Baseline Assessment of Sources and Management of Land-Based Marine Pollution in the BCLME region

Project BEHP/LBMP/03/01

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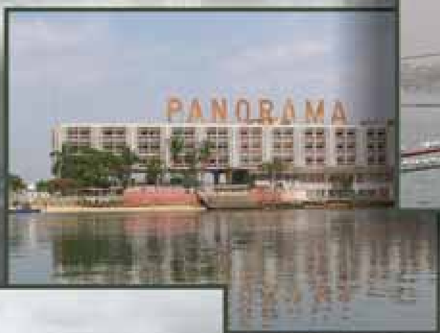

Prepared for: Benguela Current Large Marine Ecosystem Programme

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Angola: February and November/December 2005
South Africa: February and August 2005

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EXECUTIVE SUMMARY

The United Nations Office for Project Services ("UNOPS") commissioned the CSIR (South Africa) to conduct a baseline assessment of sources and management of land-based marine pollution in the Benguela Current Large Marine Ecosystem (BCLME) Region.

The primary purpose of this project was to standardize the approach and methodology by which land-based marine pollution sources in the BCLME region are managed. This was achieved through the preparation of a generic (draft) management framework, including protocols for the design of baseline measurement and long-term monitoring programmes.

An important secondary objective of this project was to initiate the establishment of a BCLME coastal water quality network to provide a legacy of shared experience, awareness of tools, capabilities and technical support. This network had to be supported by an updatable web-based information system that could provide guidance and protocols on the implementation of the management framework. The web-based information system also had to contain a meta-database on available information and expertise.

The main outputs of this project, therefore, included:

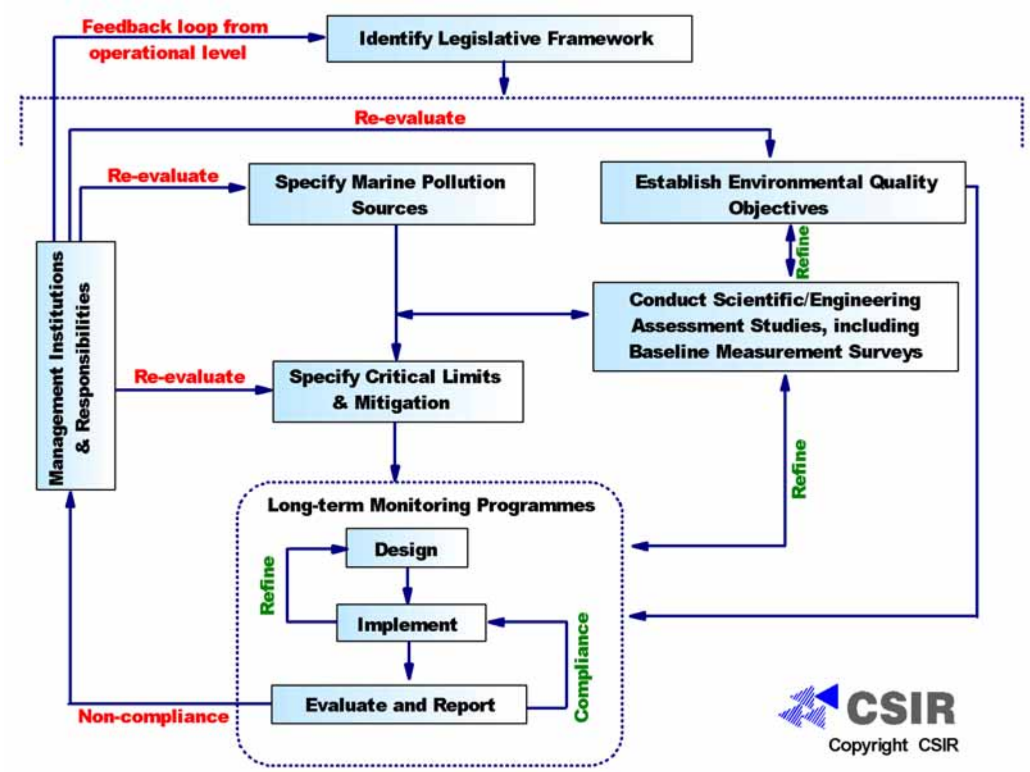
- A proposed (or draft) framework for managing a <u>land-based source of marine pollution</u>, including guidance on the implementation of such a framework
- Proposed protocols for the design of <u>baseline measurement and long-term monitoring programmes</u> related to the management of land-based marine pollution sources in the BCLME region
- <u>An inventory and critical assessment of available information and data</u> related to the management of (land-based) marine pollution sources in Angola, Namibia and South Africa
- <u>Work sessions and training workshops</u> in each of the three countries to which key stakeholders, involved in the management of marine pollution, were invited
- <u>Updatable web-based information system</u> that provides guidance on the application of the generic management framework, as well as a meta-database on available information and expertise in the BCLME region.

The proposed framework is largely based on a process that was developed for the Department of Water Affairs and Forestry (South Africa) as part of their *Operational Policy for the Disposal of Land-derived Wastewater to the Marine Environment of South Africa* (RSA DWAF, 2004) which, in turn, is based on a review of international best practice and own experience in the South African context.

The proposed framework promotes an ecosystem-based approach, identifying different components that need to be addressed as well as linkages between components. The following are considered to be key components of such a management framework:

- Identification of legislative framework
- Establishment of management institutions and their responsibilities
- Determination of environmental quality objectives
- Specification of marine pollution sources
- Scientific assessment studies
- Specification of critical limits and mitigation measures
- Design and implementation of long-term monitoring programmes.

A schematic illustration of the inter-linkages between these components is provided below. Each of the components is discussed in more detail in the document, with guidance on implementation.



An integral part of the management framework is baseline measurement and long-term monitoring programmes. As a result, this report also considers proposed protocols in the design of such programmes. In this regard it is important to note the difference between baseline measurement programmes (usually part of *Scientific Assessment Studies*) and monitoring programmes (implemented as part of *Long-term Monitoring Programmes*):

- *Baseline measurement programmes* (or surveys) usually refer to shorter-term or once-off, intensive investigations on a wide range of parameters to obtain a better understanding of ecosystem functioning
- *Long-term monitoring programmes* refer to ongoing data collection programmes (using selected indicators) that are done to continuously evaluate the effectiveness of management strategies/actions designed to maintain a desired environmental state so that responses to potentially negative impacts, including cumulative effects, can be implemented in good time.

The successful implementation of the proposed management framework relies on good cooperation, not only between responsible government departments and industries, but also with the scientific community (which plays a key role in providing the sound scientific base for decision-making). It is for this reason, therefore, that key stakeholders in each of the three countries should include members from:

- National and regional government departments
- Nature conservation authorities
- Local authorities
- Scientific community
- Industries utilizing the marine environment.

The inventory and critical assessment of available data and information relevant to the management of land-based marine pollution sources in the BCLME region focused on main development nodes in the area, as listed below:

ANGOLA	NAMIBIA	SOUTH AFRICA
Cabinda Soyo Ambriz Luanda Lobito Namibe	Henties Bay Walvis Bay/Swakopmund Luderitz Oranjemund (diamond mining areas)	St Helena Bay Saldanha Bay/Langebaan Lagoon Cape Peninsula (western section) False Bay Walker Bay (Hermanus) Mossel Bay Knysna Estuary

The following points relate to the way forward:

- The proposed framework for the management of land-based sources of marine pollution in the BCLME region still needs to be **officially approved and adopted** by responsible government authorities in the different countries.

- The management framework developed as part of this project is **closely linked to the recommended water and sediment quality guidelines** for the coastal areas of the BCLME region (developed as part of another BCLME project – BEHP/LBMP/03/04).

  In the interim, until such time as a management framework and quality guidelines have been incorporated in official government policy, it is proposed that the management framework developed as part of this project, together with the recommended water and sediment quality guidelines, be applied as preliminary tools towards improving the management of the water quality in coastal areas of the BCLME region.

- The **updatable web-based information system** (temporary web address www.wamsys.co.za/bclme), developed as part of this project, can be a very useful decision-support and educational tool provided that it is maintained and updated regularly. In the short to medium term, it is recommended that one or more of the BCLME offices within the three countries take on this responsibility.

- To facilitate wider capacity building in the BCLME region of the management of marine pollution in coastal areas, it is strongly recommended that the output of this project be included in a **training course**. In this regard, the *Train-Sea-Coast/Benguela Course Development Unit* is considered the ideal platform from which to develop and present such training (www.ioisa.org.za/tsc/index.htm).

RESUMO EXECUTIVO

O Gabinete das Nações Unidas para Prestação de Serviços (*United Nations Office for Project Services* - "UNOPS”) contratou o CSIR (África do Sul) para conduzir uma avaliação primária das fontes terrestres e gestão da poluição marinha na região do Grande Ecossistema Marinho da Corrente de Benguela (*Benguela Current Large Marine Ecosystem*) (BCLME).

O objectivo primario deste projecto foi o de padronizar a abordagem e metodologia pelo qual as origens de poluição marinha na região BCLME são geridas. Isto foi alcançado através da preparação de uma estrutura genérica (rascunho) de gestão, incluindo protocolos para a delineação de programas de monitorização a longo prazo.

Um segundo objectivo importante deste projecto foi dar início ao estabelecimento de uma rede de comunicações sobre a qualidade da água costeira no BCLME, de modo a providenciar uma partilha de experiência, conhecimentos sobre o tipo de instrumentos, capacidades e apoio técnico. Esta rede tinha de ser apoiada por um sistema de informação actualizável e apoiado na Internet que pudesse providenciar orientação e criasse protocolos na implementação da estrutura de gestão. Este sistema de informação apoiado na Internet deveria também incluir uma metabase de dados sobre informação disponível e experiência técnica.

Os principais produtos deste projecto incluíam assim:

- Uma proposta (ou rascunho) da estrutura para gerir fontes terrestres de poluição marinha, incluindo orientações quanto à implementação dessa mesma estrutura
- Proposta de Protocolos para a delineação de programas de monitorização a longo prazo relacionadas com a gestão de fontes terrestres de poluição marinha na região do BCLME
- Um inventário e availaç

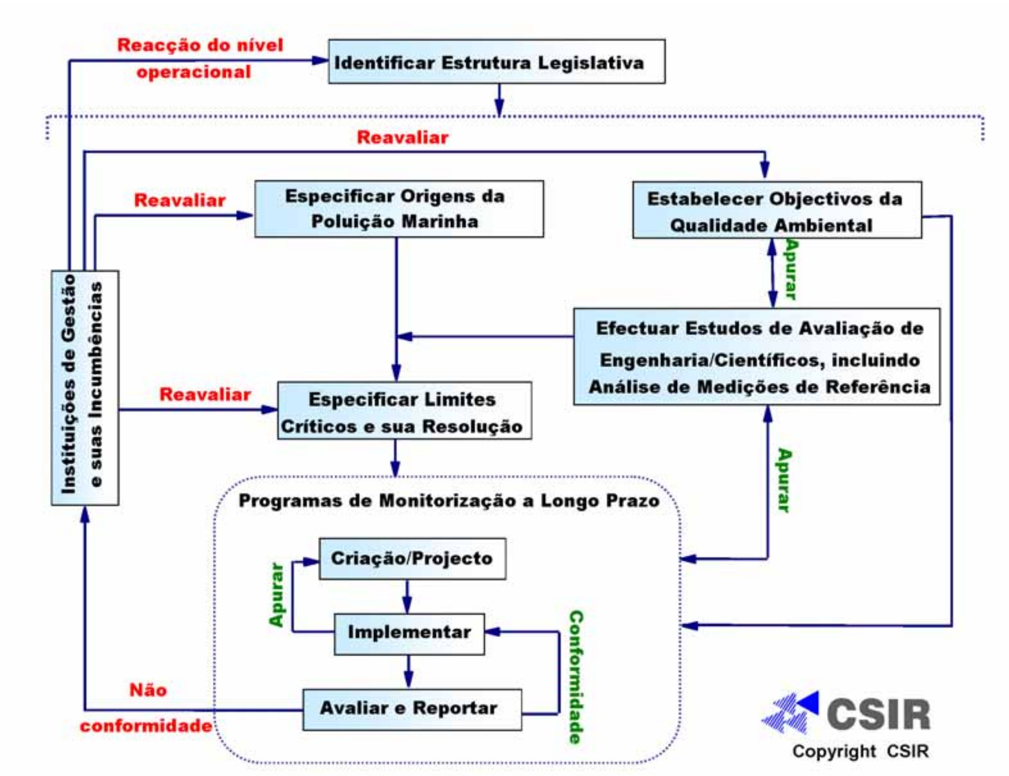
- Um inventário e uma avaliação crítica da informação e dos dados disponíveis relacionados com a gestão das fontes terrestres de poluição marinha em Angola, Namíbia e África do Sul
- Sessões de trabalho e workshops de treino em cada um dos três paises aos quais os "stakeholders" no campo de gestão de poluição marinha foram convidados
- Um sistema de informação actualizável com apoio na Internet que proporcione orientação quanto à aplicação da estrutura de gestão genérica, bem como uma metabase de dados sobre informação disponível e experiência técnica na região do BCLME.

A estrutura proposta é largamente baseada num processo desenvolvido pelo Ministério dos Assuntos de Água e Florestas (*Department of Water Affairs and Forestry*), da África do Sul, como parte da sua *Política Operacional para o Tratamento de Águas Residuais Oriundas de Terra para o Ambiente Marinho da África do Sul (RSA DWAF, 2004),* a qual por sua vez assenta numa revisão do código de boa conduta internacional e na própria experiência no contexto da África do Sul.

A estrutura proposta estimula uma aproximação com base no ecossistema, identificando componentes diferentes que devem ser estudados, bem como ligações entre as componentes. Abaixo identificam-se aqueles considerados como os componentes-chave dessa estrutura de gestão:

- Identificação de uma estrutura legislativa
- Estabelecimento de instituições de gestão e suas incumbências
- Determinação de objectivos de qualidade ambiental
- Especificação das origens da poluição marinha
- Estudos de avaliação científica
- Especificação de limites críticos e medidas de atenuação
- Criação e implementação de programas de monitorização a longo prazo.

Uma ilustração esquemática das interligações entre estes componentes é dada abaixo. Cada um dos componentes é discutido com maior pormenor no documento, com orientações para execução.



Uma parte integrante da estrutura de gestão é a medição de base e programas de monitorização a longo prazo. Como consequência, este relatório contempla igualmente os protocolos da criação desses mesmos programas. Quanto a este aspecto, torna-se importante salientar a diferença entre programas de <u>estudos de referência</u> (habitualmente fazendo parte de *Estudos de Avaliação Científica*) e programas de <u>monitorização</u> (desenvolvidos como fazendo parte de *Programas de monitorização a Longo Prazo*):

- Programas de estudos básicos (ou pesquisa) referem normalmente a investigações intensivas de um conjunto de parâmetros de curto-prazo ou realizadas de uma só com a finalidade de um melhor entendimento do funcionamento do ecossistema.
- Programas de monitorização a longo prazo referem-se a programas em curso de recolha de dados (usando indicadores seleccionados), feitos para avaliar continuamente a eficácia das estratégias/acções de gestão criadas para manter um estado ambiental, de modo a que as respostas aos impactos potencialmente negativos, incluindo os efeitos cumulativos, possam ser implementadas em devido tempo.

A implementação com sucesso da estrutura de gestão proposta assenta numa boa cooperação, não só entre os vários departamentos governamentais e indústrias, mas também na comunidade científica (que desempenha um papel chave no fornecimento de uma base científica sólida para uma tomada de decisão). É por esta razão, por isso, que os investidores potenciais em cada um dos três países devem incluir membros de:

- Departamentos governamentais nacionais e regionais
- Autoridades de conservação da natureza
- Autoridades locais
- Comunidade científica
- Indústrias que utilizam o meio ambiente marinho.

O inventário e a avaliação crítica dos dados e da informação disponíveis relevantes para a gestão das fontes terrestres de poluição marinha na região do BCLME focalizados nos principais nós de desenvolvimento na área, são apresentados de seguida:

ANGOLA	NAMÍBIA	ÁFRICA DA SUL
Cabinda Soyo Ambriz Luanda Lobito Namibe	Henties Bay Walvis Bay/Swakopmund Luderitz Oranjemund (áreas das minas de diamantes)	St Helena Bay Saldanha Bay/Langebaan Lagoon Cape Peninsula (secção ocidental) False Bay Walker Bay (Hermanus) Mossel Bay Knysna Estuary

Os pontos seguintes definem o caminho a seguir:

- A estrutura proposta para a gestão das fontes terrestres de poluição marinha na região do BCLME necessita ainda de ser **oficialmente aprovada e adoptada** pelas autoridades governamentais responsáveis nos diferentes países.

