)

This Act aims to regulate the use of pesticides through the creation of the Pesticides and Toxic Chemicals Control Board. The Board and Pesticide Control Inspectors are given the authority to enforce the policies controlling the import, manufacture, use, distribution, and disposal of pesticides. This Act also provides regulations for employers, employees, and others using pesticides in order to protect the environment and human health and safety.

Pesticides and their use, storage, transport and overall management are a particular cause for concern. They are directly and indirectly referred to in other pieces of legislation particularly the Employees (Occupational Health and Safety) Act of 1985. Land-Based Sources of Marine Pollution Protocol also addresses agricultural non-point source of marine pollution. They are of particular interest to the management of pollution of the coastal zone since agricultural non-point source of pollution is a major contributor to the degradation of the marine environment.

3.14 Public Health Act (1975)

This Act outlines the rights and powers of the Minister of Health in order to promote the public health and well-being of St. Lucians. According to Section 9, The Minister of Health can make regulations regarding:

- The prevention, treatment, limitation, and suppression of diseases;
- The prevention of overcrowding of premises;
- The maintenance of proper sanitary condition of premises and the prevention, abatement, or removal of unsanitary conditions;
- The institution of measures for ensuring the purity of the water supply;
- Sewers and sewage disposal works, as well as the collection, removal, and sanitary disposal of rubbish, night soil, and other offensive matter;
- The licensing of the relevant business; insect, vermin, and rodent control and elimination;
- The control of food and drugs sales, quality, and composition;
- The inspection of hotels, boarding houses, and other places of accommodation;
- The inspection and sanitary conditions of beaches and swimming pools in the interest of public health.

3.15 Public Health (Sewage and Disposal of Sewage and Liquid Industrial Waste Works) Regulations, 1978)

This Act specifically aims to regulate and decrease pollution through liquid waste and sewage in order to protect human health and safety. No sewer fluid or liquid industrial waste may be discharged into any watercourse, river, stream, coastline or any other place without the Public Health Board's permission. The Act provides specific regulations defining the permissible waste disposal systems and mechanisms and controls the construct of sewage systems. The department of Environmental Health also has

responsibility for the construction and approval of individual household sewage treatment and disposal systems. The Regulations stipulate that the operation and maintenance of these systems should not be at a risk to Public Health and the environment. The satisfactory maintenance of these systems is the requisite enforcement is the responsibility of the Environmental Health Department.

3.16 St. Lucia National Trust Act (1975)

This Act allows for the setting up of a statutory body whose role is to promote, conserve, and manage areas specially designated as tourist attractions and heritage sites so as to preserve their flora and fauna. The Trust may enact bye-laws for the regulation of activities within these sites. Issues related to archaeology are managed through the St. Lucia Archaeological and Historical Society. This Act ensures that areas of coastline of high biodiversity value are protected and conserved.

3.17 Tourism Industry Development Act (1982)

This Act provides for the establishment of a St. Lucia Tourist Board which is empowered with the authority to promote and develop tourism inclusive of coastal amenities. Since coastal and marine resources are the main products and attractions marketed for visitors, tourism development along the coastline is inevitable. A number of tourism projects are destined for the coastal zone throughout St. Lucia and proposals for developments along the seascape of Soufriere will emanate. It is therefore important that the tourism initiatives consider the sustainability of development in that sector.

3.18 Waste Management Act (2004)

This Act repeals the Litter Act of 1983 and the St. Lucia Waste Management Act of 1996. This act states that for any development proposal, the Ministry for Physical Development will consider issues relating to waste generation and management. All proposed developments must also take steps to ensure that proper waste management is provided throughout the pre-construction, construction, and operation phases of planned facilities. Policies regulating the generation, storage, transportation, and disposal of solid and liquid wastes are provided, along with the relevant penalties for offences against this Act. Authorized offices and the St. Lucia Solid Waste Management Authority has the power to impose new policies, restrict licenses, and take steps they deem necessary to prohibit solid and liquid waste pollution.

Of importance is the stipulations included for waste management planning in St. Lucia. It allows for and dictates the content and structure of the National Waste Management Strategy, the procedure for approval, amendments and review. The requirement of an Environmental Impact Assessment for the establishment of Waste Management Facilities and the procedure for review are elements that reduce the likelihood of environmental consequences occurring as a result of waste disposal. The schedules contained therein complement the Act and allow for the management of elements which include *inter alia*:

- Issues to be covered in any Environmental Plan submitted with Application for Waste Management License;
- Siting, Design and Operating Criteria for Waste Management Facilities and Haulage Systems;

3.19 Water and Sewerage Act (2004)

This Act describes the responsibilities and powers of the Crown and the Minister in controlling and protecting water and gathering grounds (all areas of land where water is collected for the purpose of waterworks). The Water and Sewerage Act provides legislation for investigating, controlling, conserving, and managing water resources for domestic, industrial, commercial, and agricultural purposes. The Minister and the Crown are also entrusted with protecting human and animal health and safety as relates to water matters. No area of land within the limits of a gathering ground shall be granted, devised, or otherwise disposed of except in keeping with such conditions set by the Minister. If the Minister deems regulation of water use necessary for the public interest in any area, the Minister may declare the area as a water control area. The Minister may also declare any area a waste control area if he believes the regulation of waste discharge into or on any land, sewer, or water is necessary to protect water resources. A permit is required for a person to use water or discharge waste in a water control area or a waste control area, respectively. To do so without a permit is a punishable offence. Sections of interest include Divisions 2-5 of Part II, and Divisions 2-6 of Part III.

This Act therefore impacts on the availability of sufficient quantity of water of potable quality as per The World Health Organisation (WHO) Drinking Water Quality Guidelines. Water quality must meet these guidelines in order to satisfy requirements under the Employee (Occupational Health and Safety) Act and Public Health Act. The discharge of wastewater must also conform to all legislation designed to minimize the negative impacts to the environment and human health and safety.

3.20 Wildlife Protection Act (1980)

This Act provides legislation for the protection and conservation of St. Lucian wildlife. The Wildlife Protection Act creates the position of a Chief Wildlife Officer and defines the island's wildlife as protected, partially protected, or unprotected. After the 1980 hurricane, all partially protected species were identified as fully protected. The only species that can be legally hunted are mongoose, rats, mice, and fer-de-lance snakes. Offences and penalties related to wildlife are also provided in this Act. These offences extend to harm to marine life. Sections of interest include Sections 6, 7, 10, 14, 15, and 16.

3.21 Physical Development and Planning Act (2001)

This Act makes provision for the development of land, the assessment of the environmental impacts of development, the grant of permission to develop land and for other powers to regulate the use of land, and for related matters. This Act therefore provides the legal tool for the management of the developments in the coastal zone and the protection of resources therein.

4.0 Literature Review

A number of studies with respect to sewage management disposal and protection of the marine environment of the Caribbean have been conducted by organisations such as CEHI, UNEP, and PAHO. A review of these reports will provide valuable insights into lessons learnt and factors to be considered in conducting the Assessment of the Infrastructure for Improved Wastewater Management in Soufriere

4.1 Land-based Pollution Sources and Marine Environmental Quality in the Caribbean (CEHI, 1991)

A wide range of activities on land contributes to the release of contaminants to the sea either directly or carried by rivers and the atmosphere, while sea-borne activities make a minor contribution (GESAMP, 1990). Marine environmental problems in the Caribbean are compounded by the generally small size of individual States, the relative small distance between them, and the proximity of all land-based activities to the coast. As a consequence, garbage, sewage and other forms of excreta disposal, industrial effluent discharges and run-off from agricultural areas directly affect the near shore marine environment. Adverse environmental effects may accrue from these contaminant loadings since the coastal and marine environment is their most biologically productive as well as economically important zone.

Most of the regional land-based activities have the potential to contribute to marine pollution. In addition, the possible additive and/or synergistic adverse environmental effects of the region, coupled with the fragile ecosystems, could result in the development of unique pollution conditions. Many reports have indicated that approximately 90 % of sewage discharged into the Caribbean Sea is poorly treated (Reid, 1981), which is alarming. However, the required level of concern can not be determined in the absence of statements which qualify the temporal and spatial distribution of the discharges and the local characteristics of the receiving environment – e.g. current patterns, mixing efficiency, water depth, presence or absence of sensitive systems. The situation is compounded by the paucity of coastal and marine baseline environmental data. Where data do exist they are often derived from sporadic monitoring efforts and are of little statistical value in describing the ambient environmental conditions which prevail.

Studies on bacterial contamination have indicated that most inner harbours and many beaches in the region exceed water quality limits for human contact and recreations areas. Existing studies on chemical pollution have been restricted largely to either levels of petroleum or nutrients and there is evidence that land-based sources may be contribution to this form of pollution. With respect to pesticides, several analyses for organochlorine (OC) pesticides and polychlorobiphenyl (PCB) residue levels in water were made on samples collected from seventeen coastal sites around St. Lucia between 1986 and 1989. The specific residue monitored indicated that Lindane (5-40 ng l^{-1}), dieldrin (4 ng l^{-1}), DDT and associated derivatives (4-20 ng l^{-1}) were detected in several of the samples . All other residues monitored were below the minimum quantitative limit of the analytical procedure used.

The technical paper concluded that land-based sources are important contributors to marine pollution in the Caribbean. The extent of the pollution needs to be carefully documented for use in the development of realistic control strategies. These strategies, in addition to recognizing the need for economic growth and development, must take into account the particular nature of the receiving environment.

4.2 Assessment of Operational Status of Wastewater Treatment Plants in the Caribbean (CEHI, 1992)

The increase in populations and affluence among the Caribbean States has resulted in increase wastewater to be treated to preserve public health and the unique environment. Regional Governments have expressed their concern about these matters and requested assistance in developing policies, establishing guidelines for collection, treatment and disposal of effluents. A United nations Development programme (UNDP) study was conducted by CEHI in conjunction with PAHO to Assess the Operational Status of Wastewater Treatment Plants in the Caribbean.

For the study a questionnaire was developed and submitted to relevant authorities in the 13 member CARICOM States. The survey instruments were designed to collect:

- Information on the Country;
- Treatment Plant Information;
- Environmental information;

Additionally, information was also collected during country visits and representative treatment plants were surveyed.

About 2/3 of the total population of 5,817,000 live in Jamaica and Trinidad and Tobago as well as 2/3 of 303 plants are located in these countries. The survey collected data on 138 treatment facilities, 46 % of all. It is believed that the absence of large centralized sewer systems has resulted in the proliferation of package sewage treatment plants.

Three groups of legislation dealing with wastewater management exist;

- Legislation defining Statutory Bodies responsible for wastewater management;
- Legislation relating to Public or Environmental Health;
- Environmental Legislation.

In most of the islands there are National Water and Sewerage Utilities responsible for operation of public sewerage systems and the Environmental Health Departments responsible for the enforcement of the regulations and policies.

Training in the operation and maintenance of sewerage systems is important and is offered by regional institutions such as University of Technology in Jamaica. In-house training is also conducted or coordinated by credible regional institutions such as CEHI, Caribbean Development Bank (CDB) and Caribbean Basin Water management Programme (CBWMP). Staff is usually sent extra-regionally to recognized universities for specialised training.

The indicators selected to assess the operational status (**Table 4.2.1**) are the removal of the Biochemical Oxygen Demand (BOD_5 @ 20 ^oC) and Suspended Solids (SS). In order to make an objective operational assessment and comparison between the different treatment facilities in the region the criteria in the table below were adopted.

Table 4.2.1: Operational Indicators and Criteria

	BOD_5 and SS Effluent (mg/l)	**BOD_5 and SS Removal efficiency (%)**	**Score**
Primary Treatment Facilities		> 50% SS; > 30% BOD < 50% SS; < 30% BOD	3 2 1
Secondary Treatment Facilities	< 30 > 30 and < 50 > 50	> 85 % > 60% and < 85 % < 60 %	
Facultative Lagoons	< 40 > 40 and < 60 > 60	> 70 % > 50 % and < 70 % < 50 %	

Operational Status	**Score**
Good	3
Moderate	2
Poor	1
Not Operational	0

Of the 138 plants investigated 25 % are operating good, 36 % are operating moderately and 22 % are operating poor and 13 % are not operational (**Table 4.2.2**).

Table 4.2.2: Operational Status of Treatment Plants per Country

	% Good	**% Moderate**	**% Poor**	**% None**
Caribbean	**25**	**36**	**22**	**13**
Antigua/Barbuda	12	35	24	24
Bahamas	39	17	22	22
Barbados	25	58	17	
Belize		50		
BVI	10	70	20	

Grenada	20	60	20	
Guyana			50	50
Jamaica	39	32	21	4
Montserrat		100		
St. Kitts/Nevis		75	25	
St. Lucia	23	23	15	39
St. Vincent			100	
Trinidad and Tobago	12	42	11	31

Of the plants surveyed there is a relationship between the operational responsibility and operational status indicating that 59 % of the plants are privately owned and operated of which the majority is by hotel and resort. The National Water and Sewage Utilities (NWSUs) operate about 25 % of the wastewater treatment facilities and operate their plants betters than the private and Government sector. Of all plants operated by the NWSU only 22 % comply with the criteria.

Most operators have no formal training (72%), but do have knowledge of wastewater treatment through on the job training, private studies and experience. A 7 % higher score for good operating plants with certified operators was observed compared to the plants with non-certified operators and a 6 % higher score for moderately operational plants.

The lack of test results on operational parameters is a severe constraint for proper operational management and control as well as plant monitoring and inspection. Laboratory testing facilities are generally limited to field test like residual chlorine.

The NWSUs monitor 24 % of the plants, the governmental departments monitor 23 % and in 5 % of the cases samples were sent to private laboratories. Only in 13 cases (9 %) were analyses performed onsite.

Environmental monitoring was conducted in 41 % of the cases where the effluent is discharged into aqueous environments. In nine cases the NWSU and the national government cooperated in the sampling programme.

The reuse of effluent is applied only to a limited extent in the Caribbean and only where freshwater resources are scarce.

Hospital wastewater management is of importance and requires special emphasis from a public health perspective. The plants survey during the study (10) showed that the operations of 3 were good and disinfected the effluent. The effluents were discharged in rivers, the sea and in one case into a deep well. One plant was non-functional and raw wastewater was discharged into a street drain.

Interrelated reasons for the low status of operation of treatment plants include:

- Lack of adequate regulations and approval procedures;

- Inappropriate selected technologies;
- Lack of inspection procedures and programmes;
- Lack of financial resources allocations;
- Lack of operational skills and process understanding;
- Lack of operation and maintenance manuals;
- Lack of operational support and service contracts;
- Lack of maintenance and absence of preventative maintenance;
- Lack or unavailability of spare parts;
- Lack of process monitoring and inadequate laboratory facilities.

There was also a need to provide facilities and institute measures for the control of liquid waste from large vessels and yachts as deemed necessary by MARPOL 73/78.

The study made a number of recommendations for the management of wastewater in the Caribbean. These included:

- Legislation should be enacted and implemented to address all aspects of waste water management with a clearly defined institutional and environmental focus and responsibilities.
- Licensing systems should be implemented to control the construction, operation and maintenance of wastewater treatment plants, requiring a certificate of approval for each plant.
- Effluent standards for wastewater treatment plants should be enacted and enforced.
- Ambient water quality standards should be enacted and enforced for the protection of the public health and the coastal environment as a means of safeguard of the tourist and fishing industry.
- Legislation should be developed making Environmental Impact Assessment mandatory for residential, tourism, commercial and industrial development.
- Wastewater management policies and strategies should be developed on national levels for wastewater collection, treatment, disposal, reduction and reuse of effluent and protection of human health and the environment.

- The national water and sewerage utilities should be strengthened to take over operation of sewage treatment plants.

- Financial resource mobilization and allocation needs strengthening especially adequate connection fees and tariffs must be set and collected.

- Further training is required for NWSU personnel in the design, construction, operation and maintenance of sewer systems and sewage treatment plants.

- Strengthening of the regulatory institutions for the management of wastewater.

- Monitoring programmes should be developed for treatment plants, effluents and receiving waters.

- A training and certification programme should be developed with a comprehensive curriculum in collaboration with a reputable regional institution.

- The proliferation of package treatment plants should be controlled.

- Adequate provisions have to be implemented for the final disposal of sludge.

- Effluent re-use options should receive high priority in order to reduce the stress on fresh water resources and to reduce environmental pollution.

- Further environmental studies are required to develop a standard for the maximum level of residual chlorine in the effluent.

- Disposal of effluent in shallow coastal areas should be restricted or prohibited, especially where human contact is possible.

- Rehabilitation of the plants receiving wastewater from hospitals, ensuring proper operation, sludge handling, adequate disinfection and effluent disposal should be urgent activities in all countries.

- Measures should be implemented to control the discharge of sewage from large vessels and yachts.

4.3 Suggested Effluent Guidelines for the Wider Caribbean Region (TUHH, 1998)

Finding appropriate recommendations for effluent criteria for the Caribbean poses two immediate challenges:

- Proposing values that are as stringent as European or American ones would lead to expensive wastewater treatment processes and systems;

- Caribbean ecosystems are extremely sensitive and demand very low effected environments.

The coral reefs of the Caribbean play a vital role in providing economic, social, cultural and inherent biological services. There are increasing concerns about the degradation of coral reefs in our region especially over the past 10 to 20 years. Although this has been accompanied by a growth in coral reef monitoring and management, there are only few studies that quantify trends in reef status, up to now this process are mostly described qualitatively. The occasional natural disasters are compounding the difficulties of evaluating the disturbances in coral reef ecosystems. A study of three reefs on the southwest coast of St. Lucia indicated that siltation as a result of landslide and erosion due to Tropical Storm Debbie in 994, contributed to a coral reef mortality of 50 %. Coral diseases are also negatively affecting important reef building species of coral such as Acropora palmate.

The pristine conditions are threatened by pollutants from point or non-point sources, which vary in toxicity and in their impact on marine and human life. These include: suspended solids, pathogens, nutrients, oxygen demanding substances, organic compounds of synthetic and natural origin and heavy metals.

Nutrient enrichment of the coastal waters especially from nitrogen and phosphorus compounds above threshold concentration can result in euthrophication with several hazardous ecological effects, including:

- algal blooms;

- Change in aquatic community structure;

- Decrease biological diversity;

- Fish kills;

- Oxygen depletion.

The Caribbean coral reefs appear to be much less resilient than those of the Great Barrier Reef and contain lower diversity. No or hardly any recovery could be observed on Caribbean reefs within the last 10 years.

4.3.1 Microbiological Water Quality Parameters

Marine pollution by biological agents such as bacteria pathogens, are threatening the attractiveness of bathing areas and consequently the future of the tourist industry and public health. Concerns associate with contamination of ambient waters from microbiological agents and historical episodes of endemics has led a number of agencies to take steps to establish mandatory criteria to protect public health. Total coliforms and faecal coliforms were the most common indicators used.

Recent studies have shown that Enterococci species of Faecal streptococci are a better indicator of faecal pollution because they show better correlation to human diseases and they survive longer in the water (more resistant to environmental stress). Therefore, the Environmental Protection Agency of the United States (EPA) suggested establishing Enterococci as the primary indicator organism for primary contact recreation; they should replace total and faecal coliforms as indicators.

In 1986 the EPA proposes risk level for contact with ambient waters to be 6 gastrointestinal illnesses per 1000 swimmers with proposed criteria in **Table 4.3.1.1**.

Table 4.3.1.1: EPA Microbiological Risk Criteria

Freshwater:	33 Enterococci/100 ml 126 E. coli/100 ml
Marine Water:	35 Enterococci/100 ml

It seems that the values given by the USEPA are the most reliable and therefore the most appropriate ones as they are the only ones with a scientific basis. Due to the fact that temperatures in the Caribbean are predestined to let pathogens thrive, agreeing on significantly higher values (e.g. the European criteria) might be problematic.

Nevertheless, no suggested concentration would be completely satisfactory for various reasons, including:

- Influencing risk depends on the intensity of water use;
- Acceptable level of risk is a political or social judgment. There is no definable risk–free level since there is a continuous relationship between degree of pollution or exposure and acquiring illness;
- A single sample upper limit is different to justify statistically, geometric mean (or median) and the standard deviation of log 10 bacterial counts are the ideal descriptors of central tendency and variability;

- There is no consensus on the best indicator. All microbial standards are based on the analysis for indicators of faecal pollution but those pathogens responsible for illness cannot be isolated at all, or with difficulty.

4.3.2 Chemical Parameters

To ensure the balance of a coastal ecosystem it is indispensable to define and to supervise chemical control parameters that are adapted to natural conditions and therefore guarantee the system sustainability. The effluent guidelines and standards available for the region are shown in **Table 4.3.2.1**.

Table 4.3.2.1: Available and Applied Effluent Guidelines and Standards in the Caribbean Region

	BOD_5 mg/l	TSS mg/l	pH	F-Coli #/100 ml	T-Coli #/100 ml	Res. Cl mg/l
Bahamas[2]	<30	<30	6-9	+>85% removal of BOD and TSS		
Barbados	<25	<25				
Cayman Islands	<30	<30	(disposed by deep well injection)			
Columbia[3]	>30%r	>30%r	6-9			
Colombia[4]	>80%r	>80%r	6-9			
Cuba	<50	<50	6.5-8.5	<200	<2000	
Guadeloupe[6]	<40	<30				
Honduras	<30	<30	6-9	+>85% removal of BOD and TSS		
Jamaica	<20	<30		<200		<1.5
Panama	>80%r	>80%r				
Puerto Rico	<30	<30	6-9	+>85% removal of BOD and TSS		
St. Lucia	<25	<30				
Trinidad[7]	<25	<30	6-9	<200		
Trinidad[8]	<125	<175	6-9	<400		
Venezuela	<40	<50	6-9	<200	<1000	<0.5

[2] EPA standards have been adopted in the Bahamas, Honduras and Puerto Rico

[3] Existing treatment plant, in % removal from influent

[4] New treatment plant, in % removal from influent

[5] Guidelines-use water quality base approach

[6] Effluents from aerated lagoons

[7] For discharge into inshore seas and environmentally sensitive areas

[8] For discharge into environmentally non-sensitive areas

The Total Suspended Solids (TSS) values are low compared to the European requirements for the Discharge of Municipal Effluents of 60 mg/l.