- A estrutura de gestão desenvolvida como parte deste projecto está intimamente ligada às **linhas mestras da qualidade da água e dos sedimentos** para as áreas costeiras do BCLME (desenvolvidas como parte de um outro projecto BCLME – o BEHP/LBMP/03/04).

  Neste entretanto, até que uma estrutura de gestão e as linhas mestras da qualidade da água tenham sido incorporadas numa política governamental oficial, é proposto que a estrutura de gestão desenvolvida como parte deste projecto, juntamente com as orientações recomendadas para água e sedimentos, sejam aplicadas como ferramentas preliminares com vista a melhorar a gestão da qualidade da água nas áreas costeiras da região do BCLME.

- O **sistema de informação actualizável com suporte na Internet** (endereço web temporário: www.wamsys.co.za/bclme) desenvolvido como parte deste projecto pode ser útil para apoiar a tomada de decisão e como ferramenta educativa, desde que mantido e actualizado com regularidade. A curto e médio prazo, recomenda-se que um ou mais escritórios do BCLME no âmbito dos três países seja por esse facto responsável.

A fim de facilitar uma maior e mais vasta capacidade de construção no seio da região do BCLME no que respeita à gestão da poluição marinha nas áreas costeiras, é fortemente recomendado que os resultados deste projecto sejam incluídos num **curso de formação**. Assim sendo, a Unidade de Desenvolvimento do Curso(*Train-Sea-Coast/Benguela Course Development Unit)* é tido como a plataforma ideal para desenvolver e apresentar essa formação (www.ioisa.org.za/tsc/index.htm).

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ACRONYMS, SYMBOLS AND ABBREVIATIONS

ANZECC	Australia and New Zealand Environment and Conservation Council
ANZFA	Australia New Zealand Food Authority
BCLME	Benguela Current Large Marine Ecosystem
CCME	Canadian Council of Ministers of the Environment
CEC	Council of the European Community
CTD	Conductivity-Temperature-Depth
DEAT	Department of Environmental Affairs and Tourism (RSA)
DWAF	Department of Water Affairs and Forestry (RSA)
GESAMP	Group of Experts on the Scientific Aspects of Marine Pollution (United Nations)
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities
IMO	International Maritime Organization
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
RSA	Republic of South Africa
SBWQFT	Saldanha Bay Water Quality Forum Trust
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environmental Programme
US FDA	United States Food And Drug Administration
US-EPA	United States Environmental Protection Agency
WSSD	World Summit on Sustainable Development
WWTW	Wastewater Treatment Works

INTRODUCTION

1. SCOPE OF WORK

The United Nations Office for Project Services ("UNOPS") commissioned the CSIR to conduct a baseline assessment of sources and management of land-based marine pollution in the Benguela Current Large Marine Ecosystem (BCLME) Region.

The primary purpose of this project was to standardize the approach and methodology by which land-based marine pollution sources in the BCLME region are managed. This was achieved through the preparation of a generic (draft) management framework for the management of such sources, including protocols for the design of baseline measurements and long-term monitoring programmes. It is important to realize that, although it is possible to put forward a generic management framework for such a large region, the implementation of the management framework will ultimately be more site-specific.

The BCLME region is situated along the coast of south- western Africa, stretching from east of the Cape of Good Hope in the south (Plettenberg Bay) northwards to Cabinda in Angola, and encompassing the full extent of Namibia's marine environment (Figure 1).

Figure 1: Boundaries of the Coastal Zone of the BCLME region

An important secondary objective of this project was to initiate the establishment of a BCLME coastal water quality network to provide a legacy of shared experience, awareness of tools, capabilities and technical support. This network had to be supported by an updatable web-based information system, providing guidance and protocols on the implementation of the generic management framework. The web-based information system also had to contain a meta-database on available information and expertise.

The main outputs of this project, therefore, are:

- A proposed (or draft) framework for managing a land-based source of marine pollution, including guidance on the implementation of such a framework
- Propose protocols for the design of baseline measurement and long-term monitoring programmes related to the management of land-based marine pollution sources in the BCLME region
- A preliminary list of key stakeholders involved in the management of marine pollution in each of the three countries
- An inventory and critical assessment of available information and data related to the management of (land-based) marine pollution sources in Angola, Namibia and South Africa
- Updatable web-based information system that provides guidance on the application of the generic management framework, as well as a meta-database on available information and expertise in the BCLME region.

In the **Introduction** to this Report, the *Scope of Work* (Chapter 1) is followed by a chapter describing the *Approach and Methodology* (Chapter 2) that were used in the development of the proposed management framework, followed in turn by a short *Introduction to the Proposed Management Framework* (Chapter 3).

Thereafter the layout of the report is as follows:

- **Section 1:** Guidance on the implementation of the proposed management framework, highlighting key aspects that need to be addressed within each of the identified components
- **Section 2**: Proposed protocols (or guidance) for consideration in the design of baseline measurement and long-term monitoring programmes

- **Section 3**: Preliminary list of key stakeholders involved in the management of marine pollution sources in the BCLME region
- **Section 4:** Introduction to the Desktop Assessment Studies on existing information pertaining to Land-based Sources of Marine Pollution in the BCLME region
- **Appendices A, B and C**: Detailed desktop assessment studies on existing information pertaining to land-based sources of marine pollution for South Africa, Namibia and Angola.
- **Appendix D:** User Manual for the Web-based Information System (temporary web address: www.wamsys.co.za.

2. APPROACH AND METHODOLOGY

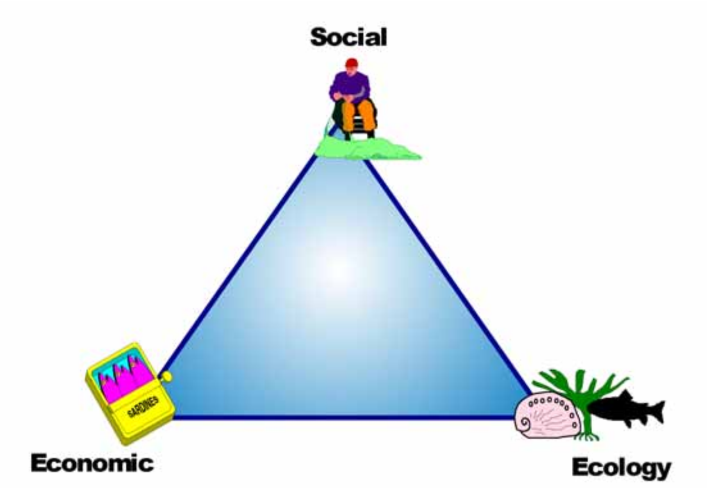
The challenge in ecosystem management is to ensure sustainable development, which is defined as:

".. development which fulfils the needs of the present generation without jeopardizing the possibilities of future generations to fulfill their needs."

This definition is echoed by the consensus agreement that was formed at the United Nation's Conference on Environmental Development, which was held in Rio de Janeiro (1992):

- The overall aim of the development of any society should be sustainable development
- Sustainable development encompasses environmental, economic, and social dimensions
- Sustainable development demands not only a governmental effort, but also an effort from all levels of society, from the global to the local perspective
- International co-operation is a prerequisite for sustainable development.

Thus, in order to be sustainable, development must be economically profitable, ecologically proper, and socially acceptable. These three considerations are described as the 'sustainability triangle':



Since nature is a complex of dynamic processes, sustainable management of any ecosystem implies that emphasis on the three priorities (i.e. various economic, ecological and social considerations) over time may not always be equal. However, as long as the management of the system does not go beyond the bounds of the 'sustainability triangle', the management and development of the system could be characterized as sustainable.

In this context, the ultimate goal in the management of coastal water resources is to keep the environment suitable for all designated uses – both existing and future uses. To achieve this goal, is important to protect the biodiversity and functioning of marine aquatic ecosystems (i.e. ecology) so as to support important (beneficial) uses of the marine environment (i.e. social and economic values).

Land-based sources of marine pollution, amongst others, are posing an increasing threat to the sustainability of the ecological, social and economic functions of the marine environment, even though the associated activities and developments may create social and economic benefits elsewhere. Towards combating this threat, the *Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA),* was adopted in November 1995. It is designed to assist states in taking action individually or jointly within their respective policies, priorities and resources that will lead to the prevention, reduction, control or elimination of the degradation of the marine environment, as well as to its recovery from the impacts of land-based activities (www.gpa.unep.org/).

In 2004, the CSIR assisted the South African Department of Water Affairs and Forestry with the *Development of an Operational Policy for the Disposal of Land-derived Wastewater to the Marine Environment of South Africa* (RSA DWAF, 2004a). As part of this operational policy, a management framework was proposed for the management of land-based disposal to the marine environment. The framework proposed for the management of land-based sources of marine pollution in the BCLME region, as part of this project, is largely based on this management framework, the motivation for this approach being:

- that the framework developed as part of South Africa's operational policy in 2004 was already based on a review of international best practice and own experience in the south(ern) African context
- rather adapt successful management practices that already exist in one or more countries within the BCLME region, than 're-invent the wheel'.

The proposed management framework promotes an ecosystem-based approach, rather than managing pollution sources on an individual basis. It identifies key components to be addressed in the management of marine pollution sources, as well as the linkages between such components. Baseline measurement and long-term monitoring programmes form an integral part of the framework.

South Africa's operational policy also includes detailed guidance on the implementation of a management framework, particularly aimed at managers, responsible authorities and scientists who typically form part of such a process (RSA DWAF, 2004b). For the same reasons as listed above, the guidance on implementation was also largely based on approach and methods of this policy.

Also incorporated was the CSIR's experience in applying a similar framework in Saldanha Bay, when it assisted local authorities with the development of a marine water quality management plan for the area. Saldanha Bay is situated along the west coast of South Africa, within the BCLME region (Taljaard & Monteiro, 2002; Monteiro & Kemp, 2004). A similar exercise has also been conducted in False Bay, a large bay just south of Cape Town, also within the BCLME region (Taljaard *et al*., 2000).

The framework proposed for the management of marine pollution in the BCLME region, as part of this project, is also similar to the Framework for Marine and Estuarine Water Quality Protection that forms part of the Coastal Catchments Initiative, which has been launched in Australia to improve coastal water quality (Australian Government, 2005).

3. INTRODUCTION TO PROPOSED MANAGEMENT FRAMEWORK

Based on a review of international practice and own experience in the South African context, the following key components should be included in a management framework for marine pollution (including land-based sources):

- Identification of legislative framework
- Establishment of management institutions and responsibilities
- Determination of environmental quality objectives
- Specification of marine pollution sources
- Scientific/engineering assessment studies
- Specification of critical limits and mitigation measures
- Design and implementation of long-term monitoring programmes.

A schematic illustration of the inter-linkages between these components is provided in Figure 2. Each of the components is discussed in more detail in Section 2, including guidance on implementation.

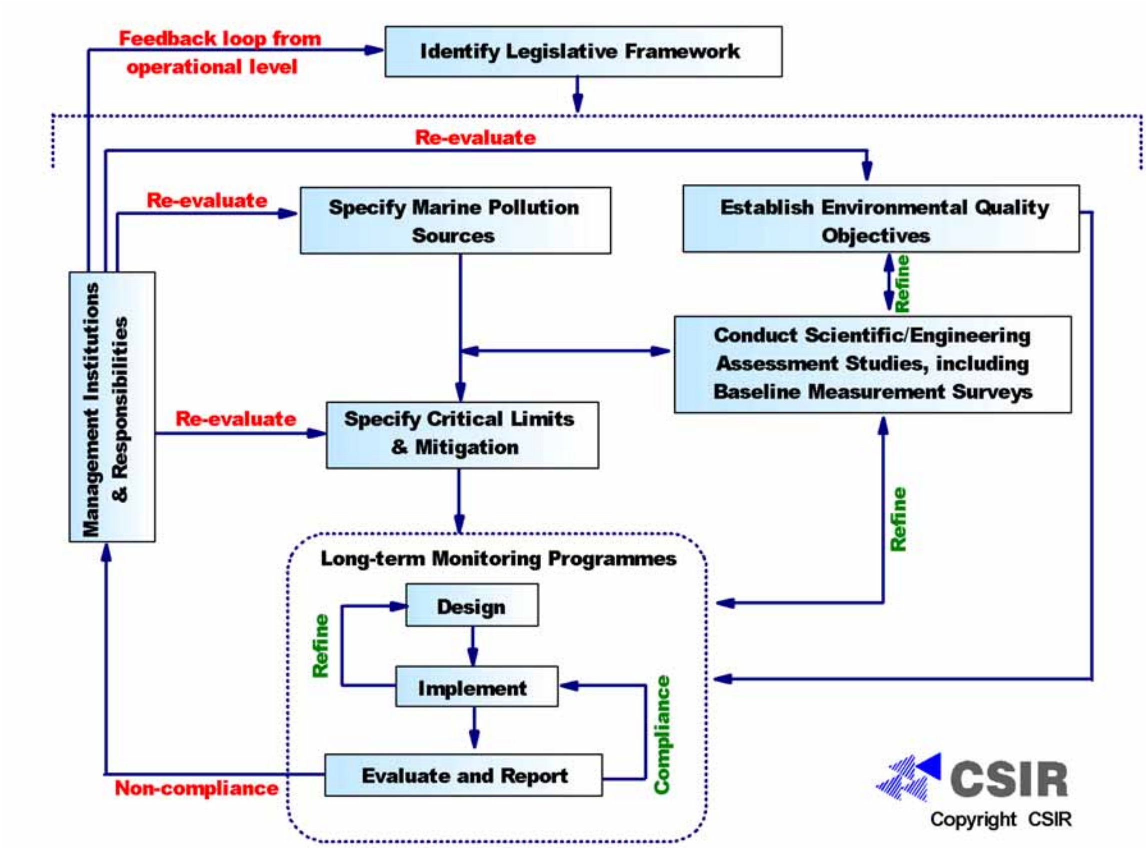


Figure 2: Proposed framework for the design and implementation of marine water quality management programmes in the BCLME region

SECTION 1.
GUIDANCE ON IMPLEMENTATION OF PROPOSED FRAMEWORK FOR MANAGEMENT OF LAND-BASED SOURCES OF MARINE POLLUTION

1.1 LEGISLATIVE FRAMEWORK

A marine water quality management programme needs to be designed and implemented within the statutory framework governing marine pollution, taking into account international and national legislation. Assessments of the current legislative framework governing such matters in each of the three countries in the BCLME region are provided in Appendix A (South Africa), Appendix B (Namibia) and Appendix C (Angola).

Although the national legislative framework differs from one country to another, key international programmes, treaties and conventions relating to the management of land-based marine pollution sources that may apply, depending on whether a country is a signatory to such agreements, include:

- **Agenda 21**, the internationally accepted strategy for sustainable development decided upon at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. Agenda 21 is a plan for use by governments, local authorities and individuals to implement the principle of sustainable development contained in the Rio Declaration. This document has significant status as a consensus document adopted by about 180 countries. Agenda 21 is, however, not legally binding on states, and merely acts as a guideline for implementation (www.un.org/esa/sustdev/agenda21text.htm).
- **Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA)**, which was adopted in November 1995 and which is designed to assist states in taking action individually or jointly within their respective policies, priorities and resources that will lead to the prevention, reduction, control or elimination of the degradation of the marine environment, as well as to its recovery from the impacts of land-based activities. The GPA builds on the principles of Agenda 21. The GPA identifies the Regional Seas Programme of UNEP as an appropriate framework for delivery of the GPA at the regional level (www.gpa.unep.org/).
- **World Summit on Sustainable Development (WSSD) (2002) -** the Johannesburg summit formulated two new principles that are central to the philosophy of managing marine water quality at the system scale (www.gpa.unep.org/news/gpanew.html):
  - Firstly, the call for a shift away from individual resources towards ecosystem-based management of coastal systems

- Setting of wastewater emission targets (WET), which limit the upper boundary of land-based discharge fluxes into coastal systems to a level in which ecosystem impacts are not measurable.

- **United Nations Environmental Programme (UNEP**), which was initiated in 1972 and which contains several programmes considering marine pollution, e.g. the Ocean and Coastal Areas Programmes and the Regional Sea Programmes (www.unep.org/).

- **United Nations Convention on the Law of the Sea (UNCLOS) (1982)** which lay down, first of all, the fundamental obligation of all states to protect and preserve the marine environment. It further urges all states to cooperate on a global and regional basis in formulating rules and standards and to otherwise take measures for the same purpose. It addresses six main sources of ocean pollution: land-based and coastal activities, continental-shelf drilling, potential seabed mining, ocean dumping, vessel-source pollution, and pollution from or through the atmosphere (www.un.org/Depts/los/index.htm).

- **United Nations Convention on Biological Diversity (1992),** which came into force in December 1993 and which has three main objectives, namely, the conservation of biological diversity; the sustainable use of biological resources; and the fair and equitable sharing of benefits arising from the use of genetic resources (www.biodiv.org).

Important international conventions that relate to marine pollution, but that are not necessarily directly linked to land-based sources, include:

- **London Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972, amended 1978, 1980, 1989)**. In November 1996, the contracting parties to the London Convention of 1972 adopted the 1996 Protocol, which, when entered into force, replaces the London Convention (www.londonconvention.org/London_Convention.htm) (related to dumping at sea)

- **International Convention for the Prevention of Pollution from Ships** (**MARPOL convention**) (1973/1978), which is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes and includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations (www.imo.org/home.asp) (related to maritime transportation).

Effective legislation (together with practical operational policies and protocols) is a key requirement for the successful management of marine pollution in a particular country. A sound legislative framework, for example, empowers responsible authorities to legally challenge offenders, provided that such legislation is supported by sufficient resources (both human and financial).

1.2 MANAGEMENT INSTITUTIONS & RESPONSIBILITIES

A key driving factor in the successful operation of any management programme is the establishment of the appropriate management institution/s, which includes identifying the roles and responsibilities of the different parties. Again, the legislative framework within a particular country should provide specifications and guidance in this regard.

In the management and control of marine pollution sources (including land-based sources), responsibilities traditionally resided with the responsible government authorities as well as the impactors (e.g. municipalities, industry and developers). Although these traditional management structures are still important, the value of also involving other local interested and affected parties through stakeholder forums or local management institutions, has proved to add great value to the overall management process (Henocque, 2001; Van Wyk, 2001; Taljaard & Monteiro, 2002; Cape Metropolitan Coastal Water Quality Committee, 2003).

Not only do these local management institutions provide an ideal platform through which to consult interested and affected parties on, for example, designated uses and environmental quality objectives for a specific area, but they also fulfil the important role of 'local watchdogs' or 'custodians'. Although such institutions usually do not have executive powers, they have shown themselves to be very successful mechanisms through which to empower (and often pressurize) responsible authorities to execute their legal responsibilities, e.g. ensuring that licence agreements are issued or that corrective action is taken timeously in instances of non-compliance.

The key to the success of local management institutions is a sound scientific information base, containing explicit scientific assumptions and outcomes, by which authorities, and also local stakeholders, are empowered to partake in the decision- making process.

It is also essential that local management institutions include all relevant interested and affected parties in order to facilitate a participatory approach to decision-making. The inclusion of responsible local, regional and national government authorities is also important, as these usually form the routes through which local management institutions have/hold executive powers. Local management institutions should therefore include representatives from, for example:

- National and regional government departments
- Nature conservation authorities
- Local authorities
- Industries
- Tourism boards and recreation clubs
- Local residents, e.g. through ratepayers' association
- Non-government organizations.

Where more than one source is responsible for pollution in a particular area (e.g. a bay area), it is usually extremely difficult and financially uneconomical to manage marine pollution issues in isolation because of potential cumulative or synergistic effects. In such instances, collaboration is also best achieved through a joint local management institution.

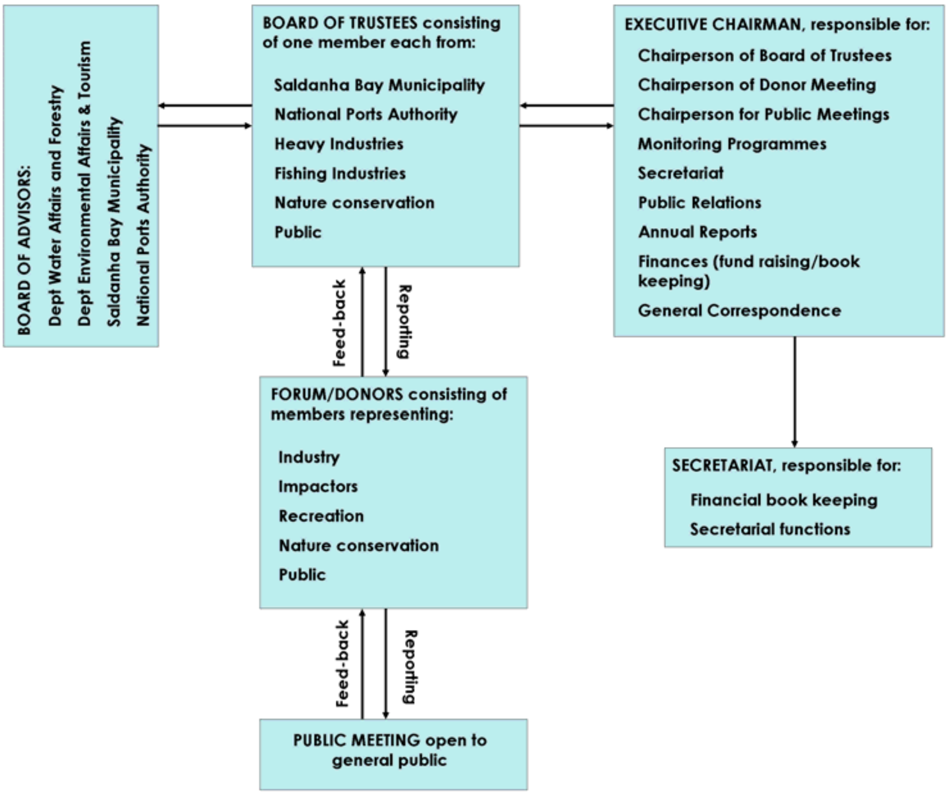
A local management institution, being actively involved in the management of marine pollution matters at local level, is also ideally positioned to test the effectiveness and applicability of legislation and policies, which are normally developed at national or regional levels. It is therefore also important that these institutions be utilized by higher tiers of government as a mechanism for improving legislative frameworks related to the management of marine pollution. Such practice supports the principle of Adaptive Management.

For the BCLME region, the coastal water quality network group, initiated as part of this study, will assist in empowering authorities in the different countries to fulfil their role as national manager of marine water quality. Furthermore, it is envisaged that the web- based information system will provide to all concerned easy access to guidance and protocols on the implementation of the generic management framework, as well as a meta-database on available information and expertise.

Within the BCLME region, the Saldanha Bay Water Quality Forum Trust (SBWQFT) is an example of an existing local management institution that works very well. The forum was established in June 1996 through the efforts of individuals with an interest in Saldanha Bay who created an awareness of the need to address the deteriorating water quality in the Bay. The SBWQFT is a voluntary organization comprising officials from local (municipality, Nature conservation), regional (regional office of the Department of Water Affairs and Forestry) and national authorities (Department of Environmental Affairs and Tourism), representatives from all major industries in the area (e.g. National Ports Authority, seafood processing industries, marine aquaculture farmers) and other groups who have a common interest in the area (e.g. tourism).

The main purpose of the SBWQFT is to work towards maintaining water quality and ecosystem functioning so as to keep Saldanha Bay fit for all its designated uses. Although the Trust does not have legislative powers, it acts as an advisory body to legislative authorities that are also members of the forum (e.g. Department of Water Affairs and Forestry, Department of Environmental Affairs and Tourism, National Ports Authority, Saldanha Bay Municipality). Through this route the Trust can thereby influence the decision-making process. A quote from *Bay Watch*, the publication of the Trust (SBWQFT, 2004) probably explains this best: '*This is a most unique forum in that, as far as I am aware, it is a the only non-government body that is totally successful in melding the private sector with their contributions and the government with their overseeing capacity, to form a unit that is ultimately functional and effective.'*

The organizational structure of the Trust is illustrated below (SBWQFT, 2004):



The SBWQFT raises funding by applying the principle of 'Polluter Pays' whereby major industries contribute. These financial resources are utilized towards:

- Commissioning scientific investigation to make informed decisions on the management of the area, albeit through advising the relevant government authorities (e.g. CSIR was commissioned to assist them with developing a management plan)
- Commissioning coordinated joint monitoring programmes in the area (e.g. CSIR was commissioned to conducting a sediment monitoring programme, while the Trust conducts its own microbiological programme)
- Producing communication tools to inform the wider community, such as the Bay Watch publication.

Because the Trust has a mechanism in place to generate its own funds it can commission scientific investigations (e.g. the development of the management plan for Saldanha Bay was commissioned through a tender process). The Trust within itself also has water quality management expertise, e.g. one of the members is responsible for running the microbiological programme in the Bay. Local expertise is also sourced, e.g. at a recent public meeting a local resident with experience in oil spill contingency planning provided his services.

Analysis of the manner in which the SBWQFT operates highlights key success factors of a local management institution that include:

- An enthusiastic executive chairperson who will keep things going!
- Active involvement of relevant government authorities (e.g. with executive powers in the domain of marine pollution and related matters)
- A mechanism in place to generate funds to, for example:
  - commission joint scientific investigations
  - produce communication tools to inform the wider local community (e.g. local news-letters
- Ensuring that all role players are on board, either actively through being members of the Trust or by involving them through <u>regular</u> public feedback meetings (at least annually or bi-annually).

1.3 ENVIRONMENTAL QUALITY OBJECTIVES

Environmental quality objectives must be set as part of the management framework to provide a basis from which to assess and evaluate management strategies and actions.

This can be achieved through a four-step approach:

- Define geographical boundaries of study area
- Define important aquatic ecosystems and designated uses within area
- Define management goals for important aquatic ecosystems and designated use areas
- Determine site-specific (measurable) environmental quality objectives, pertaining to sediment and water quality requirements.

A first and very important step in setting environmental quality objectives is to determine the <u>geographical boundaries</u> of the area within which the management framework is to be implemented. The anticipated influence of all major human activities and developments, both in the near and far field, must be taken into account, including the location of and inputs from different marine pollution sources. Important issues that need to addressed, include:

- Proximity of depositional areas in which pollutants introduced from one or more pollution sources can accumulative – these can be at distant locations for specific sources, particularly where the source discharges into a very dynamic environment, but then gets transported to an area of lower turbulence
- Possible synergistic effects in which the negative impacts from a particular source could be aggravated through interactions with pollutants introduced by other pollution sources in the area, or even through interaction with natural processes.

The ultimate goal in the management of the marine waters is to keep the environment suitable for all designated uses – both for existing and future uses (this includes the 'use' of designated areas for biodiversity protection and ecosystem functioning). The second step, therefore, is to identify and map <u>important aquatic ecosystems and designated uses</u> within the study area.

For the BCLME region, it has been proposed that three designated uses of the coastal marine environment be recognised, namely:

- Marine aquaculture (including collection of seafood for human consumption)
- Recreational use
- Industrial uses (e.g. seawater intakes for seafood processing, cooling water intakes, harbour and ports).

Management goals should be defined for each of the above uses. In the case of the protection of the aquatic marine ecosystem, these can be quantified in terms of the level of species diversity that needs to be maintained, while in the case of recreational or marine aquaculture areas, the management goal could be to achieve a certain rating or classification. Similar to the European Union's approach, it is proposed that, for the BCLME region, in contrast to designated use areas where protection is required only in the specific area where such a use occurs (e.g. popular recreation beach), protection of marine aquatic ecosystems should be striven for in all waters (CEC, 2003). ,the exception to this being perhaps in approved sacrificial zones (e.g. in proximity to wastewater discharges and certain areas within ports) – the rationale being that the natural environment needs to be protected to a high level in its entirety.

Agreement on the designated uses and management goals of a particular area should be obtained in consultation with local interested and affected parties (or stakeholders) through, for example, the local management institutions. An example of a designated (beneficial) use map is that for the Saldanha Bay/Langebaan Lagoon area along the west coast of South Africa (Figure 1.1). This map was compiled in consultation with local stakeholders, using the Saldanha Bay Water Quality Forum Trust (local management institution) as vehicle.

Once agreement has been obtained on important aquatic ecosystems and designated uses, their location, as well as the management goals for each particular area, site-specific environmental quality objectives pertaining to sediment and water quality requirements need to be derived. The rationale here is that, although management goals are the real management end-points, the goals will only be achieved if certain sediment and water quality targets are maintained, as the proximal causes in the cause–effect relationship (Ward and Jacoby, 1992).

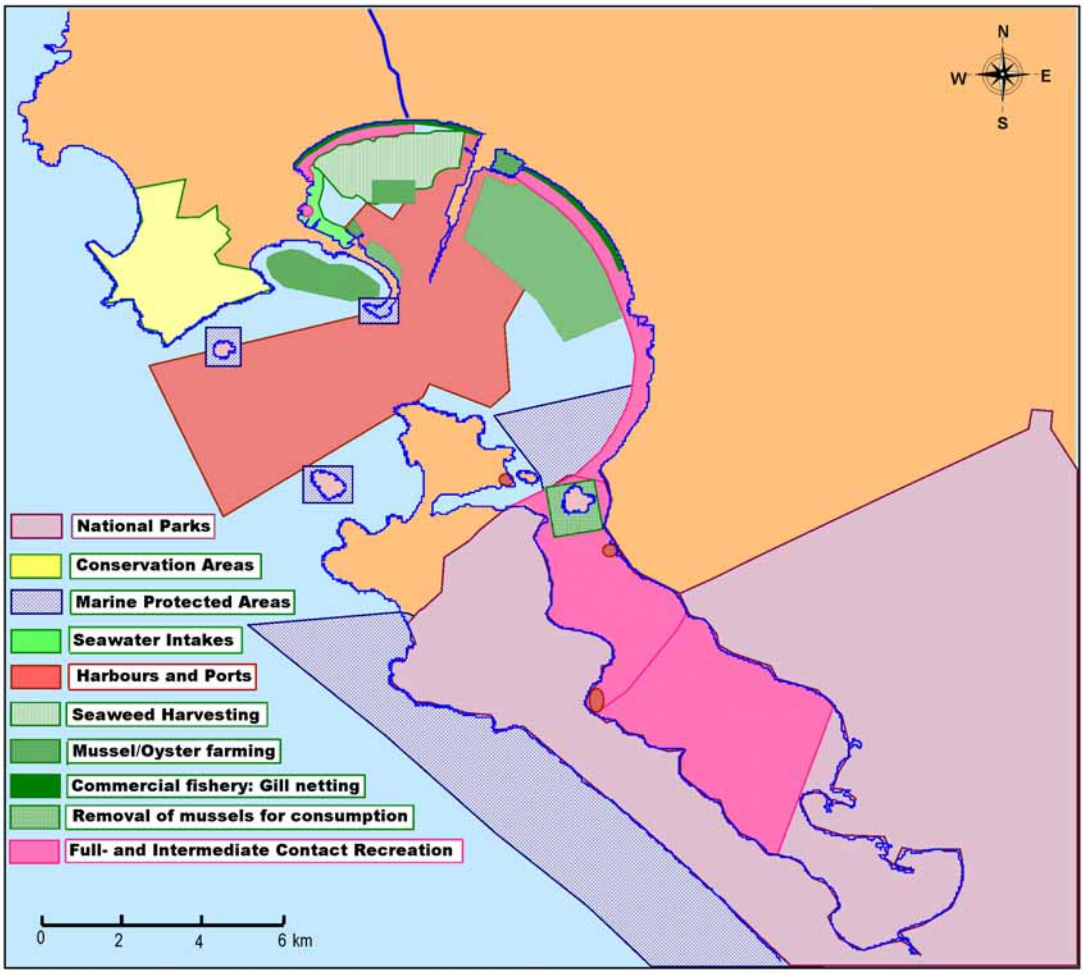


Figure 1.1: Mapping of important marine aquatic ecosystems and designated (beneficial uses in Saldanha Bay/Langebaan along the west coast of South Africa (adapted from Taljaard & Monteiro, 2002)

It is in setting these site-specific environmental quality objectives that the national (or regional) water and sediment quality guidelines provide valuable guidance to managers and local governing authorities.