Trinidad has divided their waters into sensitive and non-sensitive areas which provide an opportunity to keep sewage treatment plants with lower removal efficiencies given the definition of sensitive and non-sensitive areas may be problematic and the coastal dynamics may convey discharges from one to the other.

4.3.3 Necessity of Nutrient Removal

The continuous substantial increase in riverine input is corresponding with increase rate of primary productivity and subsequent coastal eutrophication. This is compounded by a host of other impacts such as direct sewage discharges and overfishing. Enhanced nutrient-incorporated wastewater stimulates phytoplankton growth but as the antagonist is being removed by overfishing, the system is unable to compensate this imbalance to heal itself. High nutrient influx can also have a direct toxic effect on marine ecological systems due to their low tolerance levels. The desire to reduce the loads of nutrients resulted in phosphate free detergents and the development of more efficient tertiary sewage treatment plants.

4.3.4 Demand of Sensitive Coastal Ecosystems

Coral reef systems are known to be more susceptible to anthropogenic stresses and to meet their most essential requirement (light availability) turbidity has to be extremely low. Hence, it is necessary to ensure that nutrient levels do not stimulate proliferation of the phytoplanktons and macroalgae. Oxygen depletion may also result from the degradation of organic matter.

4.3.5 Limiting Nutrients in Marine Environments

Primary productivity is enhanced significantly by the addition of nitrogen and phosphorus. Experiments have shown that varying concentrations of these elements and silica can have a significant effect on primary productivity.

When effluent concentrations are to be defined dilution ratios have to be taken into account. If the background and tolerance levels are available the dilution ratio (F) can be determined from the discharge concentration data by the following formula;

$$F = C_{discharge} - C_{tolerance} / C_{tolerance} - C_{background}$$ (Bell, 1989)

Conventional high capacity ocean outfalls that are commonly used for the disposal of sewage from coastal tourist areas, achieve a maximum initial dilution of 200 (Bell, 1989) This means that they will be insufficient to meet the coral reef nutrient requirement even if effluent phosphate and nitrate concentrations were as low as 2 mg/l and 1 mg/l respectively.

Even those high dilution ratios of the order of $10^3 - 10^5$ can be realized theoretically (**Table 4.3.5.1**) by a non-conventional diffuser of sufficient length (9 up to 100m) and depth (10m). However, the energy consumption of such systems is enormous as

additional pumping is needed at these diffusion lengths to distribute the discharge stream uniformly along the diffuser (Bell, 1989).

Table 4.3.5.1: Required Dilution Ratios for 1°, 2° and 3° Treated Sewage for Waters of the Great Barrier Reef, Australia (Bell, 1989)

	$C_{discharge}$			$C_{tolerance}$	$C_{background}$	F		
	Concentration in Sewage					Required Dilution Ratios		
Contaminant	**1°**	**2°**	**3°**	**TL (% increase over background)**	**Background Level**	**1°**	**2°**	**3°**
BOD_5 (mg/l)	300	20	10	0.78 (10%)	0.71	4300	270	130
NFR (mg/l)	300	30	10	3.3 (10%)	3.0	1000	90	20
Inorganic-N (µg/l)	50000	20000	2000	15.4 (10%)	14	36000	14000	1400
PO_4-P (µg/l)	10000	10000	1000	7.5 (10%)	6.8	14000	14000	14000
Chlorine (µg/l)	700	<700	<700	50	0.0	13	<13	<13
Salinity (ppt)	1	1	1	30	35	6	6	6
Pesticides (µg/l)	1	<1	<1	10	0.0	0	0	0
Heavy Metals (µg/l)								
Hg	3	<3	<3	0.1	0.0	30	<30	<30
Pb	70	<70	<70	10	<0.06	6	<6	<6
Zn	70	<70	<70	20	0.13	2.5	<2.5	<2.5
Cu	150	<150	<150	1	0.22	190	<190	<190
Ni	50	<50	<50	2	0.11	25	<25	<25

4.3.6 Recommendations for Nutrient Effluent Concentrations

At a UNEP-Expert-Meeting at CEHI (January, 1998) effluent guidelines were suggested (**Table 4.3.6**.1) for the municipal discharge into coastal waters of the Wider Caribbean Region. The parameters and values listed below were presented at the Final Conference for the development of the LBS protocol in June 1998.

Table 4.3.6.1: Suggested Effluent Guidelines for Coastal Discharges

Parameter	Non-Sensitive Areas	Sensitive Areas
Faecal Coliforms		Shell fish areas: 43 mpn all other: 200 mpn
pH	6-10	6-10
TSS	100 mg/l	30 mg/l
BOD_5	150 mg/l	50 mg/l
COD	300 mg/l	150 mg/l
Total Inorganic Nitrogen		10 mg/l

Ammonia		5 mg/l
Total Phosphate		1 mg/l
Chlorine Residue		0.5 mg/l
Fats, Oils and Greases	15 mg/l	2 mg/l
Floatables	Not visible	Not visible

There are some suggested permissible limits for total nitrogen and total phosphorus for seagrass and coral reef (**Table 4.3.6.2**). Above these limits, nuisance algal bloom occurs, seagrass die off and coral diversity and abundance decreases.

Table 4.3.6.2: Suggested Threshold Limits for Inorganic Nutrients (Reese, 1993)

	Threshold Limits (mg/l)	
Nutrient	**Seagrass**	**Coral Reef**
Total Nitrogen	0.35	0.015
Total Phosphorus	0.012	0.003

4.3.7 Conclusion

There is great concern about the vulnerability of coral reef ecosystems in the Caribbean, due to both ecological and economical reasons. Coral reefs thrive in oligotrophic waters, but as many Caribbean country's population and economy increase substantially they are endangered by enlarging amounts of produced waste waters - with harmful contents.

The Reefkeeper Organisation summarized the results of several reef studies conducted in Barbados, Hawaii and Australia. They determined critical nutrient concentrations for total phosphorus (0.003 mg/l) and total nitrogen (0.015 mg/l) and requested these values to be considered as threshold limits for corals (Reese, 1993).

Even if these water quality levels were convenient to ensure a reef system's sustainability, effluent concentrations have to be determined from these values. Bell (1989) stated a formula to calculate required dilution ratios for given effluent concentrations, if background and tolerance levels are known. He concluded that extremely high dilution ratios were needed to meet the ecosystems demands referring to nutrients.

It becomes apparent that even nutrient-levels for discharge suggested at the UNEP/CEHI meeting (10 mg/l and l mg/l for total inorganic nitrogen and total phosphorus, respectively) are insufficient to protect the vulnerable coral reef ecosystems of the Wider Caribbean Region if they are not effectively flushed. Simply giving maximal tolerable effluent concentrations is inappropriate to serve the demands of coastal ecosystems.

4.4 Appropriate Technology for Sewage Pollution Control in the Wider Caribbean Region (UNEP-CEP, 1998)

Under the Cartagena Convention the governments of the Wider Caribbean Region (WCR) are developing a *Protocol on Marine Pollution from Land-based Sources and Activities* (the LBS Protocol.) The LBS Protocol will have source-specific annexes, through which measures will be taken to address priority pollutants. A regional inventory from the 1994 "Regional Overview of Land-based Sources of Pollution in the Wider Caribbean Region," CEP Technical Report No. 33 (UNEP, 1994) identifies domestic and industrial sewage as the priority source of marine pollution in the Caribbean Region. The governments in the region have decided that the first two annexes will address domestic wastewater and agricultural non-point sources of pollution. This report is part of an effort by the UNEP Caribbean Regional Co-ordinating Unit (CAR/RCU) to address or identify the most appropriate wastewater treatment technologies and water quality standards for the Wider Caribbean Region (WCR).

The goals for this document are as follows:

- To identify the most appropriate technologies for domestic and industrial sewage pollution control in the WCR. Domestic sewage or wastewater is considered in this report to be the liquid waste produced by households, schools, hotels, and small commercial establishments commonly combined in town or city sanitary drainage systems. Industrial sewage is considered to be liquid waste from manufacturing plants for a variety of industrial products.
- To describe expected treatment limits for these technologies, which can help government officials develop water quality guidelines.
- To develop a reference list of relevant information that is not covered in the report or is beyond its scope.

This document is not intended to stand alone as a design manual, textbook, or reference book. It has been prepared for use by government agencies, government regulatory officials and consultants in the WCR, to help them make preliminary decisions about appropriate wastewater treatment technologies based on community size, location, hydrogeologic conditions, and other factors. Key elements include the following:

- "Decision trees" to be used in identifying appropriate pollution control technologies. The result of the decision-tree process is identification of the treatment or disposal technologies that merit further evaluation for the scenario under review. The decision tree is a general guideline taking into account the most important criteria. Other important issues, such as social acceptance, planning, and management, are not included in the decision tree, although they are discussed separately in the report.
- Fact sheets summarising key features of each technology—The fact sheets include design criteria, expected efficiency, references for more information, a list of

facilities using the technology in the WCR, and, in some cases, diagrams showing how the technology works.

- Expected treatment efficiencies for each control technology—The efficiencies are shown to give an indication of effluent discharge standards that should be achievable by the given technology when adequately designed and operated. This document has not investigated receiving water quality requirements. It is intended to support the process of standard setting by identifying the potential for sewage pollution control by different technologies, but it was not prepared to recommend specific water quality standards for the WCR.
- A review of papers, textbooks, and manuals that can be used to obtain more detailed information—The organisation of the literature review parallels that of the report, so that the reader can look up the references used in this report by topic, as well as by author.

The WCR is divided into six sub-regions for further reference, as described in the map and list below (UNEP 1994):

I. Gulf of Mexico—Cuba, Mexico, and United States (Texas, Louisiana, Mississippi, Alabama, and Florida)

II. Western Caribbean—Belize, Costa Rica, Guatemala, Honduras, Mexico, Nicaragua, and Panama

III. North-eastern and Central Caribbean—Bahamas, Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, and Turks and Caicos Islands

IV. Eastern Caribbean—Anguilla, Antigua and Barbuda, Barbados, British Virgin Islands, Dominica, Grenada, Guadaloupe, Martinique, Montserrat, St. Maarten, St. Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, and the U.S. Virgin Islands

V. Southern Caribbean—Colombia, Netherlands Antilles, Trinidad and Tobago, and Venezuela

VI. Equatorial Atlantic North West—French Guyana, Guyana, and Surinam.

For wastes from communities where most homes and businesses have piped water, typical pollutant composition of domestic sewage is as follows (**Table 4.4.1**):

Table 4.4.1: Typical Pollutant Composition for Domestic Sewage

Total Suspended Solids (TSS)	200-300 mg/L
5-day Biochemical Oxidation Demand (BOD)	200-250 mg/L
Chemical Oxidation Demand (COD)	350-450 mg/L
Total Nitrogen as N	25-60 mg/L
Total Phosphorus as P	5-10 mg/L
Oil and Grease	80-120 mg/L

In unsewered areas, septic tanks are common. Septic tanks accumulate solids known as septage, which must be removed every few years to ensure effective operation of the

system. Typical pollutant composition of septage taken to wastewater treatment facilities is as follows (Table 4.4.2):

Table 4.4.2: Typical Pollutant Composition of Septage

TSS	10,000-25,000 mg/L
5-day BOD	3,000-5,000 mg/L
COD	25,000-40,000 mg/L
Total Nitrogen as N	200-700 mg/L
Total Phosphorus as P	100-300 mg/L
Oil and Grease	2500-7500 mg/L

Industrial wastewater has a wide range of pollutant concentrations. Oil refinery wastewater produces 70 percent of the entire BOD load in the Caribbean. These wastes are high in BOD, dissolved salts, odour, phenol, and sulphur compounds. Food processing industries, distilleries, and soft drink industries produce about 5 percent of the BOD load in the Caribbean (**Table 4.4.3**). They are characterised by very high BOD concentration, suspended solids, dissolved solids, variable pH, and a high level of organic matter. Chemical industries produce about 1 percent of the entire BOD load in the WCR. Even though they have low BOD strength, wastewater from chemical industries is important because it is frequently toxic to aquatic organisms at very low concentrations. This toxicity may actually mask assessment of BOD for these wastes by killing the BOD test organisms. Pesticides and insecticides used for agriculture are the primary chemical wastes in the Caribbean. These wastes are high in organic matter and are toxic to bacteria and fish.

Table 4.4.3: Summary of Pollutant Loadings in the Wider Caribbean Basin

.SUMMARY OF POLLUTANT LOADINGS IN THE WIDER CARIBBEAN BASIN TONNES PER YEAR						
Parameter	**Subregion I**	**Subregion II**	**Subregion III**	**Subregion IV**	**Subregion V**	**TOTAL**
BOD						
Domestic	115,656	16,785	71,079	4,790	260,171	506,482
Industrial	2,245,762	126,858	357,441	94,707	603,370	3,428,138
TSS						
Domestic	116,327	16,427	90,214	4,617	228,744	456,329
Industrial	27,821,848	149,887	993,964	270,270	2,684,948	31,920,953
TN						
Domestic	34,070	2,419	5,239	710	86,338	128,786
Industrial	17,234	40,526	43,265	37,306	211,107	349,435
TP						
Domestic	19,141	1,467	5,503	531	33,475	60,117
Industrial	17,717	4,519	12,690	15,171	32,537	82,634
Oil & Grease						
Domestic	41,370	2,001	6,089	504	18,975	68,939
Industrial	640,181	8,611	128,024	41,227	162,608	908,701

In areas of higher population density, it is feasible to develop a local collection system and use a single facility to treat the community's wastes. Lagoons, stabilisation ponds, and aerobic package plants are common treatment options for mid-size communities in the WCR. Lagoons are often appropriate, but they require a large area to provide adequate treatment. Package plants are used mostly for resort communities, hotels, and other public buildings. Many package plants in the WCR are operating improperly because of improper design and inadequate maintenance. In centralised, urban centres, lagoons, package plants, and conventional activated sludge systems are used. Many of these treatment facilities do not provide adequate treatment because of improper maintenance, and lack of skilled operators.

A report by CEHI and PAHO described the following disposal practices for systems in the WCR that collect and treat sewage (Bartone, 1984):

- 21 percent reuse effluent.
- 14 percent practice subsurface discharge.
- 28 percent use marine disposal, mainly on shoreline.
- 22 percent discharge to surface waters such as lagoons or streams.
- 14 percent practice on-site disposal.

Poor sewage treatment and disposal affects the health of the local population and the environment. In St. Lucia, children have been affected by helminths. In Barbados, extremely high coliform counts have been measured. In Colombia and the United States bordering the Gulf of Mexico, sewage pollution has been identified as the cause of fish kills, while in Cuba, impacts of sewage pollution have been measured as far as 1 kilometre from sewage effluent discharge points. According to PAHO, as of 1979, enteric and diarrhoeal diseases were the most common cause of infant mortality in many Latin America and Caribbean countries.

The direct discharge/loading of sewage into the marine environment in St. Lucia is summarized in the **Table 4.4.4** below.

Table 4.4.4: Discharge into the Marine Environment for St. Lucia

	% Sewer	Treatment Level	Impacts	Monitoring
St. Lucia	13.2% of population. Treatment facility in Rodney Bay	Usually untreated raw sewage discharged into ocean & inner harbours; 54% STP are in poor condition or non-operational	High bacterial levels in some coastal areas	Random sampling of coastal waters conducted by the Ministry of Health in co-operation with CEHI

Sources upon which water quality standards can be based include extensive studies on the effects of pollution in receiving waters as well as existing standards from other countries or states. Most countries in the WCR use microbiological water quality standards taken from USEPA guidelines written prior to 1986. However, these standards often are too stringent and expensive for a developing nation. Planners need to account for the economic realities and development priorities of developing nations when setting water quality standards.

Three general categories of microbiological water quality standards are based on intended water uses: protection of indigenous organisms, primary contact recreation, and shellfish harvesting. For developing countries, the pollutants of greatest concern are pathogens because they pose an immediate health danger. The most stringent requirements are those for shellfish harvesting, since some shellfish tend to concentrate contaminants. The UNEP/World Health Organisation (WHO) standard for shellfish harvesting waters is a maximum of 10 faecal coliforms per 100 mL for 80 percent of samples taken. Shellfish contamination is associated with typhoid fever, cholera, viral hepatitis, and many other gastro-enteric conditions.

4.5 Marine Pollution in Barbados (EPD, 2004)

In Barbados the control and management of marine pollution is controlled by the Environmental Protection Department (EPD), the Coastal Zone Management Unit (CZMU), the National Conservation Authority (NCA), Ministry of Physical Development and the Environment (MPD&E) and the Ministry of Health (MoH). The main legal instruments for the control of Marine Pollution are;

- The Marine Pollution Control Act, 1998 - It is an Act to prevent, reduce and control pollution of the marine environment of Barbados from whatever source;
- Coastal Zone Management Act, 1998 – Management Protection, Conservation and Enhancement of marine and coastal resources.

The Government of Barbados is also in the process of evaluating the potential impacts of signing the Protocol Concerning Pollution from Land-Based Sources and Activities. This MEA has the same aim as the Marine Pollution Control Act i.e. to prevent the pollution and protection of the marine environment.

To fulfill its mandate, the Environmental Protection Department (EPD) is required to regulate any activity that would have a potential impact on the marine environment by;

- Maintaining a Register of Pollutants containing data on the quantity, condition and concentrations of pollutants;
- Ensuring that parties responsible for the release of pollutants on a one-time or periodic basis, carryout required documentation and monitoring in order to comply with applicable standards;
- Developing and implementing programmes to prevent, reduce and control marine pollution.

The onus of monitoring and sampling of pollutants lie with the polluter and not with the Department. However, the polluter is required to report and provide required information on their pollutants to the Department.

For enforcement purposes the EPD conducts monitoring of sewage treatment plants island-wide and effluent samples are tested to ensure that discharged water will not have a great negative impact on the environment.

The EPD in enforcing the regulation, is guided by the Marine Pollution Control (Discharge) Regulations, 2005. The Regulations include:

- Discharge Rules;
- Dilution will not cure Non-Compliance;
- Storm Sewer Requirements;
- Reporting Requirements;
- Discharger Self-Monitoring;
- Extra Strength Agreement;
- Compliance Agreement;
- Sampling and Analytical Requirements;
- Maintenance Access Points;
- Spill Management;
- Administration;
- Offences
- List of Prohibited Concentrations;
- Domestic Waste End of Pipe Standards
- Petroleum Hydrocarbons End of Pipe Standards for Class I Waters.

Of importance is the list of prohibited concentrations which was developed by adaptation and adoption of existing and acceptable relevant standards, guidelines and research. The list was compiled in October 2004 with assistance from University of the West Indies and New Water Inc.

Environmental monitoring inclusive of fresh and marine water quality monitoring, forms an inherent part of the project and programmes geared towards the execution of the Act. Water quality monitoring provides valuable information on the characteristics of water resources. When monitoring is conducted routinely in accordance with scientific principles, it allows the identification of trends in water quality over time as well as existing or emerging problems with water quality. The intended use of the water determines the water quality parameters selected for analysis. Generally, these include:

- Physical Parameters such as pH, turbidity and temperature;
- Chemical Parameters such as nitrates and phosphates;
- Microbiological Parameters such as faecal coliforms and faecal streptococcus;
- Metals such as copper and lead;
- Pesticides such as atrazine.

Nearshore bathing water monitoring is done weekly and feacal coliforms and enterococci are the main microbes analysed for. The USEPA standards for ambient/recreational waters are adopted for bathing waters.

4.6 Initial Development of a Coastal Zone Management Framework for St. Lucia (MPDEH/ATRIA, 1995)

The government of St. Lucia is aware of the need to protect and conserve the coastal resources and commissioned a study for the Development of a Coastal Zone Management Framework for St. Lucia.

The overall long-term goal of coastal zone management in St. Lucia is described as integrating the interest of economic development and environmental protection to achieve optimal allocation and use of the natural, physical and biological resources located within the coastal zone without threatening or exceeding the long-term sustainability (ecologically, economically and socially) or carrying capacity of the coastal resources and ecosystem.

Seven specific goals were proposed which recognized that there was a need for the Government to further develop its capability to manage the coastal zone if ecologically sustainable development is to be attained. This called for the following:

- Adopt a pro-active approach to environmental and resource management and protection
- Develop an appropriate institutional mechanism to overcome and correct policy and intervention deficiencies and market failures
- Generate and manage current, accurate and accessible information on the coastal zone
- Provide the opportunity and the means for all stakeholders to participate in the development of the Coastal Zone Management Plan
- Define public policy and enact legislation to legitimise the Coastal Zone Management Initiative
- Eliminate or mitigate the impacts of existing resource degradation
- Reduce conflict among and between users of coastal zone resources

Integrated coastal zone management is important to St. Lucia which is so heavily dependant on the marine and coastal resources. This integration needs to coordinate management to provide different and sometimes conflicting outputs for the following;

- The management of land resources for urban, industrial, mining, tourism and conservation activities;
- The management of coastal waters for recreation, aquaculture, transport and mining;
- The management of living marine resources;
- The management of the assimilative capacity of coastal land, waters and air to achieve environmental quality objectives;

- The provision of coastal defenses.

The management actions have to coordinate the operations of three different systems: the economic system, the biophysical system and the social system. At the same time decisions should satisfy criteria for sustainable development.

Achieving integrated coastal zone management in St. Lucia will involved the following:

- Coordinating the activities and networking between the various Government Ministries and Departments with responsibility for CZM;
- The establishment of a coastal zone management unit with a mandate for the management of coastal resources;
- The formation of an intersectoral committee acting in an advisory capacity to the CZMU;
- Data collection and research;
- Digital data sets for analyses that will guide decision making;
- Giving due consideration to the human environment and social assessment;
- Enhancing the environmental assessment process to guide development in the coastal zone;
- Public awareness and education and participation in the decision making process for the management of the coastal zone;
- Prevention and protection of shoreline hazards;
- Emergency response and disaster preparedness.

The CZM Project of 2001 – 2003 emanated from the recommendations of this study and areas specified in this study were incorporated into the policies which will guide coastal zone management in St. Lucia.

4.7 Regional Overview of Land-Based Sources of Pollution in the Wider Caribbean Region (UNEP-CEP, 1994)

During the past two decades awareness of the steadily growing pollution of the coastal and marine areas of the Wider Caribbean Region (WCR) became increasingly apparent. In response to this concern, national research institutions and international organizations have undertaken technical actions as well as the preparation of legal instruments for the prevention and control of marine and coastal pollution within the Wider Caribbean Region.

A comprehensive joint IOC-UNESCO UNEP-CEP Programme for Marine Pollution Assessment and Control (CEPPOL) in the WCR was developed. This CEPPOL Programme, which was initiated in August 1990, had seven components relevant to the assessment and control of the quality of the marine and coastal environment of the WCR. Among the above-mentioned components, the control of domestic, industrial and agricultural land-based sources of pollution (LBSP) became one of the most important activities of the programme.

As in other regions of the world, in the WCR the major sources of coastal and marine pollution originating from land-based sources vary from country to country, depending on the nature and intensity of the specific development activities. In the coastal areas these activities affect the water quality of rivers discharging into the coastal zone. Activities related to human settlements, agriculture and industry have been identified as major contributors to the pollutant loads reaching coastal and marine waters in the WCR.

In order to mitigate and control the impact of pollution originating from land-based sources on coastal marine resources, it is essential that the type and levels of pollutants be identified. This process involves the determination of the sources, localization of the discharges, volume of the wastes, concentration of potential pollutants, etc. However, point sources account for only a fraction of the land-based sources of pollution affecting the coastal and marine environment of the WCR. NOAA's National Coastal Pollutant Discharge Inventory Programme (NCPDI) has identified the following sources:

i) Point sources (industries and sewage treatment plants);

ii) Urban non-point runoff (stormwater runoff and combined overflow discharges);

iii) Non-urban non-point runoff (cropland, pastureland and forestland runoff);

iv) Upstream sources (pollutants carried into the coastal zone as part of river's streamflow); and

v) Irrigation return flows (irrigation water return to a lake, stream or canal).

Based on all the information available to date, the type of pollutants from land-based sources which may constitute the greatest real or perceived threat to coastal and marine ecosystems as well as the public health of coastal dwellers of the WCR, are the following:

- Sewage - Sewage has been identified as one of the most significant pollutants affecting the coastal environment of the WCR, particularly in developing countries;
- Oil hydrocarbons - Most of the oil produced in the Wider Caribbean Region is shipped within the region resulting in an intricate network of distribution routes.
- Sediments - A considerable amount of river-borne particulate material is introduced every year. It must also be kept in mind that the present suspended and dissolved river loads are being enhanced by contributions from human activities such as the erosion of the river basin watershed caused by deforestation, urbanization, agricultural activities and by a variety of pollutants being discharged into these waters. With reference to the impact of human activities on the sediment loads carried by the rivers of the WCR, deforestation of the river basin watersheds is probably the one which causes major concern.
- Nutrients - Among the priority pollutants entering the coastal and marine environment of the WCR, there is increasing concern regarding nutrient

enrichment, particularly nitrogen and phosphorous compounds, of coastal waters from point and non-point sources. The continuous discharge of these nutrients in enclosed coastal area is a major cause of the eutrophication phenomena. The ecological effects of this phenomenon include algal blooms, changes in aquatic community structure, decreased biological diversity, fish kills and oxygen depletion events.

- Pesticides - The extensive use of pesticide (insecticide, herbicides, fungicides, etc.) due to intensive agricultural activity within the WCR is well documented, and its impact on land and coastal marine ecosystems is evident. Through runoff, erosion and misapplication, significant quantities of pesticides are reaching the coastal and marine environment where they may affect non-target species, and, through the contamination of seafood, may become a public health problem. Pesticide compounds, once applied, reach the coastal areas of the region via rivers and by atmospheric transport. It has been estimated that about 90% of pesticides which are applied do not reach the targeted species. Consequently, pesticide contamination is a serious concern because of its high toxicity and tendency to accumulate in the coastal and marine biota.
- Litter and marine debris - The appropriate management of solid wastes from land-based sources in the WCR is a problem of great concern as it affects the ecological and aesthetic quality of the coastal and marine environment. This problem has arisen because of the increasing amount of solid wastes being generated within the region, coupled with deficient collection systems and inadequate disposal practices. Faulty disposal practices such as using rivers and streams and mangrove swamps as dumpsites are evident in many countries of the region. On the other hand, although well managed landfills should not constitute a source of solid wastes reaching the coastal and marine environment, the fact is that poorly managed landfills exist in many coastal areas of the WCR. These sources plus runoff induced by high precipitation may turn landfills into important sources of floating solid wastes en route to the sea. At present, there is no published information concerning the amount of solid wastes being generated in the WCR or the way these wastes are handled prior to final disposal.
- Toxic wastes needs to be emphasized - These priority pollutants are organic and inorganic compounds either synthesized or chemically transformed natural substances that are capable of producing adverse effects on the structure and function of land and coastal ecosystems when improperly utilized, discharged or accidentally released into the environment. The contamination of the coastal environment in the WCR by the above-described toxic compounds is a matter of great concern. Taking into account that they are very persistent in the aquatic environment, these compounds bio-accumulate in marine organisms and are highly toxic to humans via the consumption of seafood.

4.8 A Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquid and Hazardous Waste for SIDS in the Caribbean Region (UNEP/CEHI, 2004)

Waste management is a major area of concern in Caribbean SIDS and this was highlighted at all major regional conferences and environmental agreements. The Environmentally Sound Technologies (EST) Directory consists of a compilation of appropriate technologies for the management of waste which are especially applicable to the Caribbean Region. Additionally, the Directory promotes a sound practice which is technically and politically feasible, cost effective, sustainable, environmentally beneficial and socially solution to a waste management problem.

Importantly also, is the availability of alternatives and the criteria for the evaluation of their suitability.

Despite the fact that most of the technologies present would be suitable for all SIDS, the following factors may be used in assessing the background conditions present for individual situations:

- Level of development;
- Natural conditions;
- Conditions due to human activities;
- Social and political considerations.

4.8.1 Solid and Hazardous Waste

Solid waste management is critical and in Caribbean SIDS indiscriminate and improper disposal practices are responsible for the degradation of the marine environment and poor water quality. Inappropriate solid waste management practices in coastal areas are discernible with debris strewn along the coastline after washout from major drains and rivers. Additionally, leachate from improperly constructed solid waste disposal facilities could have a negative effect on the groundwater and ultimately reach the marine environment.

Hazardous wastes are defined as waste materials that cause on immediate or cumulative hazardous potential to humans and or the environment. These wastes could be toxic, poisonous, corrosive, flammable, infectious or explosive. Hazardous wastes therefore need special handling, treatment and disposal because of this hazardous potential.

4.8.2 Wastewater

Many of the wastewater technologies used in the Caribbean have failed due to *inter alia*:

- Inappropriate technology;
- Insufficient operation and maintenance practices;
- Lack of funding;

- Lack of skilled personnel.

Wastewater management for Soufriere will need to consider the appropriate technologies for domestic, commercial, agricultural and industrial sectors.

4.9 Sewage Treatment Operators Manual for the Caribbean Region (USAID/UNEP/CEHI, 1996)

Sewage is one of the main sources of pollution to the marine environment and in the WCR only 10 % of the sewage generated is treated properly. The training manual in operation and maintenance of sewage treatment plants has therefore been identified as one way to strengthen management of the sewerage sector in the region.

The objectives of the manual are:

- To give an overview of wastewater characteristics and treatment technologies;
- To provide guidelines on operational requirements and monitoring programmes for:
    - ❖ Activated sludge process;
    - ❖ Rotating biological contact;
    - ❖ Stabilisation pond.
- Provide trouble shooting methods for common problems.

The manual classify wastewater as:

- Storm water;
- Domestic water;
- Industrial water.

Selecting the treatment technologies to be employed involved:

- Evaluation of the hazards to communities;
- Aesthetic acceptable;
- Prevention of nuisance such as odors;
- Protection of the ecology of the area;
- Standards and/or guidelines for the effluent;
- Plant location and location of the wastewater;
- Treatment process.

The treatment process may constitute:

- Pretreatment;
    - ❖ Rack and screen;
    - ❖ Girt chambers;
    - ❖ Shredding.

- Primary treatment;
- Secondary treatment;
- Tertiary treatment.

4.10 Needs Assessment Guidance to Develop National Plans for Domestic Wastewater Pollution Reduction (UNEP, 2003)

To assist countries of the WCR to fulfill the requirements of the LBS Protocol, the UNEP-CEP/RCU has developed the Wastewater Needs Assessment Guidance. The goal in developing this Needs Assessment Guidance is that it will serve as a tool for regional governments, as they proceed to fulfill the domestic wastewater requirements of Annex III of the LBS Protocol. It provided guidance in the development of programmes, plans and measures to evaluate sewage management needs and lists of options to resolve wastewater discharge impacts. Governments will be provided with an overview of the how to begin planning to implement the general and specific requirements of Annex III.

A sewage needs assessment is a comprehensive profile of the program planning needs to manage sewage, the preparation of which does not necessarily imply a commitment to fulfill all or any of the needs identified. However, it does serve as an initial step and good faith expression towards fulfilling the requirements of Annex III and serves as a baseline of information from which to launch the planning process.

The purposes of the Needs Assessment Guidance are:

- Establishing a recommended framework for national assessment and planning;
- Identifying typical issues and information needs relevant to Annex III;
- Providing tools such a checklist, schematics, illustrations and other aids in planning;
- Introducing elements of follow-up planning phases to assist in understanding the importance of early-phase information needs;
- Providing case studies illustrating the application of the planning tools or environmental, social or economic considerations.

Domestic wastewater management is a key element for the protection of marine and coastal resources and can have a number of benefits:

- Public Health Protection;
- Food Security;
- Biodiversity and Conservation;
- Recreational Value;
- Economic Development.

National programmes are required for the management of domestic wastewater and conformation to the obligations under the LBS protocol. The following should be considered:

- Making water supply and sanitation integral parts of poverty alleviation programmes;
- Incorporating water supply and sanitation as integral parts of human settlement programs;
- Improving service delivery, operation, maintenance, service reliability and water quality;
- Identifying adequate financial resources coupled with effective cost recovery policies;
- Decentralisation and developing responsibilities to the lowest appropriate level of management;
- Integrating water supply and sanitation within a holistic approach to the development, management and use of water resources;
- Including and integrating stakeholder, from the local level to the regional and national levels, to build partnerships for management of domestic wastewater;
- Harmonising national plans with other existing plans, such as coastal zone management plans and development plans and evaluating them along with other national priorities;
- Long-term operation and maintenance, receiving water monitoring and management assessment of selected options.

4.11 Root Zone Wastewater Treatment in St. Lucia (CEHI, 1995)

There is an increasing amount of wastewater to be dealt with by hotels, whose expansions have not always included infrastructure development. This problem is compounded by the high concentration of nitrates and phosphates contained in grey water originating from laundry, kitchen, showers and showers. This necessitated actions geared towards experimenting with low cost but effective tertiary wastewater treatment methods such as a natural reed bed. The purpose for designing a pilot project in St. Lucia was to examine the effects such a reed bed treatment system on wastewater discharge from the Moorings Marigot Bay Resort, located at Marigot Bay. The wastewater was intended to be a combination of sewage and highly polluted domestic type effluent containing high amounts of phosphorus from laundry detergents, as well as grey water from showers and face basins.

The Resort contained a number of buildings, ranging from small two–unit cottages to a large main building housing a restaurant and offices and also a large yacht operations building with public sanitary facilities for yachtsmen and other users. The wastewater from the compound was treated by septic tanks and a package plant was also severely undersized for its intended use, resulting in poorly treated effluent being discharged into the Bay.

The tertiary treatment plant designed for the project included a system for solids removal from the sewage, sludge separation (Imhoff tanks), followed by a series of filter beds covered with reeds as final treatment. It was intended to modify the sewer system to flow to the Imhoff tanks and sampling for various parameters would have been conducted by

CEHI, at various steps in the treatment process and at various times. It was intended to collect samples at the following points:

- Prior to sludge separation (before Imhoff tanks);
- Immediately after sludge separation;
- After each reed filter bed;
- In the receiving environment (Marigot Bay).

Had this project been realized it would have provided a model for the low cost treatment of liquid waste in St. Lucia providing high quality effluent. Specific advantages of this type of treatment system included:

- Minimum smell of obnoxious odors;
- High $BOD_{5,}$ nutrients, pathogens, removal;
- Minimum energy demand;
- No technical equipment;
- Low maintenance cost;
- Low dependence on existing solid conditions;
- Complete treatment plant for 'grey' and 'black' water.

Such a project demonstrate how low cost technology can be used to improve the quality of wastewater entering the environment in the vicinity of tourism oriented facilities.

4.12 Impacts of Wastewater on Caribbean Health & Tourism (CEHI, 1998)

Threats to drinking water supplies from inadequate sewage disposal are known universally and the Caribbean and OECS sub-region are no exception. Few cities of the OECS treat municipal sewage before discharging into the sea and where it is treated, it is often inadequate to prevent biological contamination. Additionally, untreated or poorly treated sewage is discharged into rivers, freshwater courses and into the sea via short outlets from hotel operations which line the coastlines. The public health concerns associated with this malpractice are skin, ear, nose and throat (ENT), enteric infections due to contact with the waters during recreational use or extraction of fish for consumption.

The impacts of the wastewater on the marine and coastal environments of our region are of grave concern to the tourism industry which depends so heavily on this resource. In fact, it is the tourism industry which concentrates large volumes of visitors and resident in the coastal zone generating waste that pollutes the very resource on which it depends. This necessitates appropriate management of liquid waste to maintain the environmental integrity of the product marketed. However, the reality of the situation differs distinctly from the ideal in that the most common scenario is typified by tourist resorts maintaining their own collection and treatment facilities.

These plants do not comply with the criteria for good operation due to:

- Application of technologies that require high levels of skilled human resources and energy input in operation and maintenance;
- Inadequate operating skills and limited understanding of treatment processes and insufficient process monitoring;
- Insufficient time operation to operation and maintenance;
- Insufficient operational support through operation and maintenance contracts;
- Insufficient funds allocation;
- Inadequate disposal facilities for excess sludge.

Beach sampling in the OECS have produces varying results, alarming in some cases while encouraging in others. Specific beaches in St. Kitts, Antigua and St. Lucia have been found to be contaminated and unsafe for bathing, constituting a substantial public health risk. Significant improvements in the quality of the beaches after the implementation of the sewage projects have been noted. This is seen in the Grand Anse Sewerage Project in Grenada and the Rodney Bay Sewerage Project in St. Lucia. Levels of pollution have been reduced to such an extent that beaches, which a few years ago were considered unsafe for bathing, are now found to have negligible levels of bacteriological contamination.

there is no doubt that wastewater present a serious risk to human and the environment and the realization have resulted in major investment in sewerage works in a number of OECS countries. Partnership is critical if efforts to address the problems caused by wastewater are to be successful. Investments are needed by both Government and the private sector, including manufacturing plants and hotels. The investments include not only in infrastructure (e.g. treatment plant operators) but also in human resources, both at the operational level and the regulatory level (e.g. Environmental Health Inspectorate). Additionally, it is necessary to establish and/or implement effluent standards for wastewater discharges and strengthen the instructional and regulatory mechanism to allow for improved enforcement and compliance monitoring.

4.13 Papers and Proceedings from Regional Conferences

4.13.1 Near-Zero Discharge Systems: Low Cost, Advance Technology for Caribbean Water and Wastewater (Bullock, 1994).

This paper presents a concept for on-site systems including "underwater reversing sand filters" for sink and washing drainage followed by aeration and reverse osmosis. The intended use of this system is to treat household grey water for return to potable use. A separate, smaller system would be used for toilet water to prepare it for soil absorption or discharge into receiving water.

4.13.2 Coral Reefs, Sewage and Water Quality Standards (Goreau, 1994).

This paper presents summary data on the damage done to coral reefs by eutrophication of the coastal zone, soil erosion, high temperatures, sport divers, and overfishing. The author reports from a perspective of 35 years of study of the ecology of coral reefs in Jamaica. The author finds that eutrophication (excess nutrient fertilisation) of coastal waters has caused a dramatic withdrawal of coral reefs. Reefs which formally had more than 95 percent live coral are now more than 95 percent covered by algae. The author reports that rising nitrate and phosphate concentrations in the coastal waters have had a direct effect in this conversion to a less desirable ecology.

4.13.3 Impacts of Wastewater on Caribbean Coastal and Marine Areas (Archer, 1994).

This paper presents an overview of sewage pollution problems faced by the Caribbean region including algae deposition on sea-grass beds, coral reef damage, and reduction in fisheries. The potential for amelioration of these problems by nutrient removal from sewage effluent and installation of long marine outfalls is discussed.

4.13.4 Sand filtration Treatment of Domestic Wastewater aViable Option in Complex Areas (Monroe 1994).

This paper presents a discussion of potential solutions to the pressing problem of nitrate contamination of ground water supplies by septic tank effluent. A series of alternatives are considered including:

- Evapotranspiration beds
- Intermittent sand filters
- Aerobic systems
- Total retention, and
- Overland flow system

4.13.5 Developing Alternative Approaches to Urban Wastewater Disposal in Latin America and the Caribbean (Bartone 1984)

These two papers provide good overviews to wastewater disposal in the Caribbean. The authors mention such possible waste treatment technologies in the WCR as submarine outfalls with minimal pre-treatment, treated effluent reuse for irrigation and other "unconventional" technologies for urban slum sanitation. They also mention current problems in setting water quality standards. Too often, the regulatory agencies in Latin America and the Caribbean attempt to define a set of standard based on water usage or classification. This approach has not worked well because of its inflexibility, its failure to correlate water quality with discharges, and its disregard of economic issues.

4.13.6 Report on a Rapid Assessment of Liquid Effluents from Land Based Sources in Trinidad and Tobago (IMA, 1992)

This report contains a detailed survey of pollutant loads and sources in Trinidad and Tobago's coastal waters. The report identifies oil refineries, livestock farms, food and chemical processing industries, and domestic sewage as the main BOD sources in coastal waters.

4.13.7 History and Application of Microbiological Water Quality Standards in the Marine Environment (UNEP 1994)

This report provides a historical perspective of the development of water quality standards in the United States and the effect of this development on water quality standards in other countries. Water quality guidelines for the United States and a few Central American countries are listed. The author points out that most WCR countries with national water quality standards adopted them from U.S. standards, with minimal consideration given to the economic situation and priorities of the adopting country. The author feels that planners must "conduct a thorough review of the prevailing local water quality guidelines/standards (if any exist) to ensure that local economic development priorities are reasonably accounted for." Also, "the decision to design the system for other than minimum water quality standards should be supported by demonstrated need, or a state local/national policy decision." The author also introduces the controversy of whether swimming in water that is moderately contaminated with coliforms is a public health issue or one of aesthetics. Studies correlating sickness upon contact with water to quality of the water (in terms of coliform count) are reviewed.

4.13.9 Review on the Present State of Marine Pollution by Sewage and Present Monitoring and Control Practices in the Wider Caribbean" (CEPPOL 1991)

This report is an excellent review on existing wastewater treatment practices used in different countries in the region. The overwhelming trend is that most of the Caribbean is not served by wastewater collection systems with centralised treatment. For example, in the Eastern Caribbean and the Bahamas, approximately 40 percent of the population is

using pit privies, 40 percent is using septic tanks, 11 percent use connected disposal systems with centralised treatment, and 9 percent have no waste disposal facilities at all. In the WCR, many of the existing collection systems and treatment facilities are in poor state of disrepair. This review includes current monitoring programs for different countries.

5.0 Sewage Profile Survey of Soufriere

Assessing the infrastructure for Liquid Waste Management in Soufriere involved a situation analysis which constituted a profile of the current sewage disposal methods. The data and information required to determine these were acquired by the means of survey forms developed for that purpose. A household questionnaire (**Appendix 2**) was used to conduct a 'Quota' Survey among the residents of Soufriere. This involved interviewing one in every 10 houses starting from one end of the streets and alternating between the sides of the roads. A total of 28 households were surveyed.

An Organisational survey form (**Appendix 3**) was developed to capture data and information from businesses of various kinds. The relatively large hotels, institutions and industry type operations and the relatively smaller businesses such as restaurants operating in the Soufriere watershed totaling 10 were surveyed.

The extent of the survey and degree of coverage was determined and constrained by resources available.