NOTE:

Recommended water and sediment quality guidelines for the coastal zone of the BCLME regions and its beneficial uses are addressed as part of another BCLME project, namely The development of a common set of water and sediment quality guidelines for the coastal zone of the BCLME region – Project BEHP/LBMP/03/04)

Quality objectives could also be prescribed in legislation. For example, the concentration of pathogens and toxicants in seafood (which will be relevant to areas used for the culture of shellfish) are typically prescribed in national legislation, such as in:

- South Africa, where limits for chemical and pathogens are specified under the Foodstuffs, Cosmetics and Disinfectants Act (No. 54 of 1972) (Department of Health, 1973, 1994)
- European Union, where limits for shellfish flesh are specified in the S*hellfish Hygiene Directive* (CEC, 1991).
- Australia and New Zealand, where these limits are specified under the *Food Standards Code* (ANZFA 1996, and updates)
- United States Food and Drug Administration which specifies such limits for the United States – see website on *Seafood Information and Resources* (US FDA, 2004) and *National Shellfish Sanitation Program* (US FDA, 2003)
- Canada, where the Canadian Food Inspection Agency specifies action levels (Canadian Food Inspection Agency, 2004).

Development of site-specific environmental quality objectives requires knowledge of the chemical, physical, and biological properties of a water body, as well as the social and economic conditions of an area.

As a minimum, environmental quality objectives should protect the existing and potential uses of a water body. Where water bodies are considered to be of exceptional value, or where they support valuable biological resources, degradation of the existing water quality should always be avoided. Similarly, site-specific objectives should not be made on the basis of aquatic ecosystem characteristics that have arisen as a direct result of previous human activities (CCME, 1995).

Social and economic factors need to be evaluated to determine if the environmental quality objectives can realistically be attained. For example, when setting critical limits for pollution sources (e.g. wastewater emission standards) so as to meet quality objectives, social and economic factors can be factored in by giving longer deadlines to smooth out the transition period. Periodic re-evaluations and refinements of environmental quality objectives are then implemented to ensure that the desired water quality is ultimately maintained.

1.4 MARINE POLLUTION SOURCES

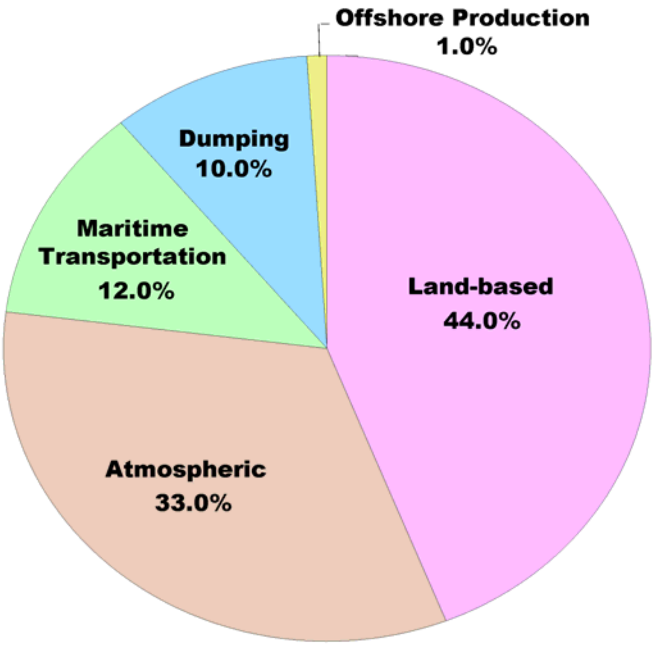
The United Nation's Group of Experts on the Scientific Aspects of Marine Pollution defines marine pollution as the (GESAMP, 1999):
Introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as to cause(?) harm to living resources, hazard to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater, and reduction of amenities.

Effective management of marine pollution in a particular area requires, amongst other things, quantitative data on marine pollution sources, as well as on other activities or developments that directly (or indirectly) affect water and sediment quality. Although human perturbations of marine water and sediment quality are usually perceived to be the result of marine pollution sources, it is important to realize that developments that modify circulation dynamics in the marine environment, such as harbour and marina structures, can also modify these quality characteristics.

Marine pollution sources can broadly be categorized into the following groups of activities, which occur either at sea or on land:

- Pollution or waste originating from <u>land-based sources</u>, including sewage effluent discharges, industrial effluent discharges, stormwater run-off, agricultural and mining return flows, contaminated groundwater seepage
- Pollution or waste entering the marine environment through the <u>atmosphere</u>, e.g. originating from vehicle exhaust fumes and industries
- <u>Maritime transportation</u> (which includes accidental and purposive oil spills, and dumping of ship garbage etc.)
- <u>Dumping at sea</u> (e.g. dredge spoil)
- <u>Offshore exploration and production</u> (e.g. oil exploration platforms).

Of the different sources of marine pollution, land-based sources are considered to be the largest - based on studies by the International Maritime Organisation (IMO, 1977):



NOTE:

Depending on the type of impact on the aquatic organisms, communities, and ecosystems, pollutants can further be grouped in the following order of increasing hazard (Patin, 2004):

- ***substances causing mechanical impacts (suspensions, films, solid wastes) that damage the respiratory organs, digestive system, and receptive ability;***
- ***substances provoking eutrophic effects (e.g., mineral compounds of nitrogen and phosphorus, and organic substances) that cause mass rapid growth of phytoplankton and disturbances of the balance, structure, and functions of the water ecosystems;***
- ***substances with saprogenic properties (sewage with a high content of easily decomposing organic matter) that cause oxygen deficiency followed by mass mortality of water organisms, and appearance of specific microphlora;***
- ***substances causing toxic effects (e.g., heavy metals, chlorinated hydrocarbons, dioxins, and furans) that damage the physiological processes and functions of reproduction, feeding, and respiration;***
- ***substances with mutagenic properties (e.g., benzo(a)pyrene and other polycyclic aromatic compounds, biphenyls, radionuclides) that cause carcinogenic, mutagenic, and teratogenic effects.***

Focusing on land-based marine pollution sources shows that these can be sub-divided into:

- Point sources (i.e. sources of which the volume and quality can be readily controlled)
- Non-point (or diffuse) sources (i.e. sources of which the volume and quality are difficult to control).

Point sources mainly comprise:

- Municipal (or sewage) wastewater discharges

- Industrial wastewater discharges from industries – these also include discharging of contaminated seawater that was used for industrial purposes on land, e.g. coastal mining activities and seafood processing industries.

Diffuse pollution sources include:

- Contaminated stormwater run-off, usually associated with urban areas
- Agricultural and mining return flows
- Contaminated groundwater seepage.

Within the BCLME region, contaminated urban stormwater runoff is probably the most important diffuse source of marine pollution to the coastal areas.

Waste loads for point source (or controlled waste disposal practices), such as those discharged through marine outfalls, can usually be measured quite easily. However, it is much more difficult to quantify waste loads for non-point (or diffuse) sources, such as urban storm-water run-off, mining return flows and contaminated groundwater seepage. Spatial and temporal quantification and establishing of variation in waste loads from diffuse sources are usually best achieved through application of appropriate statistical or mathematical predictive models, although field measurements are required for calibration and verification purposes.

Land-based activities potentially causing marine pollution are often situated in the coastal zone, in which case waste or pollutants are directly disposed of into the coastal zone, e.g. through marine outfalls or stormwater drains. However, land-based marine pollution sources can also originate from activities and developments in adjacent river catchments in which case the pollutant is routed to the marine environment via rivers.

As part of a management programme, specifications that are typically required for marine pollution sources include:

- A description of the source, activity or development, including information on the manner in which it will affect the quality of the marine environment, as well as a map indicating the location of such sources

- Volume of waste - it is of particular importance to understand typical flow distribution patterns, whether these are, for example, continuous flows, whether there are distinct daily, monthly or seasonal patterns or whether the flow is determined by specific events

- Composition of waste – this refers to the concentration of biogeochemical and microbiological pollutants, including information on diurnal, seasonal or event-driven variations in composition
- In the case of effluents, it is also important to have information on physical properties, such as density, viscosity and temperature, including specification on diurnal and or seasonal variations (e.g. for engineering design of marine disposal schemes).

An example of a map indicating the location of potential marine pollution sources is that for the Saldanha Bay/Langebaan Lagoon area along the west coast of South Africa (Figure 1.2).

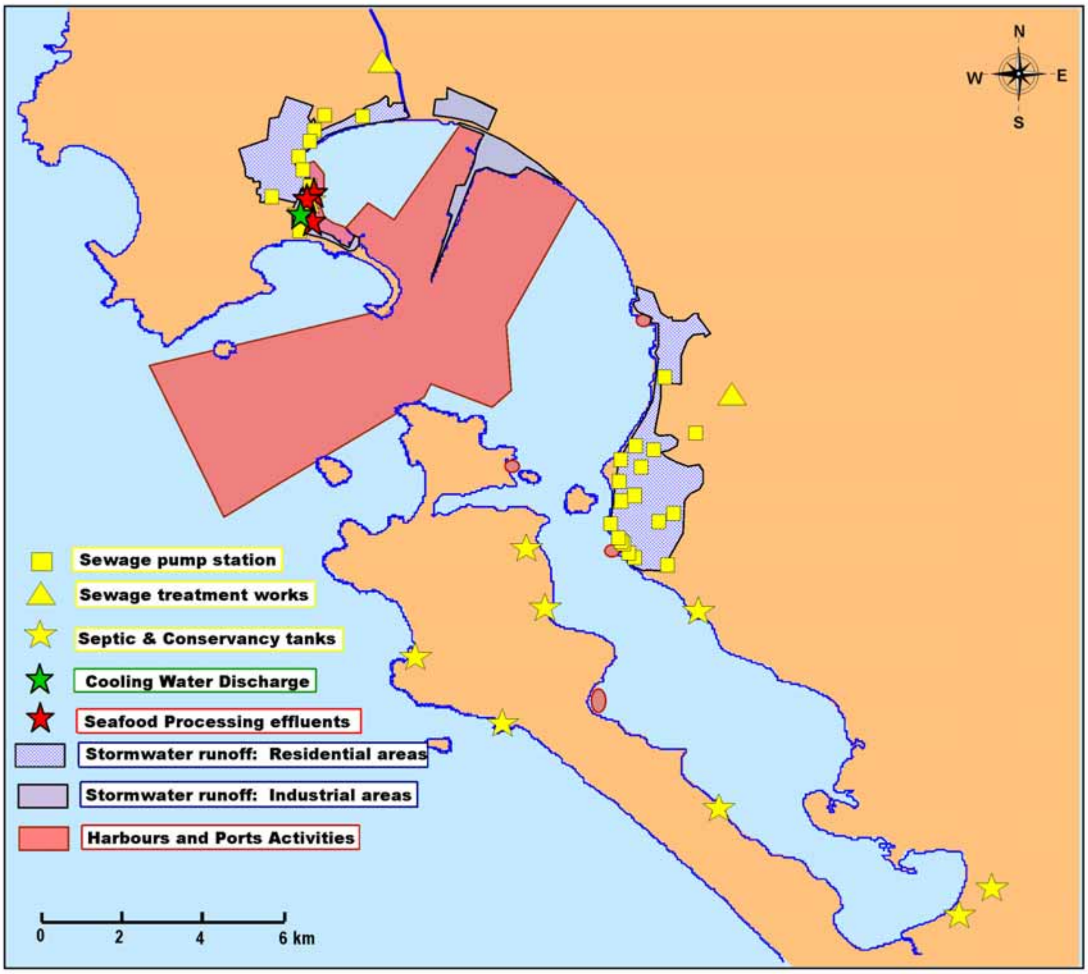


Figure 1.2: Mapping of potential marine pollution sources in Saldanha Bay/Langebaan along the west coast of South Africa (adapted from Taljaard & Monteiro, 2002)

Ultimately, the management of land-based pollution sources cannot be isolated from other marine pollution sources or other activities or developments that contribute to the modification of water and sediment quality in the marine environment. Not taking other sources into account may result in severe negative impacts due to, for example, cumulative or synergistic effects not being accounted for. Also, although atmospheric sources of marine pollution are traditionally categorized separately from land-based sources of pollution, a large proportion of the former category originate from land, e.g. emissions from land-based industries and vehicle exhaust fumes.

Therefore, although the focus of this project is on the management of land-based sources of marine pollution, potential interactions with other categories of marine pollution sources, as indicated above, cannot be ignored. The extent to which these need to be incorporated will depend on site-specific conditions and will therefore need to be evaluated on a case-by-case basis.

As a guide, a brief overview of the pollutant composition of major marine pollution sources in the BCLME region is provided in the following sections (also included are a number of non land-based sources that are considered important in the BCLME region).

1.4.1 Municipal Wastewater (including Sewage)

Municipal wastewater typically consists of:

- domestic wastewater (sewage) and/or
- industrial wastewater (also referred to as trade effluent) and/or
- urban storm-water run-off routed through wastewater treatment works (WWTW).

Municipal wastewater volumes tend to show diurnal variation with peaks during the morning, midday and late afternoon. However, each area will have its own characteristic flow pattern, depending on socio-economic factors, as well as the physical layout of the reticulation systems and taking into account retention times. Volume and flow rates may also show strong seasonal variation, particularly in small coastal towns where flows usually peak during the summer holidays. Also, infiltration (due to damaged pipes) during the wet season or during a rainstorm can also influence flow patterns (i.e. event driven).

The composition of municipal wastewater is largely dependent on the level of treatment, as well as the composition of trade effluents entering the WWTW. The composition of municipal wastewater (in particular the domestic sewage component) could contain (although the actual concentrations are dependent on the level of treatment):[keep u/c in list]

- high suspended solids
- organic matter
- inorganic nutrients, particular nitrogen and phosphate
- microbiological contaminants (e.g. bacteria and viruses).

Different treatment levels of municipal wastewater (sewage) are schematically illustrated in Figure 1.3 (RSA, DWAF, 2004b).

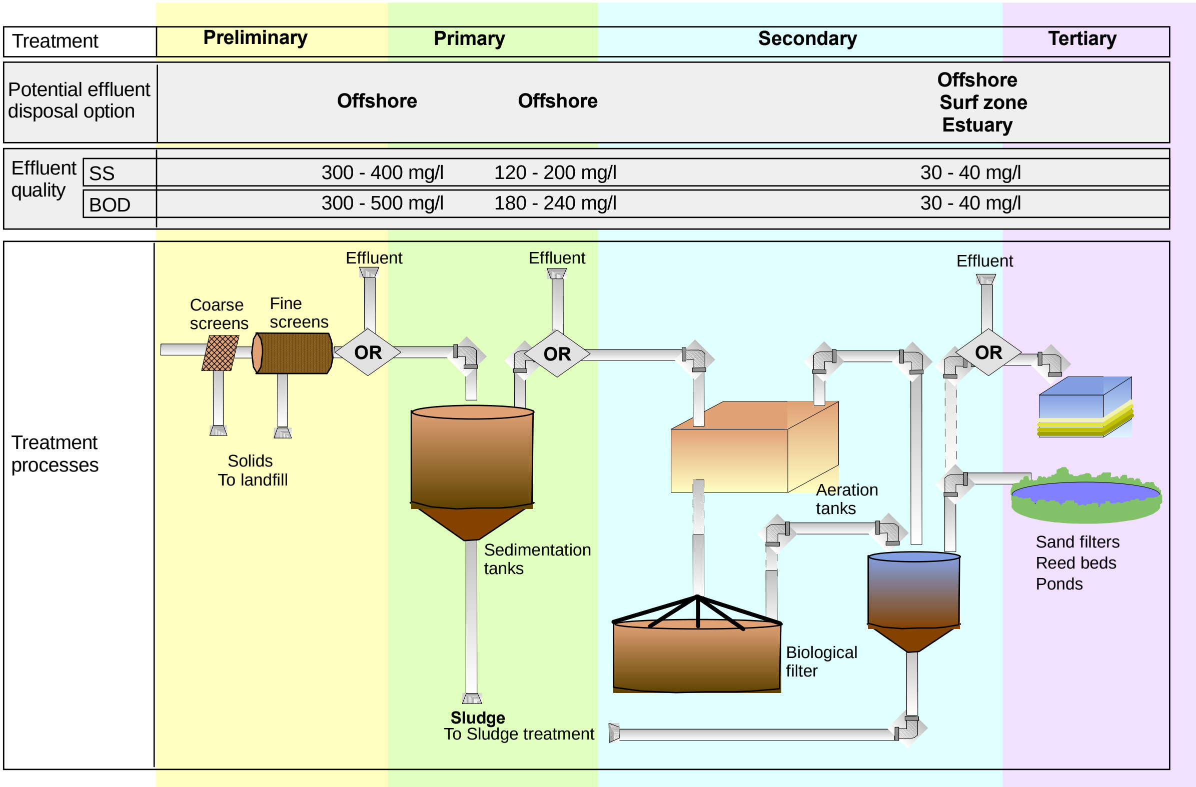


Figure 1.3: A schematic illustration of the different treatment processes for municipal wastewater (sewage) (taken from RSA DWAF, 2004b)

Treatment processes of municipal wastewater (sewage) include (RSA DWAF, 2004b):

- *Primary treatment* which removes settleable organic and inorganic solids by sedimentation, and materials that will float (scum) by skimming. Approximately 25% to 50% of the organic matter (or biochemical oxygen demand) in the incoming wastewater, 50% to 70% of the SS, and 65% of the oil and grease are removed during primary treatment. Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are also removed during primary sedimentation but colloidal and dissolved constituents are not affected.