5.1 Results from Household Survey

Findings from the household survey are presented below.

Most householders lived in excess of 26 years in Soufriere (**Figure 5.1.1**) and had a monthly income of less than XCD 3000 (**Figure 5.1.2**)

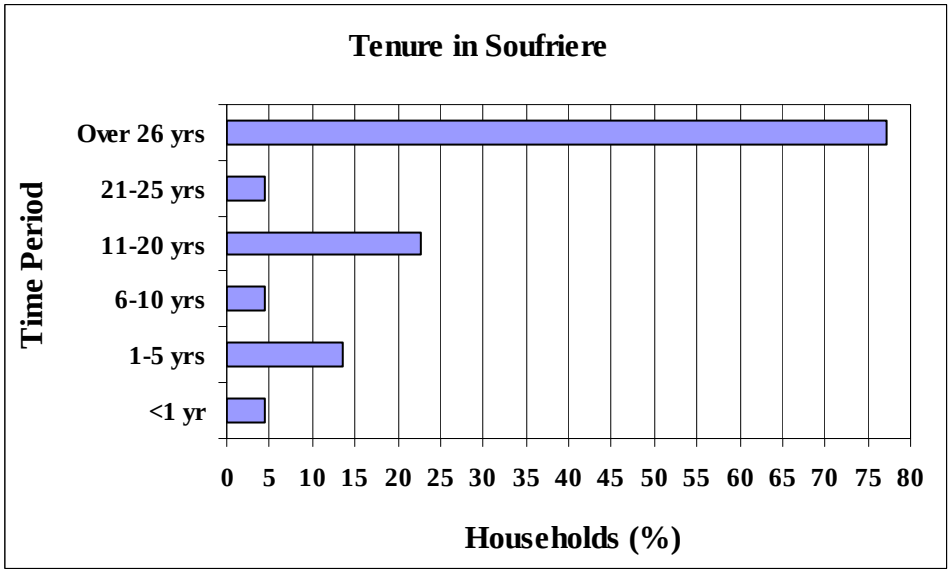

Figure 5.1.1: Tenure of Householders Living in Soufriere

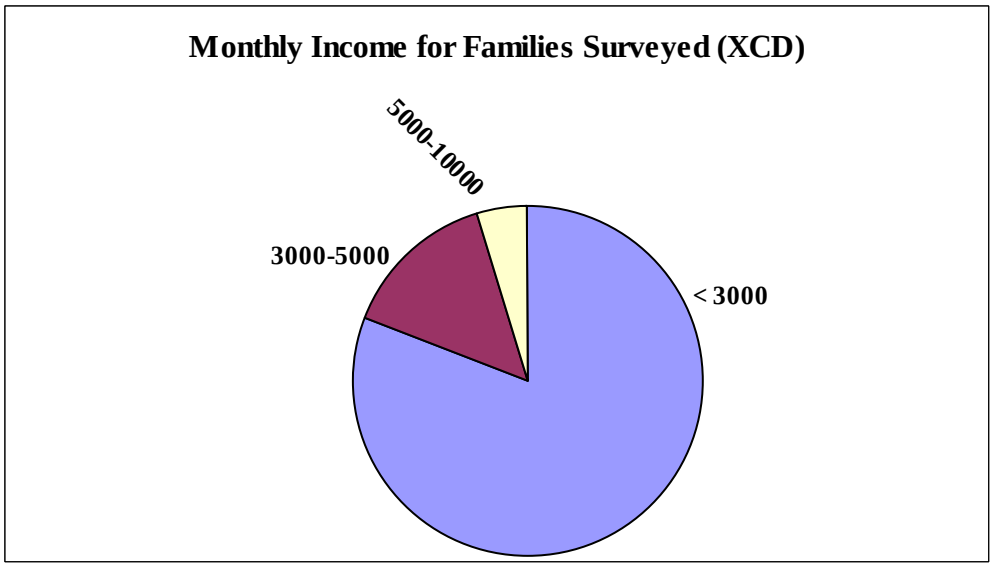

Figure 5.1.2: Monthly Income for Surveyed Residents in Soufriere

The residents had access to the public water supply, which is provided 24 hours per day with approximately 70% having connection to same.

Access to sanitary facilities are summarized and presented in the **Table 5.1.1** below.

Table 5.1.1: Access to Sanitary Facilities and Disposal of Liquid Waste

Facilities for Excreta and Bathing							
Excreta Disposal				**Bathing Facilities**			
Water Closet	Pit Privy	Pail/Bucket		Indoor	Outdoor	Communal	River
53.57%	25.00%	21.43%		60.71%	10.71%	21.43%	7.14%
Facilities for Kitchen and Laundry							
Kitchen Facilities				**Laundry Facilities**			
Indoor	Outdoor	Stand pipe		Machine	Wash Tub	Communal	River
61.86%	28.57%	3.57%		28.57%	82.14%	14.29%	10.71%
Effluent Disposal							
Black Water Disposal				**Grey Water Disposal**			
Soakaway	Pit Privy	Sea/River		Drain	Soakaway	Watercourse	Land
53.57%	25.00%	21.43%		46.43%	0%	46.43%	7.14%

The ages for the septic tank sewage treatment systems utilized by the households are shown in **Figure 5.1.3**. For these systems, 90% of the households believe that their system of sewage treatment and disposal is adequate and that at the household level 68%

(**Figure 5.1.4**) believes that nothing can be done to improve their sewage treatment and disposal systems. Some respondents think that finance, topography and space availability are the main factors limiting improvement in sewage disposal.

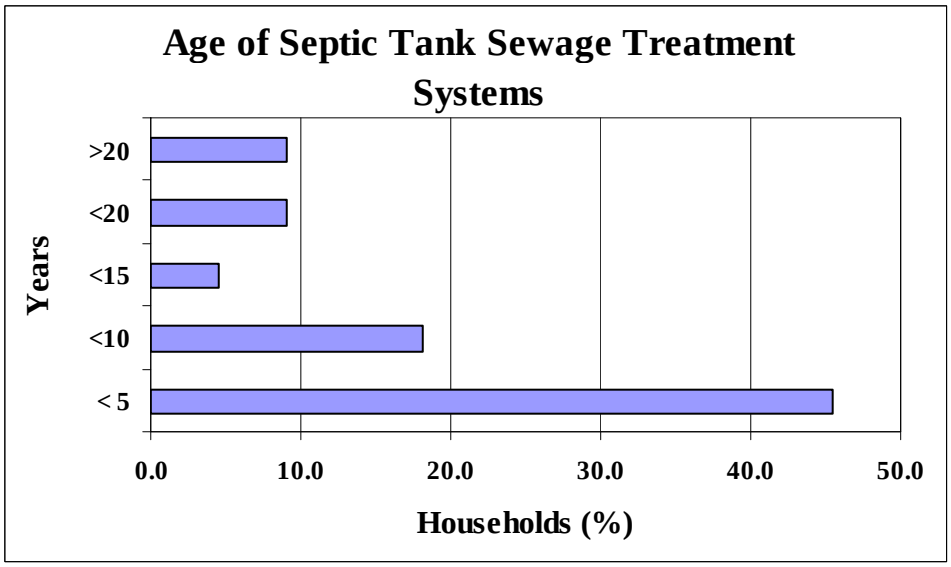

Figure 5.1.3: Ages for Septic Tank Sewage Systems

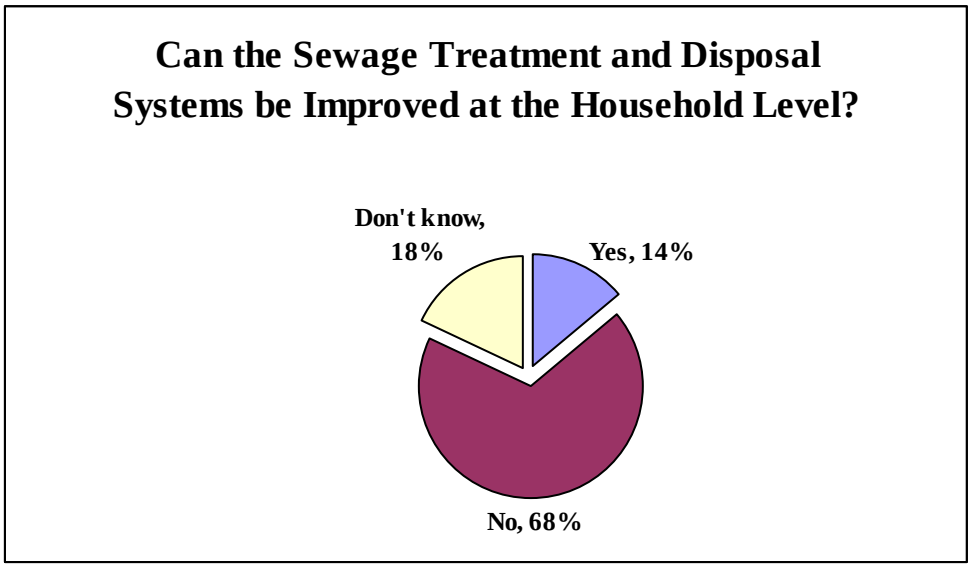

Figure 5.1.4: Can Sewage Treatment and Disposal Systems be Improved at the Household Level?

For residents utilizing the pail/bucket system of excreta disposal 100% are of the opinion that improvement in the method of excreta disposal is possible. This is basically in the form of provision of Communal Sanitary Toilet Facilities in addition to the existing laundry. The availability of space was the most common limiting factor responsible for the procurement of individual excreta disposal systems such as the Pit Privy.

Despite the provision of a refuse collection system which is accessible to all the residents, indiscriminate garbage disposal was identified as the main environmental problems in Soufriere. Additionally, the use of the river for excreta disposal and the sea for the deposition of 'night soil' were indicated to be significant sources of pollution. Better solid waste management practices with emphasis on education and public awareness and the provision of Public Sanitary Facilities were suggestions to ameliorate the situation.

An effort was made to gauge the opinion of the residents with respect to the threat to public health and the environment from the pollution of the streams and the coastal waters. **Figure 5.1.5** shows that most of the residents (50 - 65%) think that no such threats exist.

Sedimentation during torrential rains, poor agricultural practices by the use of fertilizers and pesticides and inadequate solid waste disposal practices were identified as some of the factors contributing to the threats.

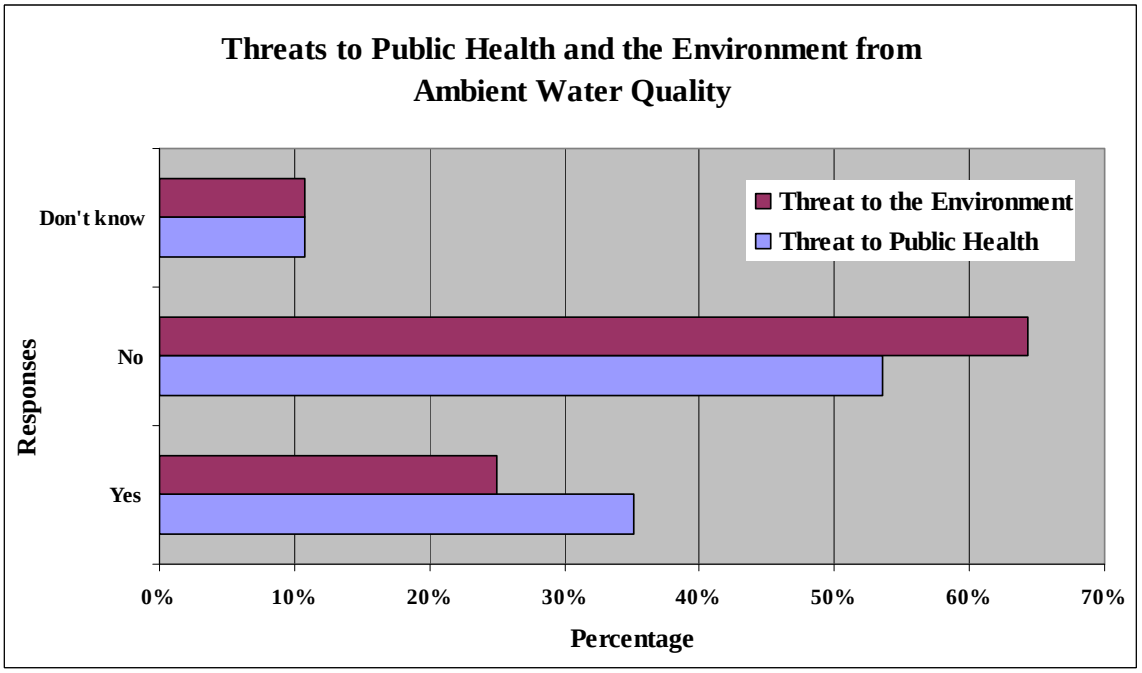

Figure 5.1.5: Threat to Public Health and the Environment from Ambient Water Quality

With regard to public health and the environment could anything be done to improve the sewage treatment and disposal systems in the community of Soufriere, the responses are shown in **Figure 5.1.6**.

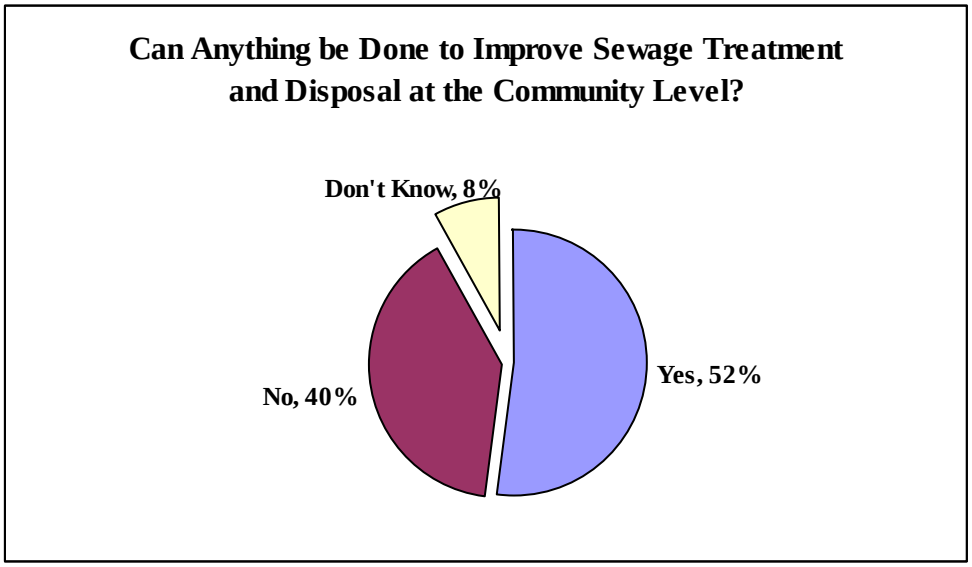

Figure 5.1.6: Can the Sewage Treatment and Disposal Systems be Improved at the Community Level?

Approximately 52% of respondents believe that measures can be employed to improve sewage treatment and disposal in Soufriere. Such actions include:

- Greater efforts to improve sanitation by the Governmental and Non-Governmentl Organisations;
- Investments aimed at increasing the number of private excreta disposal systems;
- Increasing the number of strategically placed and accessible communal systems;
- Installing of a centralized sewage disposal system to serve Soufriere;
- Increase frequency of septic tank servicing.

Some of the limiting factors to the appropriate treatment and disposal of liquid waste in Soufriere were identified as:

- Limited budgetary allocation from Government;
- Lack of financial resources;
- Land tenure and allocation of space for excreta disposal systems;
- Inadequacies in the Environmental Health Department.

Benefits to be derived from improving sewage treatment and disposal in the community of Soufriere are:

- Cleaner, healthier environment and community;
- Reduce pollution of rivers and the sea;

- Improve coastal aesthetics;
- Reduce malfunctioning septic tanks within the community;
- Increase access to acceptable means of excreta disposal by residents.

It was felt that the residents themselves, WASCO and GoSL should incur the cost associate with improved sewage management in Soufriere.

5.2 Survey Results for Institutional, Tourism and Commercial Sectors

The institutional, tourism and commercial sectors in Soufriere are characterized by the presence of schools, Soufriere hospital, hotels (including smaller guest houses), restaurants, visitor centers, and businesses. The St. Lucia Coconut Growers Association (SLCGA) factory which manufactures cooking oils is the main manufacturing plant located in the area.

All of the sectors surveyed had access to the public water supply and indoor facilities. Although the most common method of sewage disposal is septic tank with soakaway pit, very few had some measure of treatment of grey water before final disposal (**Figure 5.2.1**). Most respondents felt that their sewage disposal system was appropriate (80%) and over 90% indicated that it was in good working condition.

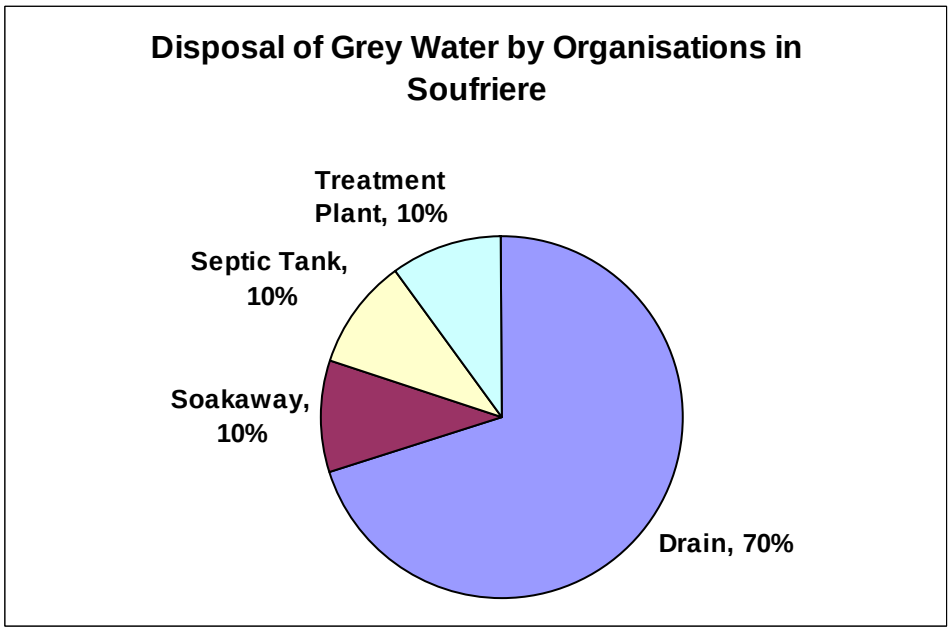

Figure 5.2.1: Method of Grey Water Disposal by Organisations in Soufriere

The efficiency of the systems used for the treatment and disposal of sewage is dependent on the initial design, operation, maintenance, substratum and age. These elements are particularly crucial to obtaining at least secondary treatment of the sewage since most of the facilities are within 50 meters to the coastline or to a down-gradient natural watercourse. The age ranges for the facilities surveyed are shown in **Figure 5.2.2**.

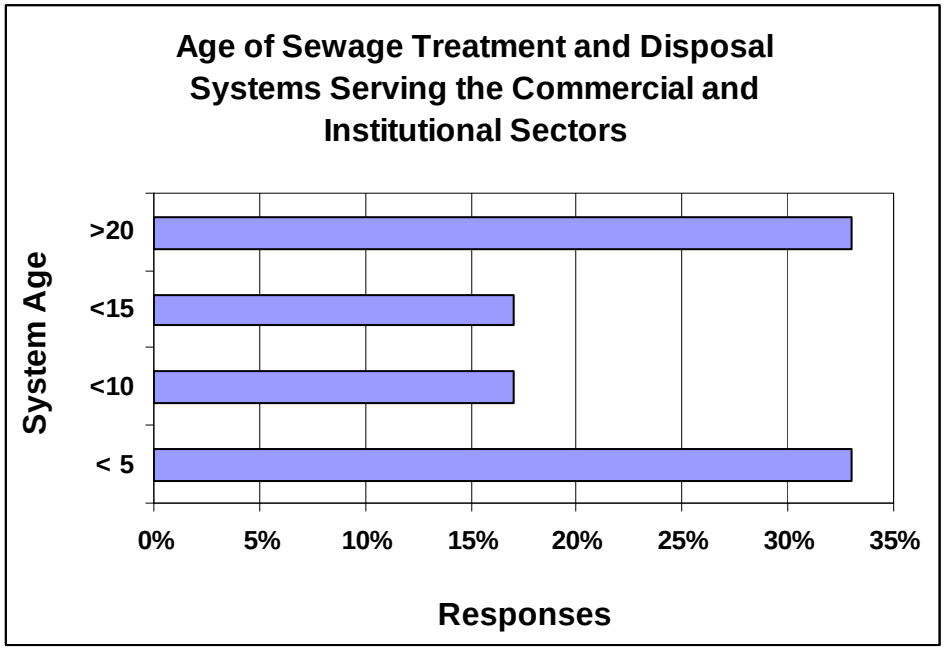

Figure 5.2.2: Age Ranges for Institutional and Commercial Sewage Treatment and Disposal Facilities

From the perspective of the resource person interviewed within the institutions and the commercial sector the following were indicated to be significant environmental problems affecting Soufriere:

- Indiscriminate disposal of solid waste particularly in watercourses;
- Sedimentation of the reef system after heavy rains due to poor watershed management practices;
- Poor excreta management practices especially among the less fortunate areas of the community.

The need for a Sewage Management Plan was expressed and the implementation of such will impact positively on the marine environment, reduce pollution and contribute to the sustainability of the resources. The private sector, residents, WASCO and the Government were identified as the main bodies that should incur the cost associated with improved sewage treatment.

6.0 Water Quality Sampling and Analyses

In an effort to evaluate the effect of sewage generated in Soufriere on the marine environment, water sampling was conducted at various points (**Figure 6.1**) along the coastline, and some freshwater bodies. Additionally, in some cases samples were collected from agencies that were surveyed to gauge the load of pollutants entering the environment.

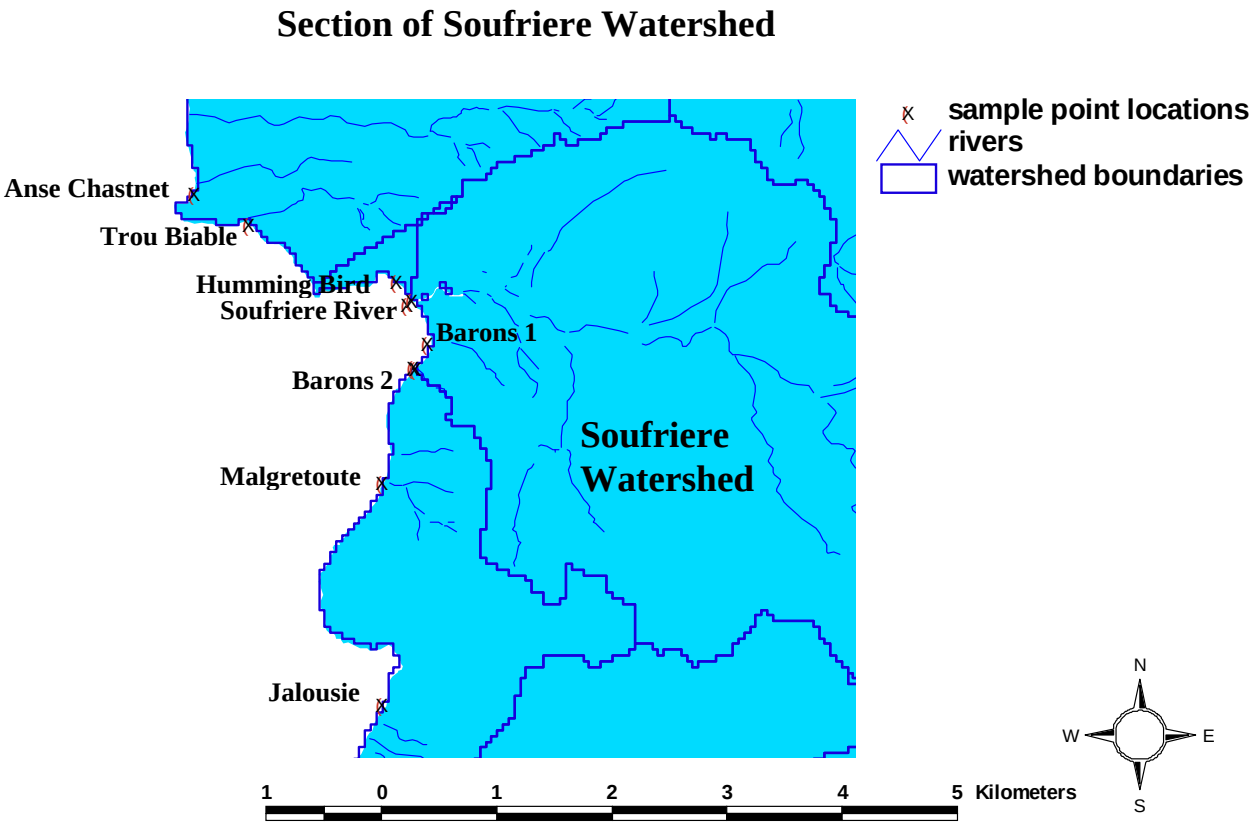

Figure 6.1: Map Showing Sample Points at Soufriere

The sample points were chosen based on the potential for influx of pollutants from land-based activities and sources. These include areas where wastewater will be discharged from Anse chastnet Hotel, Barons Drive residents and Jalousie Hotel. The receiving water in close proximity to the points of discharge of freshwater sources such as the Soufriere River and Malgretoute were also chosen.

6.1 Water Quality Analysis Results

The points of sampling and the results of the analyses conducted are presented in **Tables 6.1 (a) - 6.1(c)** below:

Table 6.1 (a): Water Quality Analyses Results - Ambient Marine Water Samples

	Ambient Marine Water Samples					
Sample Point	**pH**	**Sal (ppt)**	**Tem (^{0}C)**	**Tur (NTU)**	**DO (mg/l)**	**Enterococci (cfu/100 ml)**
Marine Samples						
Anse Chastenet	7.56	34.6	26.5	0.36	6.52	<10
Trou Biable	7.55	35.2	26.7	0.77	6.34	<10
Humming Bird	6.45	35.1	26.7	0.76	6.32	140
Off Soufriere River	6.44	35.1	26.8		6.14	210
Barons Drive 1	6.49	35.3	26.8	1.06	6.45	>800
Barons Drive 2	6.48	35.2	26.9	0.46	6.39	250
Malgretoute	7.63	35.3	26.9	0.43	6.65	6
Jalousie	6.49	35.3	26.8	0.74	6.30	<10
Standard*	**7.0-8.7**	**30-38**	**<31**	**1.5**	**6.5-7**	**35**
Standard based on Ambient Standards for Barbados						

Sal – Salinity (Parts Per Thousand)
Tur – Turbidity(Nephelometric Turbidity Units)
Cond – Conductivity (Milisemens)
DO – Dissolved Oxygen (Miligrams Per Litre)

Table 6.1 (b): Water Quality Analyses Results - Ambient Freshwater Samples

	Ambient Freshwater Samples		
Parameter	**Mouth of Soufriere River**	**Drain Barons Drive**	**Standards***
Temperature	27.0		
pH	6.62		
Salinity (ppt)	0.2		
TSS (mg/l)	8	414	Class 1-30 Class 2-150
DO (mg/l)	7.95		
BOD_5 (mg/l)	-		
Nitrate (mg/l)	3.4	0	Class 1-5 Class 2-45
Phosphate (mg/l)	0.33	5.7	Class 1-1 Class 2-10
Faecal Coliforms (cfu/100 ml)	>2,000	>20,000	200
**** Standards based on 'End of Pipe' Standards for Barbados***			

Table 6.1 (c): Water Quality Analyses Results - ***Grey Water Point Source Sampling from Agencies and Soufriere River***

Grey Water Point Source Sampling from Agencies and Soufriere River						
Sample	**pH**	**TSS** mg/l	**BOD_5** mg/l	**NO_3** mg/l	**PO_4** mg/l	**FC** (cfu/100 ml)
SLCGA	7.42	20	50	5.1	0.19	>20,000
Ladera Resort	7.71	333	460	72.3	43.20	>20,000
Sulphur Springs	7.22	23	BDL	5.7	8.70	>20,000
Soufriere Comprehensive	7.81	8	BDL	1.8	0.17	<1
Soufriere River	7.18	10	BDL	4.4	0.25	>20,000
Standard	6-9	30	25	5* 45**	1* 10**	200***
**** Standards based on 'End of Pipe' Standards for Barbados***						
**** Class 1 Waters*** ***** Class 2 Waters*** ****** Standard for Jamaica and Trinidad***						

6.2 Interpretation of Water Quality Results

Due to the relative absence of standards and guidelines specific for St. Lucia the results obtained are compared with known regional standards and guidelines that are applicable to the basis of this study. These include:

1. The Barbados Marine Pollution Control Act (1998) and Draft Marine Pollution Control (Discharge) Regulations (2005). Under this Act the University of the West Indies and New Water Inc. were given a consultancy assignment by the Coastal Zone Management Unit to develop Prohibited Concentrations for pollutants and Ambient Water Quality Standards. This action was in accordance with National Programme of Action to prevent the pollution of the marine environment as per the Cartagena Convention and LBS Protocol. These standards are particularly important to Soufriere since consideration is given to both human health on contact with the water and concentrations required for the protection of coral reefs.

2. Guidelines developed by PAHO (2001) for monitoring recreational water quality in St. Lucia. These guidelines use levels of bacteria (faecal coliforms and enterococci) as indicators of suitability of water for recreational use (CZMP/MOH, 2003).

3. USEPA Action Plan for Beaches and Recreational Waters (1998) indicated measures aimed at improving the Science that Supports Recreational Water Monitoring Programme. This document looks at raid indicators of faecal pollution, analytical methods for detecting presence of intestinal pathogens, distinguishing between human and animal faecal contamination and indicators specific to tropical climates.

4. Suggested Sewage Effluent Guidelines for the Wider Caribbean Region (CEHI, 1998) provide effluent guidelines for the discharge of municipal wastewater into coastal waters. These guidelines provide the best compromise between stringent measures which are difficult or impossible to meet given the local socio-economic and political environments and the susceptibility of humans and natural resources. This became the basis for the stipulations as per the LBS Protocol.

5. The LBS Protocol is particularly important to the assignment since St. Lucia is party to the Cartagena Convention and is in the process of making preparations to sign and enforce the Protocol. The Guidelines stipulated by the Protocol distinguishing between Class I and Class II receiving Marine Waters were summarized earlier.

Based on these standards and guidelines comparisons are made with the results obtained for the *in situ* sampling. Observations made are summarized in **Tables 6.2 (a) - 6.2 (c)** below:

Table 6.2 (a): Interpretation of Water Quality Results - ***Ambient Marine Water Samples***

Ambient Marine Water Samples	
Parameter	**Observations**
pH	• Values are within Guidelines set for Class I Waters as per the LBS Protocol
Salinity	• Values are within the Standards and Guidelines
Temperature	• Values are below the threshold implicated in Coral Bleaching
Turbidity	• Samples arebelow threshold level
DO	• Values are within acceptable levels
Enterococci	• Samples taken from Humming Bird, Off Soufriere River and Off Barons Drive exceed acceptable levels

Table 6.2 (b): Interpretation of Water Quality Results - ***Ambient Freshwater Samples***

Ambient Freshwater Samples	
Parameter	**Observations**
Temperature	• Values are within Guidelines set for Class I Waters as per the LBS Protocol
TSS	• Sample taken for Barons Drive area exceeds limits for Class I and Class II Waters

Nitrate	• Concentration at the Mouth of Soufriere River exceeds limit for Class I Waters
Phosphate	• Concentration in Drain at Barons Drive exceed limit for Class I Water
DO	• Values are within acceptable level
Faecal Coliforms	• Samples significantly exceeds the known guidelines and standards

Table 6.2 (c): Interpretation of Water Quality Results - ***Grey Water Point Source Sampling from Agencies and Soufriere River***

Grey Water Point Source Sampling	
Parameter	**Observations**
pH	• Values are within guideline
TSS	• Sample taken form Ladera Resort exceeds guideline value
BOD_5	• Values for SLCGA and Ladera Resort exceed threshold for Class I Water
Nitrate	• Concentration at the Mouth of Soufriere River exceeds limit for Class I Waters
Phosphate	• Ladera Resort and the Sulphur Springs samples exceed limit for Class I water
Faecal Coliforms	• Samples significantly exceeds the known guidelines and standards except in the case of the sample taken from the Soufriere Comprehensive School

6.3 Discussion of Water Quality Monitoring Exercise

The Water Quality Monitoring conducted as part of the Soufriere Sewage Assessment Project was used to provide a background of environmental quality and generate hard data that mirrors observations of existing liquid waste disposal observations. The following should be noted:

- Sampling points were chosen in the receiving waters close to the entry of intermittent or permanent freshwater sources, and land-based point sources of liquid waste effluent;

- Sampling was conducted during the month of February which signifies the dryer period of the year and minimum influence of land-based pollution influx;

- Test for Nitrates and Phosphates were not conducted for the marine samples since historical data indicated that such will be below 'Detection Level' for the laboratory techniques to be used;

- Based on accepted microbial ecological factors, Faecal Coliforms were the preferred microbiological indicator for freshwater samples and Enterococci were used as the indicator for marine samples;

- Biochemical Oxygen Demand was not conducted for marine samples due to equipment malfunction;

- Some physio-chemical parameters were not measured for the freshwater source at Barons Drive due to the poor appearance of the water;

- Freshwater bodies such as the Soufriere River and Barons Drive Stream were treated as point sources of pollution to the marine environment and provided dilution for the raw liquid waste plumes from individual sources;

- Septic tanks with soakaway pits formed the basis for treatment and disposal of 'black water' for the households, businesses and institutions eliminating the possibility of obtaining a sample of the effluent.

Because of the rich ecological base, existing marine habitats, food production capacity, recreational use and tourism generating potential the marine waters of Soufriere up to the 200 Meter contour seaward should be deemed Class I waters. This is based on the LBS Protocol stipulation and a geological delimitation scheme used in Barbados where consideration is given to the existing bank reef straddling the entire west coast of the island. This rationale allowed for the consideration of all the waters within the sampling exercise to be deemed Class I and comparison of the results were made principally with standards and guidelines set for such receiving environments.

7.0 The Barons Drive Situation

In shadows of St. Lucia's world famous Pitons geological feature bordered by the steep hills on the east side and the turquoise Caribbean Sea on the west side is the socially and economically less fortunate locality of Barons Drive (**Figure 7.1**). Typified by poor quality housing, unsanitary residential environment **(Figure 7.2)**, the management of sewage and excreta within this area warrants special mention.

Figure 7.1: Locality of Barons Drive, Soufriere

Figure 7.2: Unsanitary Conditions at Barons Drive

As part of the survey for the project, a visit made to the area revealed the following:

- Most of the residents fell in the low income bracket and lived in the area for considerable periods (>26 years) or all their life;

- A high population of children and in some cases overcrowded households were evident;

- A communal laundry and the public stand pipe was provided by the Soufriere Regional Development Foundation (SRDF) but the communal toilet facility is non-functional and dilapidated;

- Lack of basic individual sanitary facilities is propagating the pail/bucket system for excreta disposal;

- The 'night soil' is deposited in the sea directly opposite households which are also the receiving waters for the influx of pollutants from the drains;

- Poor drainage have resulted in stagnated grey water creating anoxic conditions and stench;

- The coastal receiving waters in the immediate vicinity is used for recreational purposes especially by children (**Figure 7.3**);

- The residents are of the opinion that the method of excreta disposal is of public health and environmental concerns but indicated that space and financial constraints are limiting factors at the household level to ameliorate the situation;

- At the community level the residents indicated that the SRDF and Town Council can assist with the refurbishment and management of the communal toilets which will improve the situation;

- Generally, residents expressed a feeling of disenfranchisement, marginalisation and existence in a state of economic stagnation all their life.

Figure 7.3: Recreational Use of Marine Area in Barons Drive

8.0 Framework for Compliance for Liquid Waste Disposal in Soufriere

The basis for determination of the level of compliance is premised on three legal instruments which are:

- Water and Sewage Act (2005);
- Public Health (Sewage and Disposal of Sewage and Liquid Industrial Waste Works) Regulations (1978);
- Public Health (Disposal of Offensive Matter) Regulations 1978.

The Water and Sewage Act (No. 14 of 2005) established the Water Resources Management Agency in St. Lucia for the purpose of managing water resources and also addresses the issue of Waste Control. Division 5, Section 24 stipulates Waste Control Areas and Permits. This Section states:

> *24 (1) Where on the advice of the Agency, the Minister is satisfied that the regulating of the discharging of wastes or classes of wastes or classes of wastes into or on –*
>
> > *(a) any land;*
> > *(b) any sewer or drain;*
> > *(c) any bore; or*
> > *(d) any water;*
>
> *Is necessary to protect the water resources from pollution or reduction in water quality, the Minister shall by order published in the Gazette declare the area to be a waste control area.*
>
> *(2) In exercising his or her authority under sub-section (1), the Minister shall have regard to the factors listed in section 23 (2) (*such as the ecology, hydrology and hydrology of the area*), and to the necessity of protecting the health of the public and the requirements of established and intended uses of water resources, including protection of the fauna and flora of watercourses and he or she shall also have regard to the desirability of protecting and enhancing the environment.*
>
> *(3) An order pursuant to sub-section (1) shall specify the boundaries of the waste control area and the waste or classes of waste required to be regulated.*
>
> *(25) (1) A person shall not use water in a water control area or discharge waste or a class of waste in a control area, except in accordance with a permit for the purpose granted to that person by the Minister under this Division.*

(3) A person who contravenes sub-section (1) commits an offence and upon summary conviction is liable to fine of not less than three thousand dollars or to imprisonment for a term of not less than six months or to both and to a further fine of not less than fifty dollars for each day during which the offence continues.

The Public Health (Sewage and Disposal of Sewage and Liquid Industrial Waste Works) Regulations is administered by the Public Health Board and is responsible for the enforcement of these regulations due to the absence of a specially appointed sewage authority. Specified areas are:

- Discharge of effluent, permission and application for discharge and the prevention of nuisances, offensive or deleterious situations;
- Sewage and Industrial Effluent Discharge into Coastal Waters;
- Applications;
- Requirements for sewage systems for individual lots in particular the septic tank and soakaway systems;
- Operation and maintenance of sewage system including the septic tank and the responsibility of the Public Health Inspectors.

The application for the construction of an individual sewage treatment and disposal systems, which is the septic tank and soakaway system, is to the Public Health Board through the Development Control Authority simultaneously with the application for the construction of a property. The application is reviewed and stipulation such as the distance from a watercourse, geology and technical design are evaluated. On granting of approval the Public Health Inspectorate perform field visit to assess the suitability of the location for the construction of the system before recommending approval.

Notwithstanding the odd cases of circumvention of the legal and administrative regime, the more affluent members and businesses of the community of Soufriere more or less adhere to the requirements for sewage treatment and disposal. This is basically in the form of septic tank and soakaway systems which is approved by the Public Health Board. However, the onus for the operation and maintenance of these systems rest with the householders and businesses and this is not always given priority. Additionally, the lack of resources and manpower by the Health Department do not allow for periodic scheduled surveys of these systems and enforcement of the Regulations.

The Public Health (Disposal of Offensive Matter) Regulations 1978, covers among other aspects:

- Restrictions of deposit of filth night soil;
- Hours for the carriage and deposition of the filth night soil;
- Restriction on the discharge of effluent into sea from public sewerage;
- Restrictions discharge of effluent from private sewerage system.

The site of deposition of night soil and sewage effluent from a private or public source must be approved by the Public Health Board and must be marked by signpost. In fact, according to the Regulations, any place of human habitation must contain suitable sanitary convenience which includes:

- A water closet;
- Pit latrine;
- Earth closet;
- Chemical closet;
- Pail latrine.

The sewage from a water closet may be disposed into a public or private sewerage system, a suck well or cess pit, a septic tank or into the sea with the prior approval of the Medical Officer of Health. Furthermore, the discharge from any sewerage disposal system into the sea must be approved by the Public Health Board.

St Lucia has ratified the Cartagena Convention and is in the process of making preparations to sign and enforce the LBS Protocol. This means that effluent to be discharged after the entry into force of the Protocol will have to comply with the limitations for the Class I or Class II Waters (Section 2.3 above).

9.0 Recommendations for Liquid Waste Management in Soufriere

9.1 Recommendations for Obtaining Compliance

The following are recommended for attaining compliance for liquid waste treatment and disposal within the legal, administrative and regulatory framework:

- Mandatory site visits by the Environment Health Department (EHD) of the Ministry of Health prior to approval and before the completion of the sewage treatment and disposal system for buildings and homes. At such visits technical advice and directions should be provided by Environmental Health Officers (EHOs for the proper construction of the systems to ensure compliance;

- Conduct biannual inspections of individual sewage treatment systems to ensure that measures required for the proper functioning of such systems are enfoirced;

- Develop a ckecklist for self-inspection and assessment for household and commercial sewage treatment and disposal systems and implement a system for self-inspection and assessment by householders and managers of commercial sewage treatment and disposal systems;

- Conduct house to house inspection throughout Soufriere concentrating on specific less fortunate localities such as Barons Drive, to obtain data required for the formulation of a plan to manage sewage and excreta;

- Identify all households without appropriate and approved excreta and sewage disposal systems and assess the measures necessary to obtain compliance on an individual basis;

- Formulate and implement a plan and strategy for attaining compliance within the framework of the legal instruments covering sewage and excreta disposal at the level of the household; The development and implementation of the strategy and plan should involved governmental and non-governmental resource management organisations, development and social services agencies such as the SRDF, Town Council, SMMA, Ministry of Social Services, Ministry of Agriculture, Ministries of Works, Health, the Environment and Tourism among others.

- Assess the possibility of relocating residents in the congested low–income localities and provide where necessary assistance in obtaining better housing and suitable sewage disposal systems for these residents;

- Implement a programme to gain commitment and support from the political directorate to enhance the standard of living and general residential environment of the town of Soufriere with special emphasis on the less fortunate localities;

- Ensure that the SLCGA, the largest manufacturing plants in Soufriere, in addition to treating its sewage also treat its 'grey water' to the tertiary level before discharge into the environment;

- Conduct a feasibility study for the installation of a sewage treatment and disposal plant that will produce high quality effluent within the national standards and the stipulations of the LBS Protocol for the community of Soufriere.

9.2 Recommendations for Training in Obtaining Compliance

Obtaining compliance to regulations or any instrument governing liquid waste disposal may not necessarily be obtained through enforcement. The element of voluntary compliance obtained through education, awareness building and training is always a feasible and sustaining alternative that tends to foster buy-in. If the public is not aware of what is required, not trained and educated in the technical aspects for obtaining compliance and not convinced of the need to be compliant, then enforcing the regulations will be extremely difficult.