- *Secondary treatment* which removes 85% to 95% of the suspended solids and the organic matter (or biochemical oxygen demand) and includes treatment processes such as trickling filters or rotating biological filters and aeration.
- *Tertiary treatment* refers to further removal of specific constituents either not permitted to be discharged or that need to be reduced to meet environmental quality objectives. This includes filtration (e.g. sand filters or reed-beds), phosphorus removal, ammonia stripping or other special treatment.
- *Disinfection* includes chemical (e.g. chlorination and ozonation) or physical (e.g. ultraviolet radiation and micro-filtration) or biological, (e.g. detention ponds) disinfection processes (usually the required pre-treatment to ensure that disinfection of an effluent is effective is secondary treatment)

1.4.2 Fishing industry

Fishing is a major industry within the BCLME region with numerous fish and other seafood processing factories situated along its coast. These include canning industries, white fish processing industries, fishmeal plants and packaging of rock lobsters (Binnie & Partners, 1983, 1986; Danish Technological Institute, 2004). Sources of marine pollution associated with the fishing industry include:

- Fishing vessels, activities ranging from deck washing to disposal of bilge water,which often occur in sheltered waters next to jetties
- Offloading and storage of fish prior to processing during which liquids need to be separated from fish - referred to as blood water
- Processing of fish during which stick water is generated in the dewatering and pressing of fish after cooking
- Wash-water, usually associated with packaging of white fish and rock lobster
- Plant and floor washing
- Fish oil polishing process during which hot water is added to fish oil prior to centrifugation, generating a concentrated effluent.
- Cooling water.

Although the quality of wastewater from the above-mentioned sources obviously varies depending on the type of industry and the production technologies, generic pollutants associated with fishing industries include:

- Suspended solids

- Biodegradable organic matters (dissolved and particulate organic carbon and nitrogen) – these include fats, oils and grease
- Inorganic nutrients, particularly ammonia and phosphate
- Microbiological contaminants.

1.4.3 Oil Refineries

A large variety of pollutants may be present in the wastewaters of oil or petroleum refineries. Pollutants can originate from a large number of sources in the plant (Rudolfs, 1953; UNEP, 1982). Pollutants generally can be grouped as follows:

- Oils (e.g. petroleum hydrocarbons, volatile organic compounds, poly-aromatic hydrocarbons) which could be present as free oil floating on the surface or as an oil emulsion which is suspended in the water. Although free oils can usually be separated from wastewater by gravity or by means of differential oil-water separators, emulsions are usually not that easily removed
- Condensate waters, which originate from distillation processes, contain high organic loads and reducing chemicals. They can also contain ammonia, heavy metals, cyanides and phenols
- Acid wastes, which originate from processes in which sulphuric acid is used as a treating agent. Not only are these wastewaters acidic but they also contain high organic loads
- Caustic wastes which originate from washing of certain oils to remove acidic materials naturally occurring in crude oil. These wastes are very alkaline (i.e. high pH) with a high organic content
- Cooling water which typically is very hot.

1.4.4 Coastal Mining

Wastewater or return flow seawater used in coastal mining activities, e.g. the diamond mining industries in the BCLME region, usually contains high levels of suspended and settleable matter.

1.4.5 Power Stations

Both fossil fuel and nuclear power stations, in some cases, use large amounts of cooling water. If such water is not re-cycled but discharged into the marine environment, it can result in thermal pollution (i.e. high water temperature), especially if discharged in sheltered areas such as estuaries and harbours.

1.4.6 Urban Stormwater Run-off

Urban stormwater run-off is probably one of the most important diffuse sources of marine pollution in coastal metropolitan (or urban) areas. Rapid development of informal townships is occurring along the coast of the BCLME region. In most of these areas, a low level of sanitary services is provided, with the result that the pollution from urban storm-water run-off, which usually drains directly into the surf zone, becomes even more serious than in formally developed areas (Miles, 1984).

It is, however, very difficult to characterize storm-water run-off because of the widely varying contaminant concentrations. The quality and quantity of storm-water run-off is determined to a large extent by catchment characteristics, rainfall characteristics and antecedent moisture conditions. In this regard, urban storm-water run-off is typically divided into three broad categories (Kloppers, 1989):

- Run-off from residential areas, either formal or informal developments
- Run-off from industrial zones
- Run-off from commercial areas (e.g. shops and restaurants).

The first flush effect, which is evident as a peak of highest pollutant concentrations at the beginning of a storm event, is the result of accumulated materials being washed from the catchment surface. This effect seems to increase in frequency and intensity as the degree of urbanization increases (Brown *et al.*, 1979; Simpson, 1986). In general, highly urbanized catchments produce the greatest concentration of pollutants in storm-water run-off and rural catchments the least (Green *et al.*, 1986).

Pollutants in storm-water runoff, therefore, depend on the characteristics of the catchment area and may include:

- Suspended solids
- Biodegradable organic matter
- Nutrients
- Heavy metals
- Toxic organic compounds (e.g. petroleum hydrocarbons)

- Pathogenic organisms (e.g. bacteria and viruses)
- Plastics and other litter.

Concern about the pollution impacts of contaminated urban storm-water run-off has increased dramatically over the past years. However, available data on the quantity, and especially the quality, of such run-off are very limited. Although there are means of calculating and measuring the volumes and composition of such diffuse sources (e.g. Pegram & Görgens, 2001), controlling such sources, once they reach the marine environment (or any other water resource), is extremely difficult. The vast volumes and run-off characteristics of urban storm-water make treatment prior to disposal extremely difficult and expensive. Mitigating treatment at source, i.e. preventing pollution rather than treatment, is usually a more cost-effective route to follow in the case of these non-point sources of pollution. An approach that appears to be effective in this regard is the establishment of Stormwater Management Programmes, as implemented for example in Scotland and the United States of America (SEPA, 2001; United States, Los Angeles County, 1996; United States, Virginia, City of Norfolk, 2004).

The policy of the Scottish Environment Protection Agency (SEPA) with regard to surface water run-off was designed to protect water quality from pollution caused by surface water run-off through active legislation (SEPA, 2001). In 1997, the Sustainable Urban Drainage Scottish Working Party was established and has been instrumental in changing attitudes towards sustainable urban drainage systems in Scotland. Positive results have been achieved through Sustainable Urban Drainage Systems (SUDS), which allow water to be treated prior to release in surface waters and also allow water to soak away into soil. The *Sustainable Urban Drainage Systems - Design Manual for Scotland and Northern Ireland* (Martin, 2000) provides a guide to the design of SUDS within the confines of existing legislation, and SEPA considers this manual as its primary source of authoritative information. SEPA also promotes SUDS as the preferred solution for drainage of surface water run-off, including roof water, for all proposed developments.

An example of a stormwater management programme in the USA is that of the Los Angeles County in California, formally known as the *Order for Waste Discharge Requirements for Municipal Stormwater and Urban Run-off Discharges within the County of Los Angeles* (United States, Los Angeles County, 1996), of which the key objectives are as follows:

- Map stormwater reticulation systems, including discharge points into water resources

- Identify and eliminate illicit connections and illicit discharges to the stormwater drainage system and facilitate the public's ability to report illicit connections and discharges.
- Reduce stormwater impacts associated with development and redevelopment projects (i.e. ensure that stormwater management considerations are integrated into planning, permitting and construction of development projects).
- Reduce stormwater quality impacts associated with public agency activities through:
  - Procedures to prevent and respond to spills or leaks from sewage system operations
  - Proper management, design and practices to prevent stormwater impacts from public construction projects
  - Pollution prevention plans and best management practices for public vehicle maintenance/material storage facilities that may discharge pollutants into storm-water
  - Procedures to minimize stormwater pollution associated with landscaping activities pools, and recreation areas
  - Best management practices for catch basin and stormwater drainage maintenance
  - Street sweeping and road maintenance programmes
  - A programme to reduce pollutants from municipal parking lots
  - Procedures to implement best management practices at municipal facilities or operated industrial facilities.
- Increase public knowledge and understanding of the quality, quantity, sources and impacts of stormwater run-off and of actions that can be taken to prevent pollution through education and outreach programs targeting specific audiences, such as residents, industrial facility operators, commercial businesses, school children and public agency employees.
- Develop a stormwater quality monitoring programme that will:
  - Track water quality status and trends
  - Identify watershed specific pollutants of concern
  - Improve understanding of the relationship between land uses and pollutant loads
  - Identify sources of pollutants and evaluate significant stormwater quality problems
  - Evaluate the effectiveness of stormwater management programmes, including pollutant reductions achieved by best management practices

- Increase knowledge about the impacts of run-off on receiving waters.

- Report and evaluate the effectiveness of implementing stormwater management programmes.

Initiatives that have been launched within the BCLME region, towards the effective management and control of urban stormwater runoff, include:

- *A framework for implementing non-point source management under the South Africa's National Water Ac*t (RSA DWAF, 1999a)
- *Guidelines for human settlement planning and design - The Red Book* (CSIR, 2001)
- Set of documents on *Managing the Water Quality Effects of Settlements* (RSA DWAF, 1999b).

The *Framework for implementing non-point source management under the National Water Act* of South Africa states that non-point source management is largely focused on land use, rather than water use, and should be conducted within the context of catchment management. The document proposes that a national non-point source strategy be put forward for South Africa as part of the national water resource strategy.

Guidelines for human settlement planning and design - The Red Book, also strongly reflect international trends in terms of stormwater management (CSIR, 2001). For example, the Stormwater Management Master Drainage Plans dealt with in detail in this manual are strongly aligned with the Stormwater Management Programmes applied in the United States. The Red Book also stresses that such plans be contemplated on a catchment-wide basis, irrespective of urban and other man-made boundaries.

Managing the Water Quality Effects of Settlements (RSA DWAF, 1999b; RSA DWAF, 2002) presents South Africa's Department of Water Affairs and Forestry's strategy for managing waste streams from dense settlements, including the control and management of stormwater and should also be taken into account in the development of a proposed stormwater operational policy for South Africa.

1.4.7 Agricultural Runoff

Run-off from agricultural areas is largely characterized by the type of farming activities and agricultural practices. Pollutants typically include:

- Suspended solids (associated with erosion in the catchment due to bad agricultural practices)
- Inorganic nutrients such as nitrate and phosphate (as a result of over-fertilization)
- Pesticides and herbicides.

1.4.8 Atmospheric Pollution

There are many man-made, or *anthropogenic*, sources of atmospheric pollution. Driving cars, operating power plants, spraying pesticides and emissions from industries all release pollutants into the atmosphere. In both developed and developing countries, the major threat is posed by traffic emissions. Petrol- and diesel-engined motor vehicles emit a wide variety of pollutants, principally carbon monoxide (CO), oxides of nitrogen (NO_x), volatile organic compounds (VOCs) and particulates, which are having an increasing impact on atmospheric quality (US-EPA, 2004).

There a number of categories of *air pollutants* with the greatest potential to harm water quality:

- Nitrogen and sulphur compounds
- Mercury, other metals
- Combustion emissions (pollutants released by incineration of waste, e.g. polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)
- Pesticides.

Pollution from the air may deposit into water bodies and affect water quality in these systems, either by falling to the ground in raindrops, in dust or simply due to gravity. To assist in the study of *atmospheric deposition*, researchers have developed the concept of an air shed. Similar to a watershed, an air shed is a geographical area responsible for emitting the *air pollutants* reaching a particular water body (US-EPA, 2004).

1.4.9 Dredging

The dredge spoil from regular maintenance dredging, for example to maintain the depth of entrance channels, in areas such as harbours and estuaries is often dumped at sea. Pollution associated with dredged material often depends on the activities associated with the dredged area. A common pollutant associated with all dredged spoil, based on its inherent character, is formed by suspended and settleable solids. Harbour sediments are often heavily contaminated with toxic chemicals such as trace metals and hydrocarbons. When dumped at sea these may be released, under suitable chemical conditions, to the receiving marine environment. On the other hand, dredged material from ecologically productive areas such as estuaries may contain high concentrations of biodegradable organic matter and nutrients.

1.4.10 Offshore Exploration and Production

Offshore petroleum exploration and production (E&P) consists of a number of activities that could result in the introduction of pollutants into the marine environment. *Exploration* consists of two main activities, namely geophysical (seismic) surveys and exploration drilling, generally of short duration (up to three months in the case of exploration drilling). *Production* consists of intensive production drilling and the installation of infrastructure (production platforms, pipelines, floating terminals, etc.), and the operation of the facilities over long periods (20+ years).

i. Exploration

The survey vessels are usually crewed by 30-40 personnel and the surveys are of 3-5 weeks duration in a limited area e.g. a “box” 100 km x 100 km. The quantities of wastes produced by such a survey vessel are typical of vessels of such size. The wastes include engine exhaust emissions, treated (macerated) sewage and galley wastes, and bilge waters treated to a maximum of 15 ppm hydrocarbons before discharge. Other wastes such as packaging materials, scrap metals and used lubricating oils and hydraulic fluids are stored aboard the vessels for disposal at suitable onshore waste disposal facilities. Almost all geophysical survey vessels comply with the requirements of the International Association of Geophysical Contractors and with MARPOL and have no more impact in terms of pollution than any other vessel of a similar size.

Exploration drilling consists of positioning the drilling unit at a pre-determined location and then drilling through the sea-floor to a target formation considered likely to contain oil. Drilling units may be jack-up units standing on the sea-floor, semi-submersible units kept in position by an anchor array, or dynamically positioned vessels kept in position by GPS-controlled motors. The latter type of unit is used in deep (500+m) water where anchoring would be impractical.

Depending on the depth below the sea-floor to be drilled and the difficulties encountered, a drilling operation for a single exploration well is usually of 60-90 days duration. With the exception of the drilling operation itself, the wastes produced by a drilling unit are similar to those of any vessel with a crew of 80-90.

In the drilling operation, specially formulated drilling muds are pumped down the hollow drill shaft to lubricate the drilling bit, transport the cuttings to the surface and to replace ("weight") the rock removed from the well-bore. In the past, drilling muds were often mineral oil-based but present practice is to use water-based muds or, in difficult drilling conditions, low-toxicity synthetic oil-based muds. Depending on the depth drilled below the sea-floor, up to 600 m^3 of muds and cuttings (rock fragments) may be discharged into the sea from the drilling unit. These muds and cuttings are discharged continuously during the drilling operation. The fine materials are distributed widely by the currents and the coarse material (cuttings) tends to be deposited in the immediate vicinity of the well-head. The slow rate of deposition usually means that benthic organisms are able to cope with the small amount of material deposited at any one time (see Coats, 1994).

ii. Production

Once a commercially exploitable hydrocarbon deposit (oil or gas or both) has been proven, production may commence. The first phase is to drill a number of production wells to exploit the find. Each well is exactly the same as an exploration well in terms of potential pollutants produced with the exception of the cumulative effect of the discharged drilling muds and cuttings. The "footprints" of these discharges may overlap and create areas that are re-colonized by benthic organisms only after some time has elapsed. To date, the majority of exploration wells drilled in the BCLME region have been in depths of 200 m or less in which benthic organisms are active components of the ecosystem and appear to have been able to handle the discharge of drilling muds and cuttings. However, the impact of overlapping discharge footprints in the deep water (1000 m-2000 m) oilfields now being brought into production in Angola is not known. It is probable, however, that recovery and re-colonization in these deep water environments will be considerably slower than on the continental shelf.

The production wells are linked to a production platform/facility which regulates the flow from the wells and separates the formation water (water which occurs in association with the oil) and gas from the oil. In the past, it was normal practice to burn ("flare") the gas at the production platform. In all the new fields in Angola, for example, the gas has to be re-injected into the formation until such time as a liquefied natural gas plant is built, which can process the gas. In the older oilfields, such as on the continental shelf of Angola, the gas is flared, thereby adding to greenhouse gases.

The produced water separated from the oil may contain small amounts of oil, BTX (benzene/toluene/xylene) and PAHs. The water is treated through an oily water separator to not more than 40 ppm residual hydrocarbons before discharge overside.