With respect to training the following are recommended:

- Provide training for the construction and building sectors in the design, erection and functioning of the septic tanks, filtering systems, absorption pits and alternatives for attaining appropriateness (A Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquid and Hazardous Waste for SIDS in the Caribbean Region (UNEP/CEHI, 2004) provides much needed information in this regard);

- Develop a manual for the design, construction and operation of sewage treatment and disposal systems that are appropriate for use in the Soufriere community;

- Promote good liquid waste management practices among the businesses of Soufriere to build awareness and generate a sense of responsibility for protecting the environment from pollution as a result of liquid waste;

- Provide training and awareness building to the management and operators of hotels and institutions in alternative waste treatment and disposal methods and the choice of appropriate systems;

- Provide training to the technicians responsible for the operation and maintenance of the sewage treatment plants in accordance with the Sewage Treatment Operators Manual for the Caribbean Region (USAID/UNEP/CEHI, 1996);

- Provide training to the EHD in the design, construction, operation, maintenance and management of on-site and communal sewage disposal systems;

- Provide training to the EHD in the design, construction, operation, maintenance and management of package treatment plants.

9.3 Recommendations for Reducing Impacts of Liquid Waste

Reducing the potential impact of liquid waste on the marine environment warrants measures to be taken from two fronts;

- Reducing the quantity of liquid waste from point and non-point sources;

- Improving the quality of the waste reaching the marine environment from land-based sources.

In the case of Soufriere the combination of both measures are necessary to improve and sustain marine water quality to minimise the threat to the environment and public health. A comprehensive system for sewage and liquid waste management in Soufriere should consider a policy, plan and strategy for improvement that covers all sectors generating such waste together with and the socio-economic and political aspects of the community.

The results of the survey indicated that residents without adequate sanitary facilities were aware that their current methods of excreta disposal have the potential to impact negatively on public health and the environment. Most householders and businesses with septic tanks and soakaway systems were of the opinion that their systems were appropriate and the potential negative impact of their liquid waste was negligible even where large volumes of 'grey water' were discharged directly into the environment. At the level of the institution where septic tanks were used to treat the 'black water' and 'grey water' entered the public drain or natural watercourse without tertiary treatment this was deemed to be appropriate.

The residents and businesses surveyed felt that solid waste issues were the most critical in Soufriere. The greater awareness of the solid waste malaise existing and the relatively easier discernment of the problem compared to the more latent liquid waste pollution problem can be attributed for should a perception. This therefore suggests that more awareness raising and education building programmes for liquid waste management targeting all sectors of the community is necessary. This can be incorporate in the policy, plan and strategy for improving liquid waste management in Soufriere.

The following are recommended to reduce the potential impact of liquid waste on the marine environment:

9.3.1 'Grey Water' Management

The threats from the significant quantities of grey water entering the marine environment are great. Subjected to no form of treatment the 'grey water', loaded with inorganic nutrients is deposited in open drains and natural watercourses and ultimately reaches the sea. Some end of pipe sampling and analysis results shows nitrates as high

as 70 mg/l and phosphates 40 mg/l. The ambient standard for the protection of coral reefs are 2.48 µg/l for phosphate and 9.8 µg/l for nitrate.

For household constructed with individual sewage treatment systems, it should be mandatory that all wastewater be subjected to primary and secondary treatment in a septic tank. Hence, the design and construction of septic tanks should take into consideration the necessity for a grease traps, increased associated wastewater flow rates and a tanks of suitable dimensions and capacity.

9.3.2 'Black Water' Management

The measures necessary for attaining compliance to the Public Health Regulations should be adhered to in the granting of approval for the construction and operation of a septic tank. The design of all individual sewage disposal system should be approved and the construction of all such systems should be monitored to ensure adherence to the approved design. This will allow for the efficient functioning of the system and obtaining the appropriate retention time necessary for the treatment process to be effective. This will allow at least secondary treatment of the sewage before final discharge to the environment.

9.3.4 Appropriate Disposal of Effluent from Household Sewage Disposal Systems

Individual sewage disposal systems, consisting of mainly of septic tanks and soakaway pits, were the most common in Soufriere. These may constitute a direct point source of pollution when the system malfunction and overflows in cases of properties located close to the shoreline or water courses. Even when such systems function efficiently they may still pose a non-point source of pollution if the are located near to the shoreline or water courses since there is percolation of the effluent into the soil which can get into the watercourses and coastal waters. Overflowing system allows the pollutants to reach the marine environment during direct washout or via natural water courses. In this case the raw untreated or partially treated liquid waste is dumped into the sea.

Percolation into the soil by the effluent of the treatment systems allow for some measure of natural treatment, attenuation, absorption by plants, adhesion to soil particles, dilution and dispersion before entering the marine environment. In this case the less concentrated pollutant may have lower impact or reduced degrading effect due to lower potency. However, the continuous influx of this low concentration pollutant can have a more delayed impact which may be realised in the longer term.

Ensuring the pollutants reaching the marine environment has minimal negative impact and consequently of the highest quality, measures should be taken to obtain the maximum treatment possible. Due consideration should therefore be given to:

- Distance from and gradient to the nearest natural watercourse or the sea;
- The hydrogeology of the area containing the treatment and disposal systems;

- The level of treatment that can be requested or stipulated within the socio-economic and political climate;

- Ratifying and enforcing the requirement of the LBS Protocol to meet its international obligations for the protection of the marine environment from land-based sources of pollution;

- Declaration of the marine space of Soufriere up to the 200 meter bathymetric contour as Class I waters under the LBS Protocol and enforcing discharge standards for the effluent entering this receiving environment;

- Application of root zone treatment to attain tertiary level treated effluent migrating within the substratum by the use of appropriate vegetation to aid in the extraction of inorganic nutrients;

- Where soil is unsuitable to allow required percolation needed for the proper functioning of the absorption pit or where the water table is high, tertiary treatment of the effluent should be requested and enforced.

9.3.4 Appropriate Disposal of Sewage from the Commercial, Tourism and Institutional Sectors

Appropriate disposal of sewage from the commercial, tourism and institutional Sectors is also needed for Soufriere. The commercial sector in Soufriere refers to businesses such as stores, restaurants, bars, and shops; the tourism sector refers to visitor reception and recreational facilities while the institutional sector refers to schools, places of worship and medical facilities. The Public Health Regulations governing liquid waste require that all such premises provide for sufficient, suitable and adequate sanitary facilities and sewage treatment and disposal systems. These places are of particular interest to any plan and strategy for the management of sewage and liquid waste since they concentrate people in confined areas and hence generate relatively larger volumes of sewage. Some of these sewage treatment systems have their biologically treated effluent entering natural water courses and all of their 'grey water' entering either the public drain or a natural watercourse.

With specific reference to the commercial, tourism and institutional sectors the following are recommended:

- Conduct an assessment of the sewage treatment and disposal facilities ;

- Identify areas for improvement and retrofitting to enhance the level of treatment required, including cost effective alternatives where necessary;

- Working with all these premises, develop a programme to enhance the quality of the liquid waste through a simple tertiary treatment system such as a sand or charcoal filter;

- Develop an operations manual for the sewage treatment and disposal systems and educate the operators in the use of the manual;

- Develop inspection forms for specified periods as deemed necessary and have them issued and checked by the EHD;

- Ensure that all 'grey water' from these premises are subjected to treatment prior to final disposal;

- Develop and implement a programme for voluntary improvements in the sewage treatment and disposal systems with emphasis placed on ensuring that the Government operated institutions adhere to the same guidelines;

- Heightened vigilance by the EHD and SDEU in monitoring the level of voluntary enhancement in sewage treatment and disposal and determine the necessity for the amendment of the Public Health Regulations to reflect what is required;

- Ensuring that enterprises such as the Fishing Complex (**Figure 9.3.4.1**) and abattoir which generate large volumes of 'grey water' are fitted with simple means of tertiary liquid waste treatment systems to generate a highly polished effluent before final disposal.

Figure 9.3.4.1: Soufriere Fishing Complex

9.3.5 Enhancing the Socio-Economic Status of the Less Fortunate Residents of Soufriere

Enhancing the socio-economic status of the less fortunate residents of Soufriere is a critical element for the reduction of pollution from liquid waste. Integrating the human element in the management and conservation of the coastal and marine resources was not adequately considered in the Management Plan of the SMMA or the Management Plan for the Pitons Management Area. This is a critical element to ensure that the financial gains from the non-extractive use of natural resources trickle to the grass-roots residents of the area either directly or through the multiplier effect. This will reduce the feeling of marginalisation among the residents by the agencies and investors, who market, sell and generate significant revenue from the natural resources that are of symbolic value to St. Lucia and to which they have a birth right.

- Improving the socio-economic status of the residents of Barons Drive so that they can improve their standard of living at the household level and manage their liquid waste on an individual basis in the long-term;

- In the short-term, refurbish the communal sanitary facility existing within Barons Drive and establish a management and operation system to prevent the abuse and vandalisation of the premises;

- Integrate the human element into the development and management plans for Soufriere and ensure that the improvements in the facilities provided for visitors and enhancement in the infrastructure to facilitate the ever increasing tourist arrivals are paralleled with the socio-economic advancement of the less fortunate residents;

- Promote alternate forms of livelihood to that of extraction of the natural resources among the less fortunate residents of Soufriere so that they can benefit from the royalties obtained from the marketing and promotion of Soufriere as a premier visitors' attraction;

- The custodians of natural resources of the area who are entrusted with the management should allocate a small percentage of the revenue generated to be pumped back into the community at the level of the household;

- Interagency collaboration between the Governmental and Non-Governmental Organisations and the residents themselves should be promoted for the development of a policy, plan and strategy for the advancement of the less fortunate residents of Soufriere.

9.4 Recommendation for Chaetomorpha aerea Monitoring

Chaetomorpha aerea, (**Figure 9.4..1**) a green algae thrive in the intertidal zone of the coastline and grow and flourish in nutrient rich waters. They uptake the inorganic fertilizing nitrogen and phosphorus contained in pollutants of which land-based activities are the major source. Hence, they provide an indication of nutrient laden waters and monitoring their abundance and proliferation in the coastal habitats can give an indication of pollution from nutrients.

http://www.horta.uac.pt/Species/Algae/Chaetomorpha_aerea/Chaetomorpha_aerea.htm

Figure 9.4.1: Green Algae *Chaetomorpha aerea*

The influx of 'grey water', effluent from sewage treatment and disposal systems and direct discharge of excreta are all nutrient rich and hence the proliferation of C. aerea is a suitable indicator of pollutant loading.

The method of monitoring of the green algae is as follows:

1. Establishing the sites to be monitored

The procedure for the establishment of the monitoring sites involves:

- Review of the map detailing the area managed by the SMMA (**Figure 9.4.2**) and determination of the sites of potential pollution from land-based to sea-based activities. This will involve a determination of the areas to the immediate north and south of the point sources of pollution such as the outfall of the Hilton Jalousie sewage treatment plant, the mouth of the Soufriere River, the mouth of the major stream at Barons Drives. It should be noted that for the purpose of this

study rivers and major drains are classed as point sources of pollution to the marine environment.

Figure 9.4.2: Area Managed by SMMA

- Determination of point of influx of pollutants outside the geographic demarcation of the SMMA that may influence the marine habitats existing within the SMMA and designating additional monitoring sites. This may extend to Canneries in the North and Choiseul in the South.

2. Procurement of Monitoring Equipment

The equipment required for the monitoring includes:

- 10 meters tape measure;
- 50 x 50 cm quadrats (metal or PVC);
- GPS receiver;
- Water resistant paper or ruled slates;
- Clip boards;
- Pencils.

3. Establishing Permanent Transects at each Monitoring Site

Line transects for the monitoring should be of a graduated tape measure (metric) with a minimum length of 10 meters or a line marked at 1 meter intervals. A minimum of 5 permanent 10 meters transects should be established at each monitoring site:

- One transect should be established at the intertidal directly in line with the point source of the pollution and two to the north and two to the south;

- All transects must be parallel to the shoreline and within the splash zone;

- Marking the start point of each transect running parallel along the shoreline by a GPS waypoint.

- Marking the end point of each 10 meter transect line running parallel along the beach by another waypoint;

- Noting the start and end waypoints for each transect and renaming them in the GPS by site;

- Allowing a minimum distance of 2 meter between each end of one transect and the start of another;

- The waypoint should be coded indicating the location and specifying whether start or end of a transect, for example transect 1 of a monitoring site on the north of the Jalousie sewage treatment plant outfall can be named JLN1S;

- A record of metadata (**Appendix 4**) should be kept containing monitoring sites, codes used to mark the start and end of the transects, the coordinates for all the waypoints and the interpretation of the codes;

4. Data Collection along Transect using Quadrat

The 50 x 50 cm Quadrats should be used to collect the percentage coverage of the C.aerea within the quadrat:

- Ensure that the transect line is fully stretched;
- Estimate percentage cover of the algae within the quadrats placed at 5 points along the transect line;
- Quadrat 1 should be placed on the transect line so that the 1 meter mark is in the middle of the quadrat;
- Subsequent quadrats should be placed sequentially and directly over at the 3, 5, 7 and 9 meters mark so that each of these marks fall in the middle of the quadrat (**Figure 12.3**);
- Record percentage algal cover for each quadrat on a data entry form (**Appendix 5**);
- Enter the data in accordance to the form on an excel spreadsheet on returning to Office.

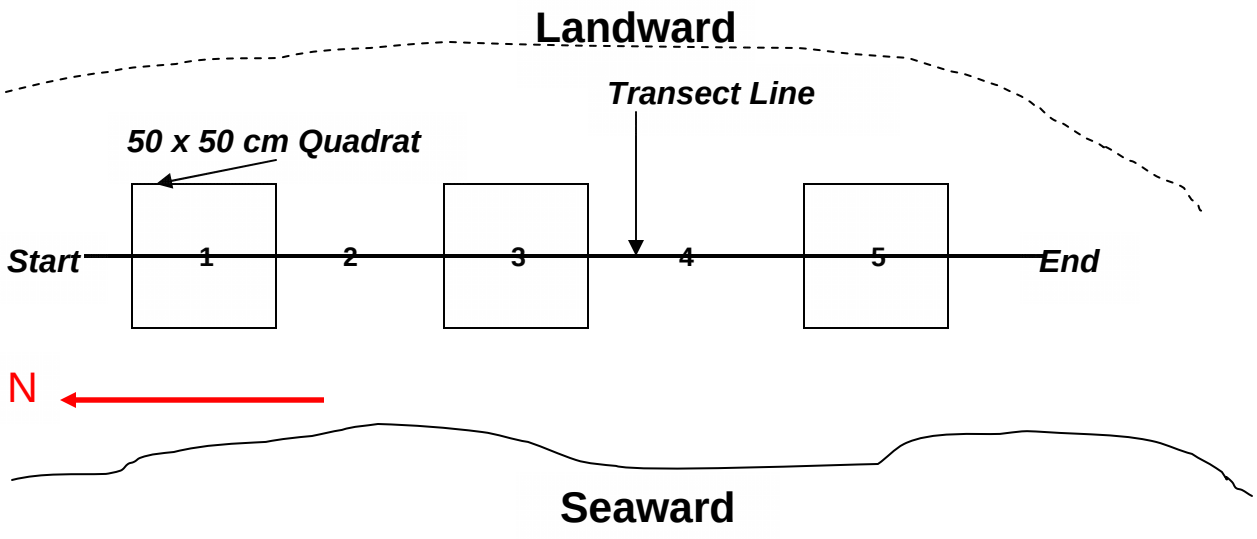

Figure 9.4..3: Position of Transect Line and Quadrat at Monitoring Site

5. Monitoring Schedule

Monitoring should be conducted monthly so that the influence of seasonality can be captured. This is important because the influx of pollutants from the land can vary with the seasonal freshwater run-off, visitor penetration ratio and occupancy level from the major hotels. Additionally, this will allow for the influence of variation in the assimilative capacity of the receiving waters due to changes in physical oceanographic factors which can then be accounted for.

The monthly monitoring should be done within a specified week of the month. If the first week of the month is the preferred time for the activity, subsequent repeats should also fall within the first week of succeeding months. Similarly the second week can be used for the collection of field data.

6. Analysis of Data

The data collected should be used to:

- Graphically plot the proliferation or reduce abundance of the *C. aerea* algae for sites and over time periods;

- Conduct time series regression analysis for determination of the temporal increase or decrease abundance of the algae (**Appendix 6**);

- Conduct statistical significance testing such as analysis of variance for differences between site and over time (**Appendix 7**).

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APPENDIX 1

Proposal and TOR

Sewage Needs Assessment for Soufriere

Proposal to Soufriere Marine Management Authority (SMMA)

TITLE OF SUB-PROJECT:	**Assessment of the Infrastructure for Improved Wastewater Management in Soufriere**
PROPOSER AND IMPLEMENTING ORGANIZATION:	**Caribbean Environmental Health Institute (CEHI)**
COLLABORATING AGENCIES:	**SMMA, OECS-ESDU, SRDF**
PROJECTED SUB-PROJECT COST	**US$ 5,500.00**
PURPOSE:	**Determine the level of compliance for the disposal of wastewater in Soufriere and formulate recommendations based on legislative, administrative and policy framework for the meeting and keeping of compliance**
DURATION:	**One (1) Month**
PROPOSED DATE OF ACTIVITY:	**February 2006**
SUBMISSION DATE:	**January 6, 2006**

PROBLEM STATEMENT:
Raw and improperly treated liquid waste from hotels, households and commercial establishments are polluting the marine environment in Soufriere. This is evident by the recent proliferation of algal growth along the coastline and on the coral reef systems.

JUSTIFICATION:
The two main hotels along the Soufriere coastline have been discharging poor quality effluent into the marine environment. Other restaurants, accommodation and commercial establishments and households have septic systems that need improvement. The situation is compounded by the discharge of gray water in open drains that convey the nutrient-rich effluent directly into the sea. Hence, there is a need to conduct a compliance study for liquid waste disposal in Soufriere focusing on the level of conformity to national legislative and regulatory framework and other existing guidelines.

SUB-PROJECT OVERVIEW:
The compliance study for wastewater in Soufriere will involve an assessment of point and non-point sources of pollution. The assessment will focus on liquid waste effluent from sewage treatment plants (STPs), washout points and other land-based sources. A survey will be conducted on a representative sample of non-point sources of pollution within the Soufriere watershed. Sampling and analyses will be conducted to guide the quantitative and qualitative aspects of the assessment. The legislative framework will be reviewed and recommendations will be made for meeting and keeping compliance so as to protect the marine environment of Soufriere.

SUB-PROJECT ACTIVITIES AND COSTING

Activities	**Unit Cost (USD)**	**Cost (USD)**
Literature review and develop survey forms	2 person days @ 300	600
Assessment of point sources of pollution	2 person days @ 300	600
Survey of non-point sources	2 person days @ 300	600
Sampling and analyses at point sources		1,000
Sampling and analyses of marine water		1,000
Collation and presentation of results	2 person days @ 300	600
Review of legislative framework	4 person days @ 300	1,200
Compilation of report	3 person days @ 300	900
Travel to Soufriere		500
Total		**7,000**
Discount of 21.43 %		**1,500**
Sub-project Cost		**5, 500**

DELIVERABLES
The wastewater assessment study for Soufriere will have the following outcomes:

- Assessment report on liquid waste management in Soufriere;
- Determination of the level of compliance for liquid waste disposal within the Soufriere watershed;
- Recommendations for compliance within the legal, administrative and regulatory framework;
- Recommendations for training in obtaining compliance;
- Recommendations to reduce the potential impact of liquid waste on the marine environment.
- Recommendations for possible amendment of the SMMA's monitoring activities (e.g. monthly GPS coordinates of green algae *Chaetomorpha aerea*).

SUB-PROJECT COMPATIBILITY
As a component of the Soufriere Watershed Management Project funded by NOAA and implemented by OECS-ESDU, this sub-project can possibly fall under:

- Components 7 - *Creation and application of the mechanism for the involvement of communities in the adoption of environmentally practical and sound resource-use practices* and
- Component 4- *Establishment and implementation of environmentally sound watershed practices (e.g. river bank stabilization systems, liquid waste management etc)*

TIME SCHEDULE

Activities	February 2006
Literature review and develop survey forms	Week1
Review of legislative framework	Week 3
Assessment of point sources of pollution	Week 2
Survey of non-point sources	Week 2
Sampling and analyses at point sources	Week 2
Sampling and analyses of marine water	Week 2
Collation and presentation of results	Week 3
Compilation and submission of report	Week 4

PAYMENT SCHEDULE
Payment for the execution of the Soufriere sewage assessment assignment will be disbursed as follows:

50 % of total sub-project sum before February 1st 2006 = USD 2,750
50 % on completion of sub-project (Final Report Submission) = USD 2,750
TOTAL **= USD 5,500**

Please indicate acceptance of this agreement by signing and returning a copy to CEHI.

Vincent Sweeney	Kai Wulf
_____	_____
Executive Director	**Manager**
CEHI	**SMMA**
_____	_____
Date	**Date**

APPENDIX 2

Household Survey Form

Knowledge, Attitude, Practice and Behaviour Study

On Sewage Treatment and Needs in Soufriere

Household Questionnaire

Introduction to the Session:
The Caribbean Environmental Health Institute (CEHI) is assisting the Soufriere Marine Management Authority (SMMA) in conducting an Assessment of the Infrastructure for Improved Wastewater Management in Soufriere. We therefore ask for your assistance in completing the following form.

All information provided would be treated with the highest level of confidentiality and no individual responses would be included in the Assessment Report

The areas to be covered by the survey are:

- Information about the household's living standards, employment, income, consumption and social and economic prospects.
- Information on sewage treatment and needs at the household level and prospective on sewage treatment and needs for community.
- Information about the community's development and infrastructure including environmental concerns and considerations.