The oil is either piped to a shore terminal or is sent to an offshore (floating) facility such as a single point mooring (SPM) for loading into tankers. In both cases there is a risk of spillage of small amounts of oil when connecting and disconnecting the pipeline between the tanker and the SPM or shore terminal.

In summary, the discharge of drilling muds and cuttings from both exploration and production drilling and the discharge of produced water from production facilities are the two activity-specific potential sources of pollution. All other waste-generating activities aboard drilling units and production facilities do not differ from those of other vessels and can be effectively managed by good housekeeping.

1.4.11 Maritime Transportation

Numerous source of pollution are associated with maritime transportation or shipping traffic, including:

i. Oil spills

Although oils spills are typically associated with large spills due to a collision or severe structural damage to oil tankers or other vessels while at sea, pollution of this nature also occurs as a result of operational discharges associated with day-to-day shipping activities at sea, accidental spillages during transfer of oil in ports or at offshore moorings and continuous diffuse spillages (owing to illegal dumping, bad operational practices, etc.) (Taljaard & Rossouw, 1999).

The input from operational and accidental spillages is typically diffuse and sporadic, which makes realistic quantification extremely difficult. Major oil spills, in contrast, occur on a different scale, being massive instantaneous events of which the impact is largely dependent on the magnitude and location of the spill and the type of oil spilled.

Chemical constituents associated with oil pollution consist mainly of petroleum hydrocarbons (including poly-aromatic hydrocarbons) and trace metals (Neff, 1979; Swann *et al.*, 1984).

The type and concentration of trace metals and hydrocarbons in oils depend on the fuel product and crude oil source. In crude oils, vanadium, nickel and lead are typically the most common trace metals.

In addition to the harmful chemicals released into the sea during an oil spillage, the oil slick also causes physical damage by creating aesthetically unpleasant conditions, clogging water intake systems and smothering benthic marine fauna and flora (Taljaard & Rossouw, 1999).

ii. Ballast water discharges

Ships take on ballast water at sea to increase their stability. Up to 125 000 tonnes per vessel are taken from the coastal waters of the world. As South Africa is a net exporter of raw materials, such as coal and mineral ores, it receives a large amount of ballast water from overseas sources. It is estimated that the annual discharge of ballast water into South African harbours is in the order of 20 million tonnes, compared with about 66 million tonnes in Australia. The risk associated with ballast water discharges from ships is mainly the introduction of exotic organisms, which occurs when ballast water taken from one part of the ocean is discharged into another. In this way the natural ecological balance is upset, resulting in a variety of secondary problems. There is increasing concern, both nationally and internationally, that a wide variety of marine plants and animals (including pathogens) are being transported in the ballast water of ships and introduced into foreign countries.

iii. Harbour activities

Activities in harbour that could result in marine pollution are numerous, including:

- Dry dock activities
- Cleaning and maintenance of vessels within harbours (e.g. dust from sand blasting), as well as emptying of toilets into harbour areas
- Dumping of blood water into harbours, as well as off-cuts and offal from fish cleaning operations being washed down into stormwater drains and eventually ending up in the harbours
- Poor waste disposal practices during the scraping and cleaning of ships, which eventually results in chemical pollution of harbour waters, e.g. by antifouling paints

- Litter which ends up in harbour basins as a result of wind, stormwater discharges or by being directly discarded from ships
- Oil originating from an accidental spill from a vessel in harbour.

Harbour water is particularly prone to pollution because harbours are sheltered basins, often with poor water circulation and pollutants entering harbours tend to accumulate. Because the sources of pollution entering harbours are diffuse and often intermittent, it is very difficult to quantify such contaminant loading, in contrast to sewage or industrial point discharges. An understanding of operational practices, and regular monitoring of the water and sediments quality in harbours constitute the best means of assessing site-specific pollution characteristics of this nature.

1.5 SCIENTIFIC & ENGINEERING ASSESSMENT STUDIES

Scientific assessment studies are required to assess whether the marine environment is able to support important ecosystems and designated beneficial uses (as defined in terms of the environmental quality objectives) in a sustainable manner, in addition to being subject to marine pollution inputs and other modifications associated with developments in the study area.

These assessments need to take into account environmental process complexities and natural variability, which require data, understanding and information on physical, biogeochemical and biological characteristics and process scales.

Depending on the availability of scientific data and information in the study area, scientific assessments may also include baseline field measurement programmes. Proposed protocols for consideration in the design of baseline measurement programmes in relation to the management of marine pollution sources are provided in Section 2.

The level of detail required for scientific assessment studies largely depends on the type of investigation and the purpose for which it is intended. For example, a preliminary investigation into the viability of a wastewater discharge may, for example, be based on only available data and information together with professional judgement. On the other hand, where the output from a scientific assessment study is to be used to set design criteria for expensive structures, such as marine outfalls, or where the implications of non-compliance with environmental quality objectives in the study area can have serious socio-economic consequences, a detailed investigation is required. Detailed investigations usually require extensive baseline field measurement programmes and sophisticated assessment tools, such as numerical models.

Numerical modelling techniques have proven to be powerful tools in the management of marine pollution (Monteiro, 1999) in that:

- Models provide a workable platform for incorporating the complexity of spatial and temporal variability in the marine environment
- Model assumptions and inputs provide a means of synthesizing existing understanding of the key processes and, in doing so, provide a means of stimulating stakeholder discussion on their relevance to achieving environmental quality objectives
- Modelling assists in defining the most critical spatial and time scales of potential negative impacts on the receiving system
- Model outputs provide quantitative results which can be used, together with field data, to check the quality of assumptions and insights.

The aim of using numerical modelling, therefore, is to assess, through sensitivity analyses, the consequences of uncertainty in relation to system variability, key processes and most importantly, how these influence the transport and fate of pollutants. By reducing uncertainty, modelling provides greater confidence in the reliability of the predicted outcomes and can therefore be used to focus investment in, for example, monitoring programmes, to critical parameters at critical time and spatial scales. Quality data on the volumes (in particular flow rates) and contaminant composition are crucial input data to the above-mentioned approach.

However, in the application of numerical modelling techniques, the following must be complied with:

- The model chosen must be appropriate to the situation in which it is utilized
- The model must be calibrated and validated against a full field data set adequately describing the site-specific physical and biogeochemical oceanographic conditions (‘ground truthing’)
- A sensitivity analysis must be conducted to demonstrate the effect of the uncertainties of estimates of key parameters, based on the variation in input data and controlling assumptions

- The reporting of model outputs must include a clear description of assumptions, a summary of numerical outputs, and confidence limits and sensitivity analyses.

In addition to scientific assessment studies that are aimed at understanding the physical, biogeochemical and biological processes and assessing potential impacts from marine pollution sources and other anthropogenic disturbances, engineering studies may also be required. An example is the engineering studies that are linked to the design of environmentally acceptable offshore marine outfall schemes. More details on such studies are provided by the Department of Water Affairs and Forestry (South Africa) as part of their *Operational policy for the disposal of land-derived wastewater to the marine environment of South Africa* (DWAF, 2004b).

Key engineering aspects that need to be addressed in the design of, for example, an offshore marine disposal scheme, within the context of the proposed management framework, is highlighted in Figure 1.4.

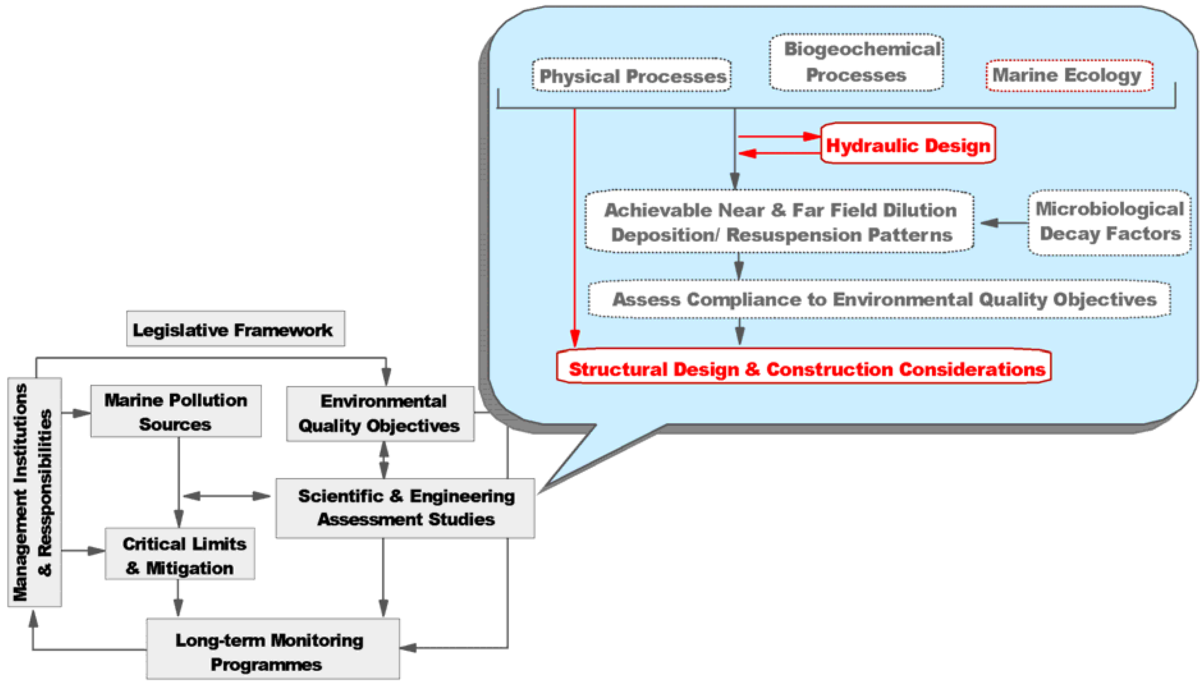


Figure 1.4: A schematic illustration of components to be addressed as part of scientific and assessment studies, highlighting key engineering aspects (e.g. related to the design of marine wastewater disposal scheme) (adapted from RSA DWAF, 2004b)

Key outcomes of the scientific (and engineering) assessment studies include:

- Refinement of environmental quality objectives, based on an improved understanding of site-specific physical, biogeochemical and biological characteristics, processes and scale complexity (where and if applicable)
- Recommendations on critical limits in terms of the volumes and pollutant composition of marine pollution sources so as to ensure compliance with environmental quality objectives (e.g. wastewater emission targets [WET])
- Design criteria and construction considerations for marine structures related to the effective management of land-based pollution sources (e.g. marine outfalls), where and if applicable
- Recommendations on modifications to structural designs of developments (e.g. marinas and harbour structures can modify circulation patterns in the marine environment which may also negatively impact on water and sediment quality) so as to ensure compliance with environmental quality objectives, if and where applicable.
- Recommendations on mitigating actions (and/or contingency plans) to be implemented during the construction and/or operations of specific developments and activities related to the management of marine pollution from land-based sources so as to minimise any risks to marine water and sediment quality.

1.6 CRITICAL LIMITS AND MITIGATING ACTIONS

The outcome of scientific and engineering assessment studies provides responsible authorities and local management institutions with the information to make informed (final) decisions regarding:

- Critical limits for developments and activities (critical limits on waste volumes and pollutant composition are typically written into licence agreements for waste disposal practices)
- Design criteria and construction considerations, e.g. for marine wastewater disposal schemes, where relevant
- Modifications to the structural design of developments, where relevant
- Mitigating actions (e.g. contingency plans) to be implemented during the construction and/or operations of relevant developments and activities.

In the confirmation of, for example, the critical limits for land-based pollution sources (e.g. wastewater emission standards), broader social and economic factors also need to be evaluated to determine if the environmental quality objectives can realistically be attained.

Ultimately, the challenge is to ensure sustainable utilization of resources, where developments should be economically profitable, ecologically proper and socially acceptable.

1.7 LONG-TERM MONITORING PROGRAMMES

Long term monitoring programmes refer to ongoing data collection programmes, which are designed to continuously evaluate:

- Effectiveness of management strategies and actions to comply with critical limits and the implementation of mitigating actions, e.g. limits on volume and composition of the wastewater discharges (i.e. source monitoring)
- Trends and status of changes in the environment in terms of the health of important ecosystems and designated beneficial uses in order to respond, where appropriate, in good time to potentially negative impacts, including cumulative effects (i.e. environmental monitoring).

Long-term monitoring programmes can also be used to assess whether predicted environmental responses, made during the initial scientific assessment studies, match actual responses, as well as to test whether the starting assumptions remain valid such as, the geographical boundaries selected for a particular area's boundary conditions and the pollutant loads specified for particular sources.

It is also important to remember that long-term monitoring programmes should be dynamic, iterative processes that need to be adjusted continuously to incorporate new knowledge, thereby supporting the principle of adaptive management.

Proposed protocols for the design of long-term monitoring programmes related to the management of marine pollution sources are provided in Section 2.

SECTION 2.

PROPOSED PROTOCOLS FOR BASELINE MEASUREMENT AND LONG-TERM MONITORING PROGRAMMES

2.1 INTRODUCTION

It is important to note the differences between baseline measurement programmes (usually part of *Scientific Assessment Studies*) and monitoring programmes (implemented as part of *Long-term Monitoring Programmes*):

- Baseline measurement programmes (or surveys) usually refer to shorter-term or once-off, intensive investigations on a wide range of parameters to obtain a better understanding of ecosystem functioning

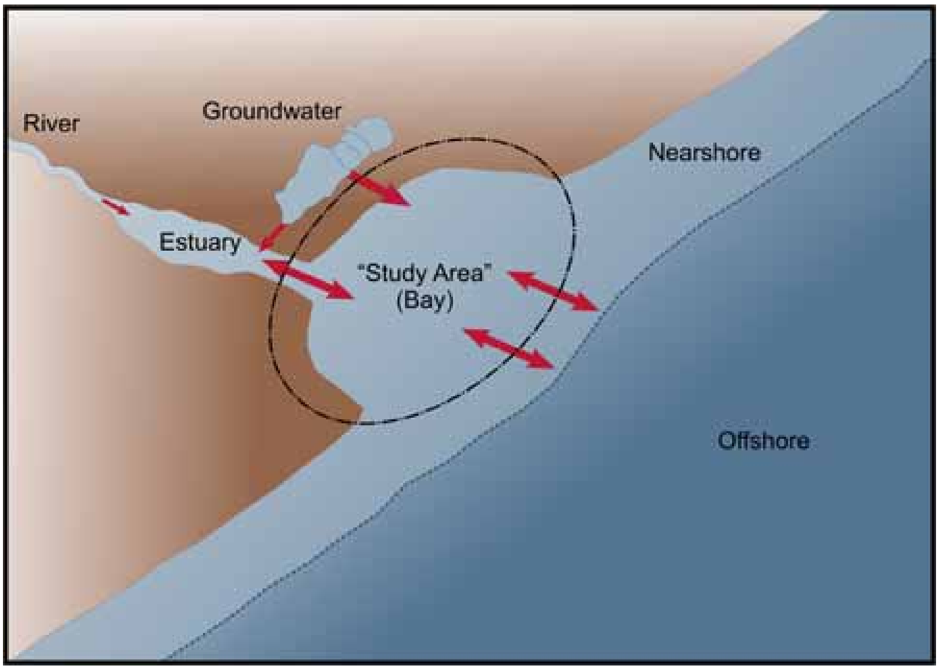
- Long-term monitoring programmes refer to ongoing data collection programmes that are done to evaluate continuously the effectiveness of management strategies/actions designed to maintain a desired environmental state so that responses to potentially negative impacts, including cumulative effects, can be implemented in good time (using selected indicators).

Proposed protocols (or guidance) for the design of baseline measurement and long-term monitoring programmes related to the management of marine pollution sources are provided in Sections 2.2 and 2.4, respectively.

2.2 BASELINE MEASUREMENT PROGRAMMES

The main purpose of baseline measurement programmes is to gain knowledge and understanding on the physical, biogeochemical and biological processes within a particular study area, as well as the interrelationships between these processes, so as to understand ecosystem functioning.

It is also important to understand and, where applicable, to measure processes in adjacent aquatic domains that influence ecosystem functioning in the study area, as illustrated below:



Together with the data and information on marine pollution sources (as discussed in Section 1.3), baseline measurement programmes are crucial for quantitatively assessing or predicting the impact of human activities within a particular study area, and subsequently, for deciding on appropriate management actions that will ensure sustainable utilization of the resource.

2.2.1 Physical Data

Data on physical parameters are required to quantify hydrodynamic (or water circulation) processes and sediment dynamics (i.e. the transport, deposition and re-suspension of sediment particles), which include data on:

- Bottom topography or bathymetry of a particular area
- Winds
- Currents
- Tides
- Waves
- Water column stratification
- Geomorphology.

Both hydrodynamic and sediment dynamic processes are key aspects of the transport and fate of pollutants in the marine environment. Information on these processes is also important for engineering studies, e.g. the structural design of offshore marine wastewater disposal schemes.

i. Bathymetry

The bottom topography or bathymetry of a particular area strongly influences both its hydrodynamic and sediment dynamic processes (Figure 2.1). During a bathymetric survey, seawater depths at a large number of sites are determined using an echo-sounder operated from a survey boat. Integrative survey software packages are available that provide accurate position fixing, capturing of bathymetric data and corrections for tides and swells (RSA DWAF, 2004b). Bathymetric surveys are usually once-off unless there is evidence that the bathymetry of an area has been markedly modified, e.g. large floods are known to have a major influence on the bathymetry of estuaries.

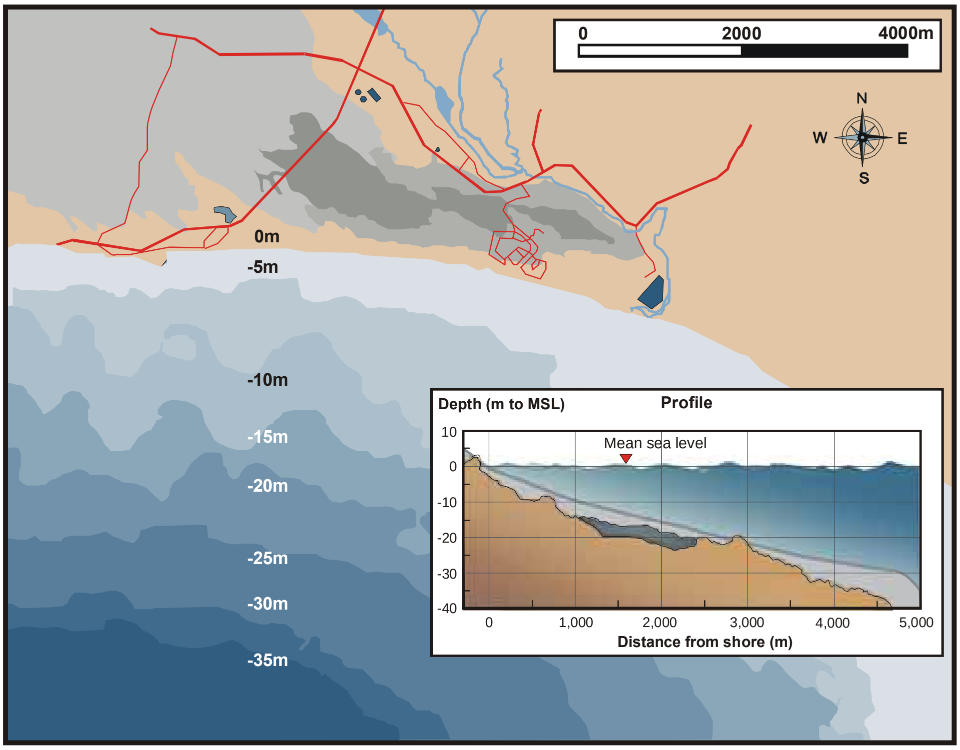


Figure 2.1: Example of bathymetric contour map and typical profile (taken form RSA DWAF, 2004b)

ii. Winds

Winds can play an important role in the behaviour of surface currents, and subsequently influence the transport and fate of pollutants. In the absence of strong ocean currents, wind-driven currents usually dominate.

To obtain representative wind data, wind recordings are typically collected from a particular study area for a limited period (e.g. one year) using an automatic weather station. The limited data set is then correlated with long-term wind data from a nearby weather station to predict long-term wind patterns for the study area.

Wind data records need to reflect natural variability. Usually wind patterns show strong seasonal variability, influenced by remote climatological conditions. However, a local phenomenon can also affect wind patterns. For example, near the coast changes in the temperature differences between land and sea can change the direction of winds (breezes), resulting in a strong diurnal signal (Figure 2.2) (RSA DWAF, 2004b).

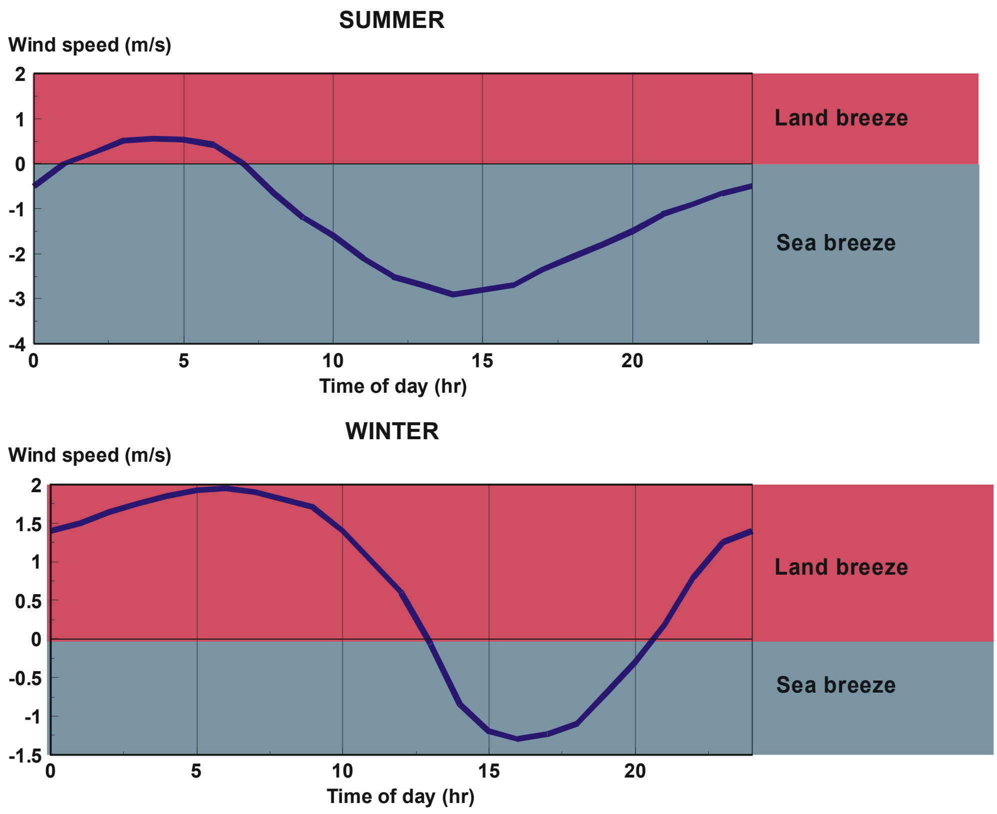


Figure 2.2: Typical diurnal land- sea breeze variations (taken from RSA DWAF, 2004b)

iii. Waves

Wave data are particularly important for understanding or predicting the deposition and redistribution of sediment or other solid phase particles. Also, waves are an important factor in determining the sediment dynamics in shallower water and in the shoreline geomorphology. In the surf zone, the mixing, transport and dispersion of pollutants in the water column are controlled by the breaking waves and the currents generated by waves approaching the shoreline (RSA DWAF, 2004b).

To obtain representative wave data, wave recordings are usually collected at a particular study area for a limited period (e.g. one year) using, for example, a wave buoy. The limited data set is then correlated with a nearby long-term wave data recording location to predict long-term wave patterns for the study area.

Wave data typically need to include time-series plots of wave height and period, occurrences and exceedances for wave height and period and persistence of calms and storms.

iv. Currents

The speed and direction of currents are the main oceanographic processes that influence the transport and fate of pollutants in the marine environment.

In the offshore zone, the net (resultant) current is the result of a complex of numerous driving forces: the local wind forcing, ambient continental currents (for example the Benguela current), and surf zone long-shore and rip currents generated by waves, tidal currents and density differences. In the near-shore zone, the circulation is strongly influenced by the seabed topography and the configuration of the coastline. Currents in the surf zone are usually wave-dominated. Long-shore transport is driven by the momentum flux of shoaling waves approaching the shoreline at an angle, cross-shelf transport is driven by the shoaling waves, while water is transported out of the surf zone by rip currents. In open estuaries, currents are primarily influenced by the state of the tide, the size (cross-sectional area) of the estuary mouth and the volume and timing of river inflow (RSA DWAF, 2004b).

Eulerian measurements are continuous recordings of current data collected at pre-determined time intervals by the use of moored current meters at fixed points in the study area. Eulerian data provide the basis for statistical estimates of occurrence and persistence of current speed and direction. Lagrangian measurements include spatial studies with drogues, drifters, or dye, in which the path and velocity of a particle are determined.

Continuous current measurements, preferably taken throughout the water column (i.e. current profiles) are ideally required, using, for example, an acoustic Doppler Current Profiler (ADCP). A baseline measurement programme must be arranged to reflect adequately seasonal and other cyclical current trends and should have a typical duration of between 12 and 18 months if previous data are not available (Figure 2.3). The output of a calibrated numerical model could be used to supplement the limited current measurements, i.e. provide more extensive spatial information.

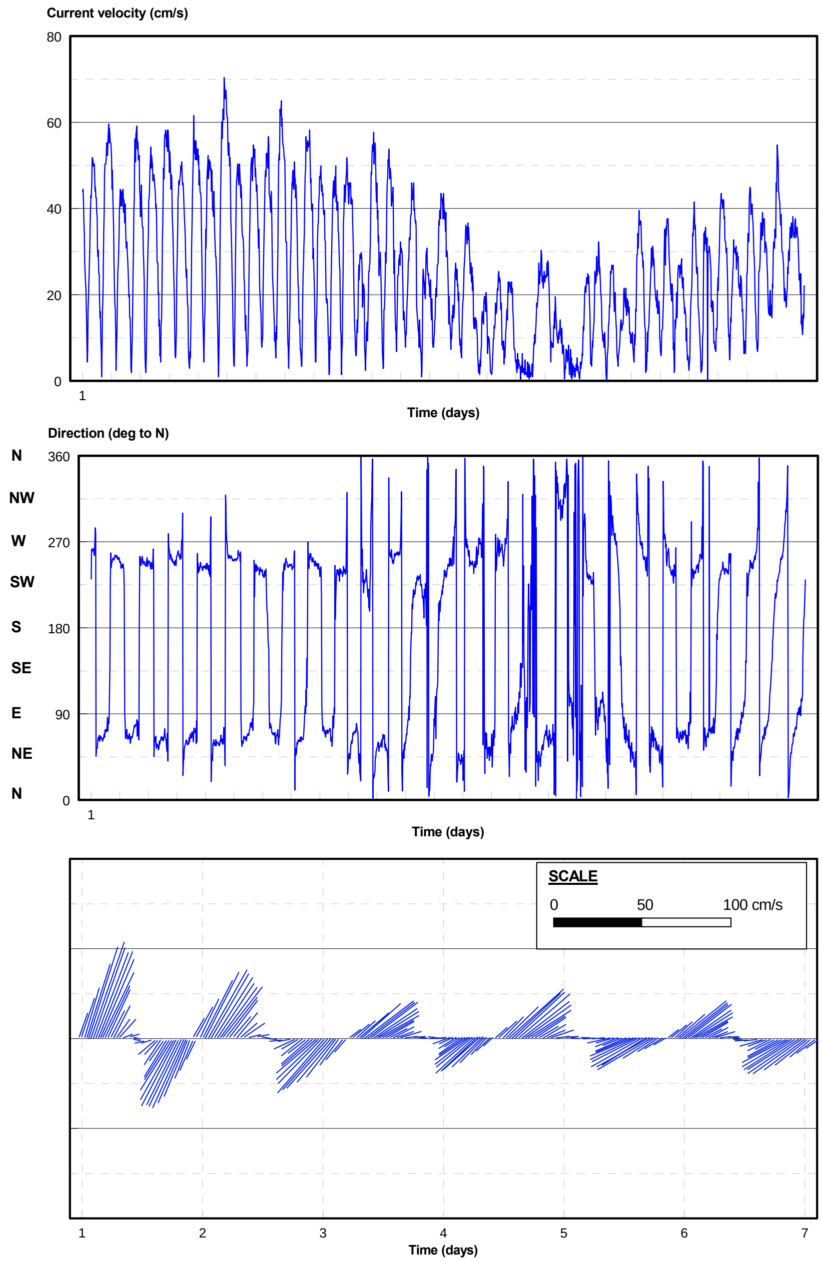


Figure 2.3: Time series data showing current velocities, directions and vectors (taken from RSA DWAF, 2004b)

vii. Stratification

In the marine environment, vertical density gradients develop as a result of differences in the water temperature and salinities throughout the water column. Density stratification affects the transport and fate of pollutants, for example, it is one of the major factors that determine whether a buoyant effluent discharge from an ocean outfall remains beneath the surface as a submerged field or continues to rise to become a surface field.

In order to detect stratification in the water column, both temperature and salinity profiles should be measured since seawater density is a function of both these properties. Measurements should also be done on a similar scale as that used for the current measurements. For example, temperature and salinity probes could be attached to current profilers so as to maximize the information obtained from each measured profile. Conductivity-Temperature-Depth (CTD) profilers can also be used for measurements from a survey boat.

ix. Geomorphological data

The purpose of geomorphological measurement programmes is to obtain data on the sediment characteristics of the study area. These data, together with information on the hydrodynamic processes, are used to assess and predict sediment processes (i.e. transport deposition and re-suspension).

Important aspects that need to be measured as part of geomorphological surveys are particle size distribution and organic content (deposited particles in the marine environment are not only of lithogenous origin but can also be of an organic nature - breakdown of marine fauna and flora or introduced from land sources such as rivers, stormwater and wastewater streams) (Figure 2.4). Samples can either be collected as grab samples (which essentially provide data on surface sediments) or sediment cores (which provide a 'history' of the geomorphology of the sediments). Traditionally, samples were collected along uniform sampling grids across the study area, but it has been shown that an understanding of the hydrodynamic processes (e.g. using numerical modelling) greatly assists in optimizing these spatial grids (RSA DWAF, 2004b).

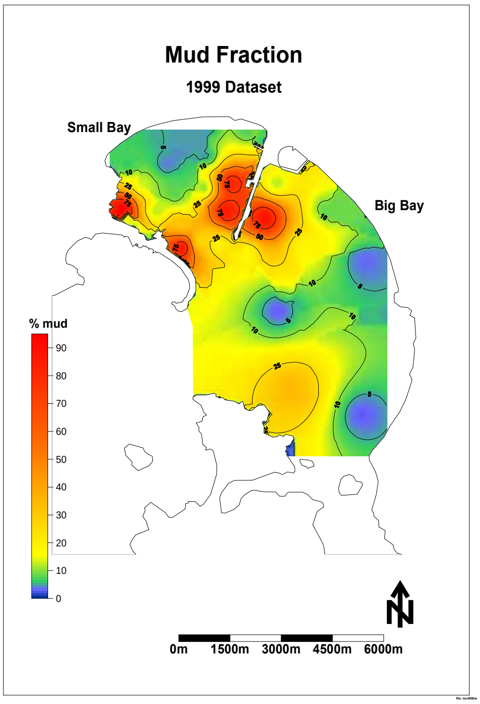


Figure 2.4: Spatial plot of the distribution of particle size in Saldanha Bay (South Africa) (Monteiro et al., 1999)

In terms of the engineering studies, the design of structures such as offshore marine outfalls usually requires more detailed, site-specific geomorphological studies, including:

- Seismic surveys, which are conducted to obtain information from beneath the sea-floor, using a sound source or transducer towed behind the survey vessel either on a surface float or below the surface (Figure 2.5)
- Detailed geotechnical reports to support the seismic interpretation (soil classification, cohesive and shear strength of soils, internal angle of friction, soil density characteristics, rock classification and hardness, seismic activities)

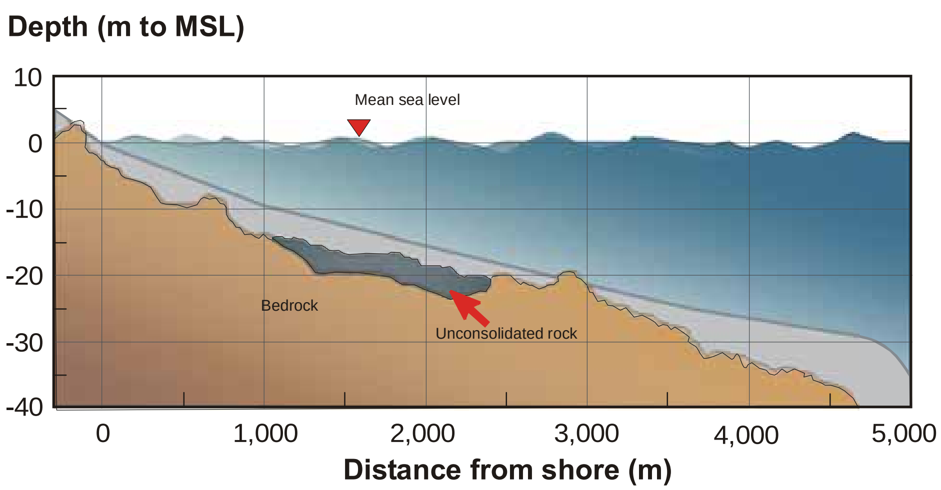


Figure 2.5: Sub-bottom profile derived from a seismic trace (taken form RSA DWAF, 2004b)

2.2.2 Biogeochemical Data

Biogeochemical characterization of the marine environment requires data on the spatial and temporal variability of biogeochemical parameters, both in the water column and in the sediments, as well as an understanding of the key processes that govern such variability. It is important that data used in the characterization reflect the present status of the receiving marine environment, i.e. any modifications to the biogeochemical characteristics and processes as a result of existing human activities need to be taken into account. This is particularly relevant when assessing the suitability of historical data sets.