The interviewers should inform the respondents that there will be a mix of standard questions, which are known as closed questions, and open questions, which provide the respondents with opportunities to explain, elaborate and add more information.

Interviewed by: _____ Date:_____

Place/Location: _____

Respondent's Gender: M = Male F = Female

Section A: Household description: Living Standards, Employment, Income, Expenditures and Prospects

Q1. Approximate Distance for the Coastline (Meters) ……

Q2.	How Long have you lived in this community?

	☐	Less than a year	☐	1 – 5 years	☐	5 – 10 years		
	☐	10 – 20 years	☐	20 - 25 years	☐	Over 25 years		
Q3.	**Number of persons in this household?**							
Q4.	**Type of dwelling**							
	☐	Separate House detached	☐	Semi-detached	☐	Apartment Building		
	☐	Improvised housing unit	☐	Other, please specify				
Q5.	**Main use of dwelling**							
	☐	Residential	☐	Residential/Commercial/Industrial				
Q6.	**Ownership of dwelling**							
	☐	Owned	☐	Leased/Rented	☐	Government Rented		
	☐	Rent Free	☐	Company Owned/rented	☐	Squatting		
	Other, please specify							
Q7.	**What is your family estimated monthly income? (Please Tick one)**							
	☐	Less than EC $3,000	☐	EC $3,001 - $5,000	☐	EC $5,001 - $10,000		
	☐	EC $10,001 - $15,000	☐	Over EC $15,000				
Section B: Sewage Treatment and Needs								
Q8.	**What is the main source of drinking water for your household? (Please Tick one)**							
	☐	Inside tap/pipe	☐	Outside private tap	☐	Public Standpipe		
	☐	Well/spring	☐	Rainwater/tank	☐	River/Stream		
	Other, please specify							
Q9.	**Access to Public Water Supply (please tick one)**							
	☐	24 hours/day	☐	Once per day	☐	Once per week		
	☐	More than once per week but less than 4 times per week			☐	Infrequently		
	☐	No Access	☐	Other, please specify				
Q10.	**What type of toilet facilities do you have at home? (Please Tick one)**							
	☐	Water Closet	☐	Pit Latrine	☐	Open Defecation		
	☐	Pail System	☐	Communal				
	Other please specify							
	What type of bathing facilities does your family use? (Please Tick one)							

Q11.	**What type of bathing facilities does your family use? (Please Tick one)**							
		In-door private shower		Out-door private shower		Public Standpipe		
		Communal shower		River/Stream				
	Other, please specify							
Q12	**What type of Laundry facilities does your family use? (Please Tick one)**							
		Washing machine		Washing Tub		Public Standpipe		
		Communal		River/Stream		Commercial		
	Other, please specify							
Q13	**What type of Kitchen cleaning facilities does your family use? (Please Tick one)**							
		In-door dish washing		Out-door dish washing		Public Standpipe		
		River/Stream						
	Other, please specify							
Q14	**How do you dispose of your garbage? (Please Tick one)**							
		Collect by garbage truck		Place in Skip		Burn/bury		
		Dump in empty lot		Dump in gully/river/Stream				
	Other, please specify:							
Q15	**How do you dispose of your Grey water? (***Grey water includes discharge from kitchen sink, shower, laundry and other washing facilities.)*							
		Drain		Soakaway		Septic Tank		
		Natural Watercourse		Sewage Treatment Plant				
	Other, please specify:							
Q16	**What system do you have in place for Sewage/Excreta Treatment?** *(Sewage refers to waste from toilet)*							
		Septic Tank and Soakaway		Septic Tank and Tile Field				
		Septic Tank and Watercourse		Pit Latrine				
		Nightsoil/Bucket		Sewage Treatment Plant				
	Other/None, please comment:							
Q17	**For the Treatment System you identified in Q16 above:**							
	What is the age of the System?							
		<5yrs		<10yrs		<15yrs		<20 yrs	>20 yrs
	What is the frequency for servicing/emptying the system?_____years							
	Comments:							

Q18	**Has the Treatment System ever overflowed/flooded?**		Yes		No		Don't Know
	If yes, what would you say were the reasons:						
	What is the frequency of overflowing/flooding?_____years						
Q19	**Approximate Distance of Sewage System from Watercourse or Drain:**……..Meters						
Q20	**Approximate Distance of Sewage System from Sea:**……Meters						
Q21	**Do you think that your Sewage Disposal System is Appropriate? Yes No**						
	Please explain:						
Q22	**In your opinion, what is the condition of your sewage treatment/disposal system?**						
		Good		Moderate		Poor	
	Comments:						
Q23	**From a public health and environmental point, is there anything that could be done to improve YOUR sewage treatment/disposal system? Yes No Don't Know**						
	Please explain, indicating what can be done:						
Q24	**What would you say are the factors limiting improvements to YOUR treatment/disposal system?**						
	Please explain, indicating what can be done:						

Section C: Community Development, Infrastructure, Prospects	
Q25.	**What do you think are the three main environmental problems facing your community?**
	1
	2
	3
Q26.	**In your opinion, what do you think should be done to address these three main environmental problems facing your community?**
	1
	2
	3
Q27.	**Do you think that the quality of the water in the rivers/streams/surrounding beaches can pose a threat to public health? (Tick one)**
	Y = yes; N = No; DK = Do not Know **If yes, Why and How?**
Q28.	**Do you think that the quality of the water in the rivers/streams/surrounding beaches can pose a threat to marine life**

	and resources(Tick One)
	Y = yes; N = No; DK = Do not Know **If yes, Why and How?**
Q29	**From a public health and environmental point, is there anything that could be done to improve sewage treatment/disposal in the COMMUNITY? Yes No Don't Know**
	Please explain, indicating what can be done:
Q30	**What would you say are the factors limiting improvements to treatment/disposal in the COMMUNITY?**
	Please explain:
Q31	**What would you say are the benefits for improving sewage treatment and disposal in the COMMUNITY?**
	Please explain:
Q32	**Who should pay for improving sewage treatment and disposal in the Soufriere community? (Tick all that apply)**
	☐ Residents ☐ Private Sector in V/F ☐ WASCO ☐ Government ☐ Donor Agencies
	Other, please specify:

Thank you very much, you have been most helpful

APPENDIX 3

Organisation Survey Form

Knowledge, Attitude, Practice and Behaviour Study

On Sewage Treatment and Needs in Soufriere

Organisation/Businesses Questionnaire

Introduction to the Session:
The Caribbean Environmental Health Institute (CEHI) is assisting the Soufriere Marine Management Authority (SMMA) in conducting an Assessment of the Infrastructure for Improved Wastewater Management in Soufriere. We therefore ask for your assistance in completing the following form.

All information provided would be treated with the highest level of confidentiality and no individual responses would be included in the Assessment Report

The areas to be covered by the survey are:

- Information about organization.
- Information on sewage treatment and needs at the organizational level and prospective on sewage treatment and needs for community.
- Information about the community's development and infrastructure including environmental concerns and considerations

The interviewers should inform the respondents that there will be a mix of standard questions, which are known as closed questions, and open questions, which provide the respondents with opportunities to explain, elaborate and add more information.

Interviewed by: _____ Date:_____

Place/Location: _____

Section A: General Organization Information

1. Name of Organization:	
2. Acronym of Organization:	

3. Contact Information (Head Office):

Mailing Address:			
Telephone:		Telefax:	
Email Address:		Website:	

4. Contact Person within Organization

Contact Person:	
Designation:	

5. Ownership Type:

Government		State Enterprise		Private Enterprise		Individual	
Multinational		Cooperative		NGO			

6. Year of Establishment: 7. Year of Operation: ☐☐☐☐ ☐☐☐☐

7. Type of Business/Organization/Institution

	School		Church		Health Facility
	Retailer		Manufacturer		Transportation
	Restaurant		Hotel		Financial/Services
	Medical/Doctor		Touristic Business		Shop/Mall
Other, please specify:					

8. Please describe the organization activities

9.	**Average number of employees/ Students_____**
10.	**Average number of customers/client/guests per month _____**
11.	**What are the overall prospects for future development/expansion of your organization in the next five years? (Please Tick one)**
	☐ Poor ☐ Good ☐ Very Good
	Why

12.	**Environmental Responsibility**

General Environmental Issues	**Yes**	**No**	**D/K**	**Comments/Remarks**
1. Was an EIA/EIS conducted for the plant?				
2. Has there been an Environmental Audit done on the facility? (If yes, when last?)				
3. Is there an EMS in place?				
4. Is there and Environmental Policy in place?				
5. Is there a Waste Management Plan/Policy in place?				
6. Is there a Hazardous Waste Management Plan/Policy in place?				
7. Is there a Workers' Health and Safety Plan/policy in place?				
Notes: D/K = Do not know				

Section B: Sewage Treatment and Needs	
13.	**What is the main source of drinking for your organisation? (Please Tick one)**
	☐ Inside tap/pipe ☐ Outside private tap ☐ Public Standpipe
	☐ Well/spring ☐ Rainwater/tank ☐ River/Stream
	Other, please specify
14.	**Access to Public Water Supply (please tick one)**
	☐ 24 hours/day ☐ Once per day ☐ Once per week
	☐ More than once per week but less than 4 times per week ☐ Infrequently

		No Access		Other, please specify			
15.	**What type of toilet facilities do you have? (Please Tick one)**						
		Water Closet		Pit Latrine		Open Defecation	
		Pail System		Communal			
	Other please specify						
16.	**What type of bathing facilities is available? (Please Tick one)**						
		In-door private shower		Out-door private shower		Public Standpipe	
		Communal shower		River/Stream		N/A	
	Other, please specify						
17.	**What type of Laundry facilities does your organization use? (Please Tick one)**						
		Washing machine		Washing Tub		Public Standpipe	
		Communal		River/Stream		Commercial	
	Other, please specify					N/A	
18.	**What type of Kitchen cleaning facilities does your organization use? (Please Tick one)**						
		In-door dish washing		Out-door dish washing		Public Standpipe	
		River/Stream		N/A			
	Other, please specify						
19.	**How do you dispose of your garbage? (Please Tick one)**						
		Collect by garbage truck		Place in Skip		Burn/bury	
		Dump in empty lot		Dump in gully/river/Stream			
	Other, please specify:						
20.	**How do you dispose of your Grey water? *(****Grey water includes discharge from kitchen sink, shower, laundry and other washing facilities.)***						
		Drain		Soakaway		Septic Tank	
		Natural Watercourse		Sewage Treatment Plant			
	Other, please specify:						
21.	**What system do you have in place for Sewage/Excreta Treatment?** *(Sewage refers to waste from toilet)*						
		Septic Tank and Soakaway		Septic Tank and Tile Field			
		Septic Tank and Watercourse		Pit Latrine			
		Nightsoil/Bucket		Sewage Treatment Plant			
	Other/None, please comment:						

22.	**For the Treatment System you identified in Q21 above:**
	What is the age of the System?
	☐ <5yrs ☐ <10yrs ☐ <15yrs ☐ <20 yrs ☐ >20 yrs
	What is the frequency for servicing/emptying the system?_____years
	Comments:
23.	**Has the Treatment System every overflowed/flooded?** ☐ Yes ☐ No ☐ Don't Know
	If yes, what would you say were the reasons:
	What is the frequency of overflowing/flooding?_____years
24.	**Approximate Distance of Sewage System from Watercourse or Drain:**……..Meters
25.	**Approximate Distance of Sewage System from Sea:**……Meters
26.	**Do you think that your Sewage Disposal System is Appropriate?**
	Yes | **No** | **Don't Know**
	Please explain:
27.	**In your opinion, what is the condition of your sewage treatment/disposal system?**
	☐ Good ☐ Moderate ☐ Poor ☐ Don't Know
	Comments:
28.	**From a public health and environmental point, is there anything that could be done to improve YOUR sewage treatment/disposal system? Yes No Don't Know**
	Please explain, indicating what can be done:

29.	**What would you say are the factors limiting improvements to YOUR treatment/disposal system?**
	Please explain, indicating what can be done:
Section C: Community Development, Infrastructure, Prospects	
30.	**What do you think are the three main environmental problems facing your community?**
	1
	2
	3
31.	**In your opinion, what do you think should be done to address these three main environmental problems facing your community?**
	1
	2
	3
32.	**Do you think that the quality of the water in the rivers/streams/surrounding beaches can pose a threat to public health? (Tick one)**
	Y = yes; N = No; DK = Do not Know **If yes, Why and How?**

33.	**Do you think that the quality of the water in the rivers/streams/surrounding beaches can pose a threat to marine life? (Tick one)**
	Y = yes; N = No; DK = Do not Know **If yes, Why and How?**
34.	**From a public health and environmental point, is there anything that could be done to improve sewage treatment/disposal in the COMMUNITY? Yes No Don't Know**
	Please explain, indicating what can be done:
35.	**What would you say are the factors limiting improvements to treatment/disposal in the COMMUNITY?**
	Please explain:
36.	**What would you say are the benefits for improving sewage treatment and disposal in the COMMUNITY?**
	Please explain:

37.	**Do you feel that there is a need for developing a Plan for improving sewage treatment and disposal in Soufriere Community? Yes No Don't Know**					
38.	**If yes, what do you think are the three main benefits of such a Plan**					
	1					
	2					
	3					
39.	**Who should be involved in developing such a Plan?**					
40.	**Who should pay for improving sewage treatment and disposal in the Soufriere community? (Tick all that apply)**					
		Residents		Private Sector in V/F		WASCO
		Government		Donor Agencies		
	Other, please specify:					

Thank you very much, you have been most helpful

Appendix 4

Metadata Form for Algal Monitoring

Appendix 4: Metadata Form - Monitoring Site and Transect Location

Waypoint Code	Site Location	Northing	Easting	Transect and Waypoint Details
JLN1S	Jalousie	0501275	15279997	Start of transect 1 located to north of outfall
SRS1E	Soufriere River	0501493	1531484	End of Transect 1 south of river

Appendix 5

Monitoring Data Entry Form

Appendix 5: Algal Cover Data Entry Form

Waypoint Code				% Cover		
Start	**End**	**Transect #**	**Quadrat #**	**C. aerea**	**Other Algae**	**Date**
JLN1S	JLN1E	1	1	25	10	23/3/06
		1	2	10	5	23/3/06
		1	3	15	50	23/3/06
		1	4	30	25	23/3/06
		1	5	5	20	23/3/06
JLN2S	JLN2E	2	1			
		2	2			
		2	3			
		2	4			
		2	5			
SRN1 S	SRN1E	1	1			
		1	2			
		1	3			
		1	4			
		1	5			

Appendix 6

Notes on Time Series Regression Analysis

17 Simple Linear Regression

Previous chapters have discussed various methods of statistical analysis that deal with a single variable. Techniques that consider relationships between two variables are described in this and the following two chapters. Chapter 20 presents the expansion of such techniques to analyze situations where more than two variables may be related to each other.

17.1 REGRESSION VS. CORRELATION

The relationship between two variables may be one of functional dependence of one on the other. That is, the magnitude of one of the variables (the *dependent variable*) is assumed to be determined by—i.e., is a function of—the magnitude of the second variable (the *independent variable*), whereas the reverse is not true. For example, in the relationship between blood pressure and age in humans, blood pressure may be considered the dependent variable and age the independent variable; we may reasonably assume that although the magnitude of a person's blood pressure might be a function of age, age is not determined by blood pressure. This not to say that age is the only biological determinant of blood pressure, but we do consider it to be one determining factor.

Such a dependent relationship is termed a *regression*; the term *simple regression* refers to the fact that only two variables are being considered. In the case of simple regression, the adjective *linear* is used to refer to the relationship between the two variables being a straight line. Data amenable to simple regression analysis will consist of a dependent variable that is a random effect factor and an independent variable

that is either a fixed-effect or a random-effect factor. (See the end of Section 11.1 to review these concepts.)

It is very convenient to graph simple regression data, using the ordinate (*Y* axis) for the dependent variable (conventionally termed *Y*) and the abscissa (*X* axis) for the independent variable (*X*). Thus, as shown in Fig. 17.1, the data of Example 17.1 appear as a scatter of points, each point representing a pair of *X* and *Y* values. One pair of *X* and *Y* data may be denoted as (X_1, Y_1), another as (X_2, Y_2), another as (X_3, Y_3), etc. (The line in this figure will be explained shortly.)

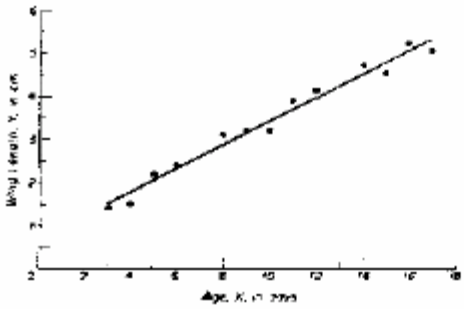

Figure 17.1 Sparrow wing length as a function of age. The data are from Example 17.1.

Example 17.1

Sparrow wing lengths at various times after hatching. The data are plotted in Fig. 17.1.

Age (days) (*X*)	*Wing length* (cm) (*Y*)
3.0	1.4
4.0	1.5
5.0	2.2
6.0	2.4
8.0	3.1
9.0	3.2
10.0	3.2
11.0	3.9
12.0	4.1
14.0	4.7
15.0	4.5
16.0	5.2
17.0	5.0

$n = 13$

In many kinds of biological data, however, the relationship between two variables is not one of dependence. In such cases, the magnitude of one of the variables changes as the magnitude of the second variable changes, but it is not reasonable to consider there to be an independent and a dependent variable. In such situations, *correlation*, rather than regression, analyses are called for, and both variables are theoretically

to be random-effects factors. An example of data suitable for correlation analysis would be measurements of human arm and leg lengths. It might be found that an individual with long arms will in general possess long legs, so a relationship may be describable; but there is no justification in stating that the length of one limb is mathematically dependent upon the length of the other. Correlation techniques involving two variables will be discussed in Chapter 19; if more than two variables are being considered, then the appropriate procedures are found in Chapter 20.

17.2 THE SIMPLE LINEAR REGRESSION EQUATION

The simplest functional relationship of one variable to another in a population is the *simple linear regression*,

$$Y_i = \alpha + \beta X_i. \tag{17.1}$$

Here, α and β are population parameters (and, therefore, constants), and this expression will be recognized as the general equation for a straight line.*

Consider the data in Example 17.1, where wing length is the dependent variable and age is the independent variable. From a scatter plot of these data (Fig. 17.1), it appears that our sample of measurements from 13 birds represents a population of data in which wing length is linearly related to age. Thus, we would like to know the values of α and β that would uniquely describe the functional relationship existing in the population.

If all the data in a scatter diagram such as Fig. 17.1 occurred in a straight line, it would be an unusual situation. Generally, as is shown in this figure, there is considerable variability of data around any straight line we might draw through them. What we seek to define is what is commonly termed the "best fit" line through the data. The criterion for "best fit" that is generally employed utilizes the concept of least squares. Figure 17.2 is an enlarged portion of Fig. 17.1. Each value of X will have a corresponding value of Y lying on the line that we might draw through the scatter of data points. This value of Y is represented as $\hat{Y}$ to distinguish it from the Y value actually observed in our sample.† Thus, as Fig. 17.2 illustrates, an observed data point is denoted as (X_i, Y_i), and a point on the regression line is $(X_i, \hat{Y}_i)$.

The criterion of least squares considers the vertical deviation of each point from the line (i.e., the deviation describable as $Y_i - \hat{Y}_i$), and defines the best fit line as that which results in the smallest value for the sum of the squares of these deviations for all values of Y_i and $\hat{Y}_i$. That is, $\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$ is to be a minimum,‡ where n is the number of data points comprising the sample. The sum of squares of these deviations is called the *residual sum of squares* (or, sometimes, the *error sum of squares*) and will be discussed later in this chapter.

*α and β have become standard symbols for these population parameters, and as such should not be confused with the standard use of the same Greek letters to denote the probabilities of a Type I and a Type II error, respectively (see Section 5.3).

†Statisticians refer to $\hat{Y}$ as "Y hat."

‡Another way to express this is to say that the correlation between Y_i's and $\hat{Y}_i$'s is to be maximum.

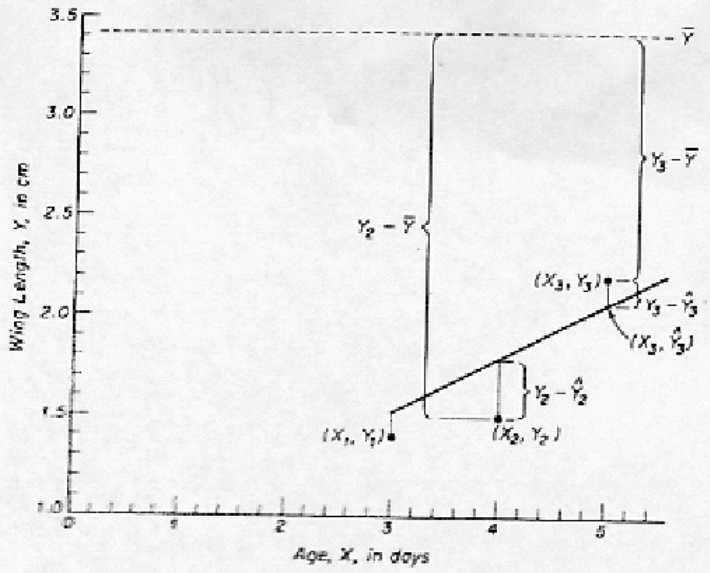

Figure 17.2 An enlarged portion of Fig. 17.1, showing the partitioning of Y deviations.

The only way to determine the population parameters α and β with complete confidence and accuracy would be to possess all the data for the entire population. Since this is nearly always impossible, we have to estimate these parameters from a sample of n data, where n is the number of pairs of X and Y values. The calculations required to arrive at such estimates, as well as to execute the testing of a variety of important hypotheses, involve the computation of sums of squared deviations from the mean, just as has been encountered before. Recall that the sum of squares of X_i values is defined as $\sum (X_i - \bar{X})^2$, which is more easily obtained on a calculator as $\sum X_i^2 - (\sum X_i)^2/n$. It will be convenient to define $x_i = X_i - \bar{X}$, so that this sum of squares can be abbreviated as $\sum x_i^2$, or, more simply, as $\sum x^2$.

We shall also be required to calculate a quantity referred to as the *sum of the crossproducts* of deviations from the mean:

$$\sum xy = \sum (X_i - \bar{X})(Y_i - \bar{Y}), \tag{17.2}$$

where y denotes a deviation of a Y value from the mean of all Y's just as x denotes a deviation of an X value from the mean of all X's. The sum of the crossproducts, analogously to the sum of squares, has a simple-to-use machine formula:

$$\sum xy = \sum X_i Y_i - \frac{(\sum X_i)(\sum Y_i)}{n}, \tag{17.3}$$

and it is recommended that the latter formula be employed.

The Regression Coefficient. The parameter β is termed the *regression coefficient*, or the *slope* of the best fit regression line. The best estimate of β is

$$b = \frac{\sum xy}{\sum x^2} = \frac{\sum X_i Y_i - \dfrac{(\sum X_i)(\sum Y_i)}{n}}{\sum X_i^2 - \dfrac{(\sum X_i)^2}{n}}. \tag{17.4}$$

Although the denominator in this calculation is always positive, the numerator may be either positive, negative, or zero, and the value of b theoretically can range from $-\infty$ to $+\infty$, including zero (see Fig. 17.3).

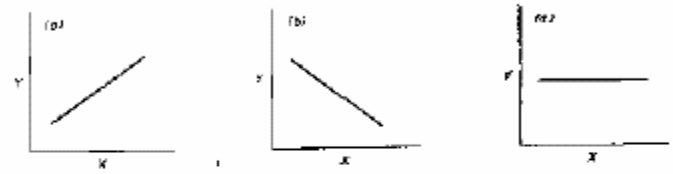

Figure 17.3 The slope of a linear regression line may be (a) positive, (b) negative, or (c) zero.

Example 17.2 demonstrates the calculation of b for the data of Example 17.1. Note that the units of b are the units of Y divided by the units of X. The regression coefficient expresses what change in Y is associated, on the average, with a unit change in X. In the present example, $b = 0.270$ cm/day indicates that there is a mean wing growth of 0.270 cm each day. Determination of the precision of b will be considered in Section 17.4.

Example 17.2

The simple linear regression equation calculated by the method of least squares for the data of Example 17.1.

$$n = 13 \qquad \sum Y = 44.4$$

$$\sum X = 130.0 \qquad \bar{Y} = 3.415$$

$$\bar{X} = 10.0 \qquad \sum xY = 514.80$$

$$\sum X^2 = 1562.00 \qquad \sum xy = 514.80 - \frac{(130.0)(44.4)}{13}$$

$$\sum x^2 = 1562.00 - \frac{(130.0)^2}{13} \qquad = 514.80 - 444.00$$

$$= 1562.00 - 1300.00 \qquad = 70.80$$

$$= 262.00$$

$$b = \frac{\sum xy}{\sum x^2} = \frac{70.80}{262.00} = 0.270 \text{ cm/day}$$

$$a = \bar{Y} - b\bar{X} = 3.415 \text{ cm} - (0.270 \text{ cm/day})(10.0 \text{ day})$$

$$= 3.415 \text{ cm} - 2.700 \text{ cm}$$

$$= 0.715 \text{ cm}$$

So, the simple linear regression equation is $\hat{Y} = 0.715 + 0.270X$.

The Y Intercept. An infinite number of lines possess any stated slope, all of them parallel (see Fig. 17.4). However, a line can be defined uniquely by stating, in addition to β, any one point on the line—i.e., any pair of coordinates, $(X_i, \bar{Y}_i)$. The point conventionally chosen is the point on the line where $X = 0$. The value of Y in the population at this point is the parameter α, which is called the *Y intercept*.

It can be shown mathematically that the point $(\bar{X}, \bar{Y})$ always lies on the best fit regression line. Thus, substituting $\bar{X}$ and $\bar{Y}$ in Equation (17.1), we find that:

$$\bar{Y} = \alpha + \beta\bar{X} \tag{17.5}$$

Section 17.4 discusses the estimation of the error and confidence intervals associated with predicting $\hat{Y}_i$ values.

Assumptions of Regression Analysis. Certain basic assumptions must be met in order to test validly hypotheses about regressions or to set confidence intervals for regression parameters. First, we must assume that for any value of X there exists in the population a normal distribution of Y values and that we sampled this distribution at random. Second, the variances of these population distributions of Y values must all be equal to one another. (Indeed, the residual mean square, to be described shortly, estimates this common variance, just as the error variance estimates the common variance assumed in the analysis of variance in previous chapters.) Third, the errors in Y are assumed to be additive (discussed in Chapter 14). Fourth, the values of Y are to be independent. Fifth, our measurements of X must be obtained without error. This last requirement, of course, is often impossible; so what we are doing in practice is assuming that the errors in the X data are negligible, or at least small compared with the measurement errors in the dependent variable. Regression statistics are known to be robust with respect to at least some of these underlying assumptions (e.g., Jacques and Norusis, 1973), so violations of them are not of concern unless they are severe. These assumptions will be discussed further in Section 17.10. Some nonparametric regression hypothesis testing is discussed by Daniel (1978; Chapter 10) and others.

17.3 TESTING THE SIGNIFICANCE OF A REGRESSION

The slope, b, of the regression line computed from the sample data expresses quantitatively the straight-line dependence of Y on X in the sample. But what is really desired is information about the functional relationship (if any) in the population from which the sample came. Indeed, the finding of a dependence of Y on X in the sample (i.e., $b \neq 0$) does not necessarily mean that there is a dependence in the population (i.e., $\beta \neq 0$). Consider Fig. 17.6, a scatter plot representing a population of data points with no dependence of Y on X; the best fit regression line would be parallel to the X axis (i.e., the slope, β, would be zero). However, it is possible, by random sampling, to obtain a sample of five data points having the values circled in the figure. By

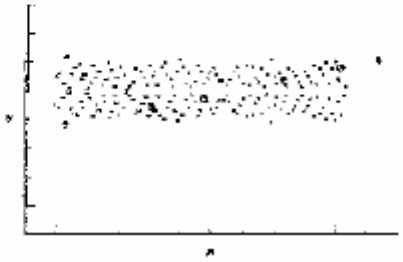

Figure 17.6 A hypothetical population of data points, having a regression coefficient, β, of zero. The circled points are a possible sample of five.

Appendix 7

Notes on Analysis of Variance

11 Multisample Hypotheses: The Analysis of Variance

When measurements of a variable are obtained for each of two samples, hypotheses such as those described in Chapter 9 are appropriate. However, biologists often collect measurements of a variable from three or more samples, a situation calling for multisample analyses, as introduced in this chapter.

It is tempting to strive to attempt the testing of multisample hypotheses by applying two-sample tests to all possible pairs of samples. In this manner, for example, one might proceed to test the null hypothesis H_0: $\mu_1 = \mu_2 = \mu_3$ by testing all the following null hypotheses: H_0: $\mu_1 = \mu_2$, H_0: $\mu_1 = \mu_3$, and H_0: $\mu_2 = \mu_3$. But such a procedure of employing a series of two-sample tests to attack a multisample hypothesis is *invalid*. The calculated test statistic, t, and the critical values we find in the t table, are designed to test whether two sample statistics, $\bar{Y}_1$ and $\bar{Y}_2$, are likely to have come from the same population (or from two populations with identical means). In employing this test, we could randomly draw two sample means from the same population and wrongly conclude that they are estimates of two different populations' means; but we know that the probability of this error will be no greater than α. However, consider that three random samples were taken from a single population. As previously stated, three possible t tests can be performed, and the probability of wrongly concluding that two of the means estimate different parameters is considerably greater than α. In fact, if α is set at 5%, and three means are tested, two at a time, by the two-sample t test, there is a 13% chance of wrongly concluding a difference between the two most extreme means. Using the critical values for t at $\alpha = 5\%$ for two-at-a-time comparisons of 10 means, there is a 63% chance of committing a Type I error; if there are 20 means being so tested, the probability of a Type I error is 92%. As the number of means increases, it approaches certainty that the t test will conclude the two

extreme sample means to estimate different values of μ, even though they may have come from the same population (see Table 11.1). Two-sample tests, it must be emphasized, cannot be utilized validly to test multisample hypotheses. The appropriate procedures are introduced in the following sections.

TABLE 11.1 PROBABILITY OF COMMITTING A TYPE I ERROR BY USING MULTIPLE t TESTS TO SEEK DIFFERENCES BETWEEN ALL PAIRS OF k MEANS

Number of means (k)	Level of Significance Used in the t Tests					
	0.20	0.10	0.05	0.02	0.01	0.001
2	0.20	0.10	0.05	0.02	0.01	0.001
3	0.41	0.23	0.13	0.05	0.03	0.003
4	0.58	0.36	0.21	0.09	0.05	0.006
5	0.71	0.47	0.23	0.13	0.07	0.008
10	0.96	0.83	0.63	0.37	0.23	0.036
20	1.00	0.98	0.92	0.71	0.52	0.109
∞	1.00	1.00	1.00	1.00	1.00	1.000

Note: The particular values were derived from a table by Pearson (1942) by assuming equal population variances and large samples.

11.1 SINGLE FACTOR ANALYSIS OF VARIANCE

To test the null hypothesis H_0: $\mu_1 = \mu_2 = \ldots = \mu_k$, where k is the number of experimental groups, or samples, we need to become familiar with the topic of *analysis of variance*, often abbreviated ANOVA (or ANOV or AOV). Analysis of variance is a large area of statistical methods, owing its name and much of its early development to R. A. Fisher;* in fact, the F statistic was named in his honor by G. W. Snedecor† (1934: 15). There are many ramifications of analysis of variance considerations, the most common of which will be discussed in this and subsequent chapters. More complex applications and greater theoretical coverage are to be found in Cochran and Cox (1957), Cox (1958), Scheffé (1959), Guenther (1964), and others. At this point, it may appear strange that a procedure used for testing the equality of means should be named analysis of variance, but the reason for this terminology soon will become apparent.

Let us assume that we wish to test whether four different feeds result in different body weights in pigs. Since we are to test for the effect of only one factor (namely feed type) on the variable in question (namely body weight), the appropriate analysis is termed a single factor (or "single criterion" or "single classification" or "one-way") analysis of variance. Furthermore, each type of feed is said to be a *level* of the factor. The design of this experiment should have each experimental animal being assigned at random to receive one of the four feeds, with approximately equal numbers of pigs receiving each feed. (Although equal sample sizes are not required for the single

*Sir Ronald Aylmer Fisher (1890–1962), British statistician.

†George W. Snedecor (1881–1974), American statistician.

factor ANOVA, such a situation is statistically desirable.) Because the pigs are assigned to the feed groups at random, the single factor ANOVA is said to represent a *completely randomized experimental design*.

Example 11.1 shows the weights of 19 pigs subjected to this feed experiment, and the null hypothesis to be tested would be H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$. Each datum in the experiment may be uniquely represented by the double subscript notation, where X_{ij} denotes datum j in experimental group i. For example, X_{23} denotes the third pig weight in feed group 2; that is, $X_{23} = 74.0$ kg. Similarly, $X_{14} = 96.5$ kg, $X_{43} = 87.9$ kg, etc. We shall let the mean of group i be denoted by $\bar{X}_i$, and the grand mean of all observations will be designated by $\bar{X}$. Furthermore, n_i will represent the size of sample i, and $N = \sum_{i=1}^{k} n_i$ will be the total number of data in the experiment.

Example 11.1

A single factor analysis of variance (Model I)

Nineteen pigs are assigned at random among four experimental groups. Each group is fed a different diet. The data are pig body weights, in kilograms, after being raised on these diets. We wish to ask whether pig weights are the same for all four diets.

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$.
H_a: The mean weights of pigs on the four diets are not all equal.
$\alpha = 0.05$

	Feed 1	*Feed 2*	*Feed 3*	*Feed 4*	
	60.8	68.7	102.6	87.9	
	57.0	67.7	102.1	84.2	
	65.0	74.0	100.2	83.1	
	58.6	66.3	96.5	85.7	
	61.7	69.8		90.3	
n_i	5	5	4	5	$N = \sum_{i=1}^{k} n_i = 19$
$\sum_{j=1}^{n_i} X_{ij}$	303.1	346.5	401.4	431.2	
$\bar{X}_i$	60.62	69.30	100.35	86.24	
$\frac{\left(\sum_{j=1}^{n_i} X_{ij}\right)^2}{n_i}$	36775.922	24012.450	40280.490	37186.688	$\sum_{i=1}^{k} \frac{\left(\sum_{j=1}^{n_i} X_{ij}\right)^2}{n_i} = 118853.550$

$\sum_i \sum_j X_{ij} = 1482.2$ $\qquad$ total DF $= N - 1 = 19 - 1 = 18$
$\sum_i \sum_j X_{ij}^2 = 119981.900$ $\qquad$ groups DF $= k - 1 = 4 - 1 = 3$
$\qquad$ error DF $= N - k = 19 - 4 = 15$

$$C = \frac{\left(\sum_i \sum_j X_{ij}\right)^2}{N} = \frac{2196916.84}{19} = 115627.202$$

$$\text{total sum of squares} = \sum_i \sum_j X_{ij}^2 - C = 119981.900 - 115627.202 = 4354.698$$

$$\text{groups sum of squares} = \sum_i \frac{\left(\sum_j X_{ij}\right)^2}{n_i} - C = 119853.550 - 115627.202 = 4226.348$$

$$\text{error sum of squares} = \text{total SS} - \text{groups SS} = 4354.698 - 4226.348 = 128.350$$

Example 11.2

A single factor analysis of variance for a random effects model (i.e., Model II) experimental design.

A laboratory employs a certain technique for determining the phosphorus content of hay. The question arises: "Do phosphorus determinations differ with the technician performing the analysis?" To answer this question, each of four randomly selected technicians was given five samples from the same batch of hay. The results of the 20 phosphorus determinations (in mg phosphorus/g of hay) are shown.

H_0: Determinations of phosphorus content do not differ among technicians.
H_A: Determinations of phosphorus content do differ among technicians.
$\alpha = 0.05$

	Technician			
	1	2	3	4
	36	37	34	36
	36	36	37	34
	34	35	35	37
	35	37	37	34
	34	37	36	35
Group sums:	173	182	179	176

$$\sum_i \sum_j X_{ij} = 710$$

$$\sum_i \sum_j X_{ij}^2 = 25234$$

$N = 20$

$$C = \frac{(710)^2}{20} = 25205.00$$

total SS $= 25234 - 25205.00 = 29.00$

groups (i.e., technicians) SS $= \frac{(173)^2}{5} + \frac{(182)^2}{5} + \frac{(179)^2}{5} + \frac{(176)^2}{5} - 25205.00$

$= 25214.00 - 25205.00 = 9.00$

error SS $= 29.00 - 9.00 = 20.00$

Source of variation	SS	DF	MS
Total	29.00	19	
Groups (technicians)	9.00	3	3.00
Error	20.00	16	1.25

$$F = \frac{3.00}{1.25} = 2.40$$

$F_{0.05[3,16]} = 3.24$

Do not reject H_0.

$0.10 < P < 0.25$

Underlying Assumptions. Recall from Section 9.4 that to test H_0: $\mu_1 - \mu_2$ by the two-sample t test, we had to assume that $\sigma_1^2 = \sigma_2^2$ and that the two samples came from normal populations. Similarly, $\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \sigma_4^2$ should be true in order to apply the analysis of variance to H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$, and each

calculating b for this sample of five we would estimate that β was positive, even though it is, in fact, zero.

Now, it is not likely to obtain five such points out of this population, but we should desire to determine just how likely it is; therefore, we can set up the null hypothesis, H_0: $\beta = 0$, and the alternate hypothesis, H_a: $\beta \neq 0$. If we conclude that there is a reasonable probability (i.e., a probability greater than the chosen level of significance—say, 5%) that the calculated b could have come from sampling a population with a $\beta = 0$, the H_a is not rejected. If the probability of obtaining the calculated b is small (say, 5% or less), then H_0 is rejected, and H_a is assumed to be true.

Analysis of Variance Testing. The preceding H_0 may be tested by an analysis of variance procedure. First, the overall variability of the dependent variable is calculated by computing the sum of squares of deviations of Y_i values from $\bar{Y}$, a quantity termed the *total sum of squares*:

$$\text{total SS} = \sum (Y_i - \bar{Y})^2 = \sum Y^2 - \sum Y_i^2 - \frac{(\sum Y_i)^2}{n} \tag{17.10}$$

Then, one determines the amount of variability among the Y_i values that results from there being a linear regression; this is termed the *linear regression sum of squares*:

$$\text{regression SS} = \sum (\hat{Y}_i - \bar{Y})^2 = \frac{(\sum xy)^2}{\sum x^2} = \frac{\left(\sum X_i Y_i - \frac{\sum X_i \sum Y_i}{n}\right)^2}{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}; \tag{17.11}$$

since $b = \sum xy / \sum x^2$, this can also be calculated as

$$\text{regression SS} = b \sum xy. \tag{17.12}$$

The value of the regression SS will be equal to that of the total SS only if each data point falls exactly on the regression line, a very unlikely situation. The scatter of data points around the regression line has already been alluded to, and the residual, or error, sum of squares has been defined. Knowing the total and the linear regression sums of squares, we may, by difference, obtain

$$\text{residual SS} = \sum (Y_i - \hat{Y}_i)^2 = \text{total SS} - \text{regression SS}. \tag{17.13}$$

Table 17.1 presents the analysis of variance summary for testing the hypothesis H_0: $\beta = 0$ against H_a: $\beta \neq 0$. Example 17.3 performs such an analysis for the data from Examples 17.1 and 17.2. The degrees of freedom associated with the total variability of Y_i values are $n - 1$. The degrees of freedom associated with the variability among $\hat{Y}_i$'s due to regression is always 1 in a simple linear regression.* The residual degrees of freedom are calculable as residual DF = total DF − regression DF $= n - 2$. Once the regression and residual mean squares are calculated (MS = SS/DF, as usual), H_0 may be tested by determining

$$F = \frac{\text{regression MS}}{\text{residual MS}}, \tag{17.14}$$

*In general, the regression DF is the number of parameters being estimated minus 1. Since we are here estimating two parameters (α and β), the regression DF $= 2 - 1 = 1$.

ANOVA Using Means and Variances The above discussion assumes that all the data from the experiment to be analyzed are in hand. It may occur, however, that all we have are the means for each group and some measure of variability based on the variances of each group. That is, we may have $\bar{X}_i$ and either SS_i, s_i^2, s_i, or $s_{\bar{X}_i}$ for each group, rather than all the individual values of X_{ij}. If the sample sizes, n_i, are also known, then the single factor analysis of variance may still be performed, in the following manner.

First, determine the sample variance for each group; recall that

$$s_i^2 = (s_i)^2 = n_i(s_{\bar{X}_i})^2. \tag{11.19}$$

Then, calculate

$$\text{error SS} = \sum_{i=1}^{k} SS_i = \sum_{i=1}^{k} (n_i - 1)s_i^2 \tag{11.20}$$

and

$$\text{groups SS} = \sum_{i=1}^{k} n_i \bar{X}_i^2 - \frac{\left(\sum_{i=1}^{k} n_i \bar{X}_i\right)^2}{\sum_{i=1}^{k} n_i}. \tag{11.21}$$

Knowing the groups SS and error SS, the ANOVA can proceed in the usual fashion.

Two Types of ANOVA. In Example 11.1, the biologist designing the experiment was interested in whether all of these particular four feeds have the same effect on pig weight. That is, these four feeds were not randomly selected from a feed catalog but were specifically chosen. When the levels of a factor are specifically chosen, one is said to have designed a *fixed effects model*, or a *Model I, ANOVA*. In such a case, the null hypothesis H_0: $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$ is appropriate.

However, there are instances where the levels of a factor to be tested are indeed chosen at random. For example, we might have been interested in the effect of geographic location of the pigs, rather than the effect of their feed. It is possible that our concern might be with certain specific locations, in which case we would be employing a fixed effects model ANOVA. But we might, instead, be interested in testing the statement that in general there is a difference in pig weights in animals from different locations. That is, instead of being concerned with only the particular locations used in the study, the intent might be to generalize, considering the locations in our study to be a random sample from all possible locations. In this *random effects model*, or *Model II, ANOVA*,* all the calculations are identical to those for the fixed effects model, but the null hypothesis is better stated as H_0: There is no difference in pig weight among geographic locations (or H_0: There is no variability in weights among locations). Examination of Equation 11.18 shows that what the analysis asks is whether the variability among locations is greater than the variability within locations. Example 11.2 demonstrates the ANOVA for a random effects model. Although the biologist will find that Model I analyses are far more commonly encountered than are Model II situations, when dealing with more than one experimental factor (as in Chapters 13 and 15) the distinction between the two models becomes essential.

*Also referred to as a "components of variance model." The terms "Model I" and "Model II" for analysis of variance were introduced by Eisenhart (1947).