Information from the physical process study programme can be used to assist in the design of the biogeochemical data collection programme, particularly in terms of setting the critical time and space scales.

In addition to gaining knowledge on biogeochemical processes in the study area, biogeochemical data are also required for the calibration and validation of numerical modelling platforms (where applicable), as well as to provide a benchmark (baseline) for future monitoring programmes.

It is important, therefore, that the manner in which biogeochemical data are collected is appropriate to the different purposes. For example, numerical model calibration and validation usually require time series data collected over a pre-determined time-scale.

i. Receiving marine environment

The selection of measurement parameters to be sampled in the receiving environment is site-specific. A key determining factor in the selection of such parameters is the composition of pollution sources as well as the anticipated effects on the biogeochemical characteristics of, and processes in, the receiving environment.

Essential, therefore, to the design of the biogeochemical measurement programme is the preparation of a preliminary conceptual model of the key biogeochemical processes governing the ‘cause-and-effect’ linkages between the wastewater discharge and the receiving environment.

Biogeochemical parameters (e.g. pH, dissolved oxygen, turbidity, particulate organic carbon and nitrogen, dissolved nutrients, toxin concentrations and microbiological parameters) can be measured in the water column and/or the sediments, including interstitial waters.

Depending on the nature of the investigation, sediment data should be collected from sub-tidal and/or inter-tidal sediments. An understanding of the physico-chemical characteristics of the inter-tidal area is particularly relevant where, for example, a wastewater discharge to the surf zone is under investigation.

The spatial scales at which data need to be collected vary. For example, time series data collected from the water column may require only one or two pre-selected locations, whereas data on spatial distribution patterns require more intensive sampling.

A guiding principle is that the initial sampling should cover the near and far field scales (e.g. an entire bay), making no assumptions on the locations of, for example, depositional areas. This typically requires a high resolution, unbiased grid.

The temporal scale at which biogeochemical data need to be collected, as part of the measurement programme, largely depends on:

- The variability in the load of contaminants from waste inputs
- The variability in processes driving transport and fate of the wastewater plume in the receiving environment
- The temporal sensitivity of the ecosystem to contaminant loading, i.e. exposure time versus negative impact.

The temporal scale of sampling should at least resolve the main source of natural variability of the constituent under investigation. Scales of temporal variability are very different in the water column (minutes – days) compared with sediments (days – seasons – decades). Non-periodic events, such as storms, can also have a dramatic influence that needs to be taken into account where appropriate. Therefore, a sampling frequency that is too low relative to the underlying natural variability will result in biased data that will make it difficult, for example, to separate anthropogenic impact from natural water quality anomalies. This is illustrated in dissolved oxygen concentrations measured in Saldanha Bay (South Africa): With an hourly data record (automated) it was possible to show that variability in oxygen was linked to variability in upwelling, and that the low oxygen concentrations were brought into the system by upwelled waters rather than by any localised anthropogenic effects. Weekly sampling, for example, would have resulted in an apparently random variability of high and low concentrations. This illustrates the importance of characterising natural variability prior to interpreting the impacts of pollutant sources on the biogeochemistry of a receiving water body.

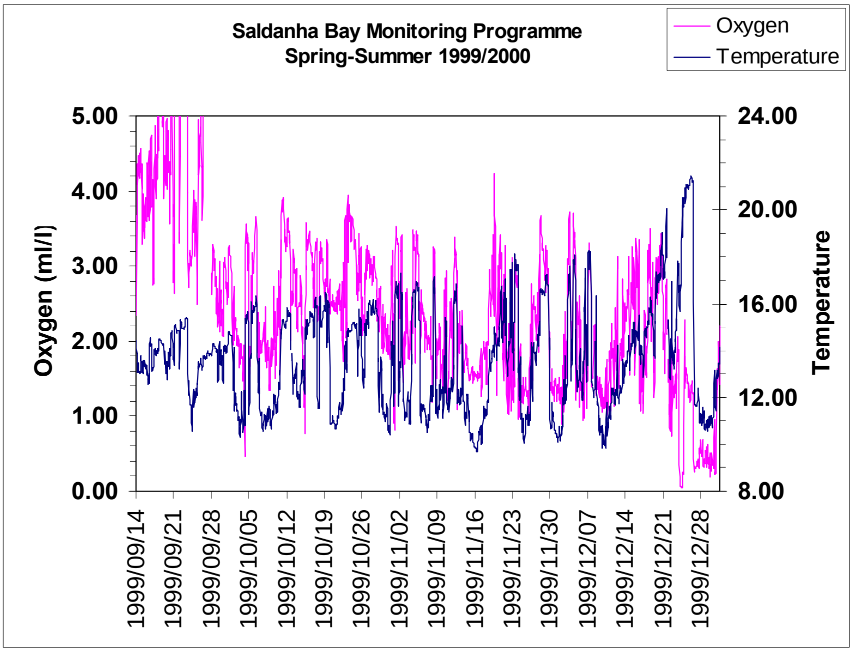


Figure 2.6: Dissolved oxygen variability (mℓ/ℓ) in the bottom water layer in Saldanha Bay, South Africa (from Monteiro *et al*., 1999)

In summary, data required for the characterization of biogeochemical processes include:

- A contour map showing the distribution of relevant chemical constituents in the marine sediments of the study area, including details on sediment particle size distribution and particulate organic carbon and nitrogen. Expected variability, both temporally and spatially, needs to be addressed.

  Geochemical ratios of trace metals can be used to determine whether the trace metals are of natural or anthropogenic origin. It is possible for conditions to arise in which the total trace metal concentration in the sediment is high (particularly in depositional areas) but completely linked to the natural structure of clay minerals, in which case the trace metals will not be bio-available. This condition would be characterized by geochemical ratios very similar to those of unpolluted sediments typical of the area. The geochemical ratio of each trace metal relative to aluminium (TM [µg/g]: Al [%]) is used, usually allowing a conservative two-fold natural variation in the geochemical ratios. Natural geochemcial ratios are site specific for different geographical regions and need to be sourced from the literature (Monteiro & Scott, 2000).

- Graphs showing the temporal (and, where applicable, spatial) variability of system variables (temperature, salinity, dissolved oxygen and suspended solids/turbidity), inorganic nutrients (nitrate, ammonia, reactive phosphate and reactive silicate), and organic nutrients (dissolved organic carbon, particulate organic carbon and particulate organic nitrogen) in the water column.

ii. Behaviour of pollutants

To be able to interpret biogeochemical data, it is also important to collect data on the behaviour of pollutants immediately after entering the marine environment. A description of the expected interaction of pollutants with biogeochemical processes in the receiving marine environment is therefore also important. On entering the marine environment, pollutants can either (WHO, 1982):

- *Remain in solution (i.e. remain in the 'dissolved phase')*. Pollutants associated with the 'dissolved' phase can either behave conservatively (i.e. their behaviour reflects only the advective and dispersive characteristics of the water body) or non-conservatively (i.e. they are rapidly transformed on entering the marine environment as a result of system variables, such as pH, salinity and temperature, being different from those in the wastewater).
- *Adsorb onto solid phase particles.* On entering the marine environment, toxic compounds, such as trace metals and poly-aromatic hydrocarbons, poly-nuclear aromatics and pesticides, tend to adsorb onto 'solid' phase particles present either in the wastewater or in the receiving environment. 'Solid' phase particles comprise cohesive (non-biological) particles and organic particles. Cohesive (non-biological) particles represent very fine sediment particles (< 60 µm) on which adsorption phases such as aluminium hydroxides, manganese hydroxides and iron hydroxides are common. The origin of the organic particles can be natural (e.g. phytoplankton) or introduced through anthropogenic activities (e.g. sewage disposal).

  Adsorption to 'solid' phase particles is typically described by means of equilibrium partitioning, on the basis of partition coefficients, which are different for each 'solid' phase particle.

  The transport and fate of chemical constituents associated with the 'solid' phase are largely determined by the flux and sedimentation/re-suspension behaviour of solid phase particles. The sedimentation/re-suspension behaviour of solid phase particles is a sensitive indicator of the potential fate of toxic compounds in the receiving marine environment (Luger *et al.,* 1999; Monteiro, 1999).

- *Precipitate from the water column*. A rise in pH and oxygen content promotes the formation of metal hydroxides, carbonates and other metal precipitates. Under such conditions, if the concentration of a trace metal is higher than the solubility of the least soluble compounds that can be formed between the metal and available anions in the receiving water, precipitation will occur.

  Where appropriate, solubility products and stability constants, which describe precipitation processes and which are specific to the metal/anion complex, need to be sourced from the literature in order to quantify such transformations (Stumm & Morgan, 1970; Faust & Aly, 1984). However, most metals, with the exception of iron (Fe) and manganese (Mn) that readily precipitate their hydroxides, will usually remain in solution in seawater at concentrations that are much higher than those occurring naturally (Solomons & Förstner, 1984; WHO, 1982).

Another type of transformation is that of certain poly-aromatic hydrocarbons, in particular volatile organics (e.g. benzene, toluene and xylene). On entering marine waters, such compounds do not follow the conventional 'dilution' behaviour. It is thought that these substances are actually extracted out of the aqueous phase and into the buoyant hydrophobic fraction that results in concentration as a film at the water's surface (referred to as the surface micro-layer), which subsequently evaporates to the atmosphere, rather than diluting. It will be extremely difficult to predict the transport and fate of such volatile substances in the receiving environment. Removing such compounds from the wastewater before discharging to sea best mitigates their potential risk to the marine ecosystem and other beneficial uses.

2.2.3 Biological data

To characterize the biology of a particular marine environment requires data on the following:

- Identification of habitat types, e.g. reefs, kelp beds, sandy and rocky bottoms
- Community structure within each of the habitat types
- Community composition and list of species (and abundance) associated with the different habitat types, focusing on dominant species, species of particular conservation importance and species targeted for exploitation.

The high mobility of pelagic and planktonic organisms in the water column makes representative sampling nearly impossible and particular care should be taken when interpreting data on such organisms. In addition, the distribution and abundance of marine organisms often show strong diurnal and/or seasonal variability, depending on numerous climatic, physical and biogeochemical factors. It is important, therefore, to ensure such information is collected simultaneously and is taken into account when interpreting the ecological data. Ecological data should be adequate to perform valid statistical and community analyses as proposed below.

In summary, data required to characterize biological processes include:

- A geo-referenced map showing the distribution of the various habitat types and their associated biological resources (i.e. to refine the beneficial use map in terms of the distribution of marine ecosystems), highlighting areas with:
    - Biological resources of conservation importance
    - Biological resources targeted for exploitation
    - Biological resources that have been lost or are stressed, as a result of anthropogenic influence
- For each of the habitat types, a listing of the key species and their abundance and community composition, as well as expected temporal and spatial variability (this may be expensive to obtain and it may therefore be more realistic to focus on selected indicator species and community structure)
- Data on biological resources that are potentially sensitive to anthropogenic (existing or proposed) influences, including information on cause-and-effect relationships.

2.3 LONG-TERM MONITORING PROGRAMMES

NOTE

This section provides protocols or guidance on key aspects to be taken into account in the design of long-term monitoring programmes or plans. It has been largely extracted from the Operational policy for the disposal of land-derived wastewater discharges of the Department of Water Affairs and Forestry – South Africa (RSA DWAF, 2004b) It is by no means exhaustive and the reader is referred to the following additional reading for further detail:

- ***NATIONAL RESEARCH COUNCIL (1990), ANZECC (2000a), ANZECC (2000b), NZWERF (2002), US-EPA (1994) and US-EPA (2003) – design of monitoring programmes***
- ***UNESCO/WHO/UNEP (1992), Devore and Farnum (1999), Spiegel (1972) and US-EPA (2002) - statistical analysis of numerical data***
- ***Clarke and Green (1988) - complexity in statistical design and analysis for biological studies.***

Long-term monitoring programmes relevant to the management of land-based sources of marine pollution consist mainly of three components:

- *Source monitoring,* to determine the effectiveness with which facilities, aimed at managing and controlling marine pollution, are operated, as well as to determine the effectiveness of management strategies and actions to meet wastewater emission targets or standards (i.e. the critical limits that were defined for a specific marine pollution source)
- *Environmental monitoring*, to determine the trends and status of changes in the receiving marine environment, in terms of the health of important ecosystems and designated beneficial uses. Also, to evaluate whether the actual environmental responses match those predicted during the assessment process. This evaluation is necessary in order to respond, where appropriate, in good time to potentially negative impacts, including cumulative effects.

2.3.1 Source Monitoring

Source monitoring programmes are primarily focused on continuously assessing whether <u>wastewater emission targets</u> (or critical limits) are being met by potential marine pollution sources. For point source discharges (e.g. municipal wastewater or industrial effluents), the implementation of source monitoring programmes is often a legal requirement, as part of their licence agreements. Parameters to be monitored include:

- *Flow*: The sampling frequency needs to be sufficient to resolve the actual *variability* in the wastewater volume.
- *Composition of wastewater*: The list of constituents to be monitored will depend on the composition of the wastewater, while the frequency of monitoring needs to reflect the actual *variability* in wastewater composition.

  Urban/municipal wastewater discharges, consisting mainly of domestic sewage, have a characteristic wastewater composition. Key pollutants that need to be included in the monitoring programme of discharges to the marine environment are:

  - Biochemical oxygen demand/Chemical oxygen demand
  - Total suspended solids
  - Particulate organic carbon and nitrogen
  - Inorganic nitrogen and phosphate
  - Microbiological indicators.

In the case of industrial wastewater discharges, or where industrial wastewater discharges enter a municipal WWTW, the constituents included in the monitoring programme will depend on the constituents present in the wastewater and their potential to impact negatively on the receiving marine environment and its designated beneficial uses.

Although systems performance monitoring (also a form of source monitoring) primarily refers to performance monitoring of effluent disposal schemes (e.g. offshore marine outfalls), a monitoring programme can easily also be designed for other facilities aimed at preventing marine pollution, such as artificial wetlands constructed to improve the quality of urban stormwater runoff, or monitoring the effective implementation of certain agricultural practices so as to the prevent contamination of river runoff.

In the case of effluent disposal schemes, system performance monitoring programmes typically include

- Regular physical inspections of the system to identify malfunctioning or system failures
- Hydraulic performance (e.g. offshore marine outfalls) inspections, which should be conducted at any stage during the lifetime of the outfall when physical changes or alterations, which may have an effect on the hydraulic characteristics, are introduced or when there is a substantial change to the wastewater quantity or composition.

2.3.2 Environmental Monitoring

Key elements of a successful monitoring programme include (ANZECC, 2000b; US-EPA 2003):

- Monitoring objectives
- Selection of monitoring parameters (indicators)
- Refinement of spatial and temporal scales
- Appropriate sampling and analytical techniques
- Evaluation and Reporting

However, the design of long-term monitoring programmes should be a dynamic, iterative process to be adjusted continuously to incorporate new knowledge, thereby supporting the principle of adaptive management. The key aspects to be addressed as part of long-term monitoring programmes are schematically illustrated in Figure 2.7.

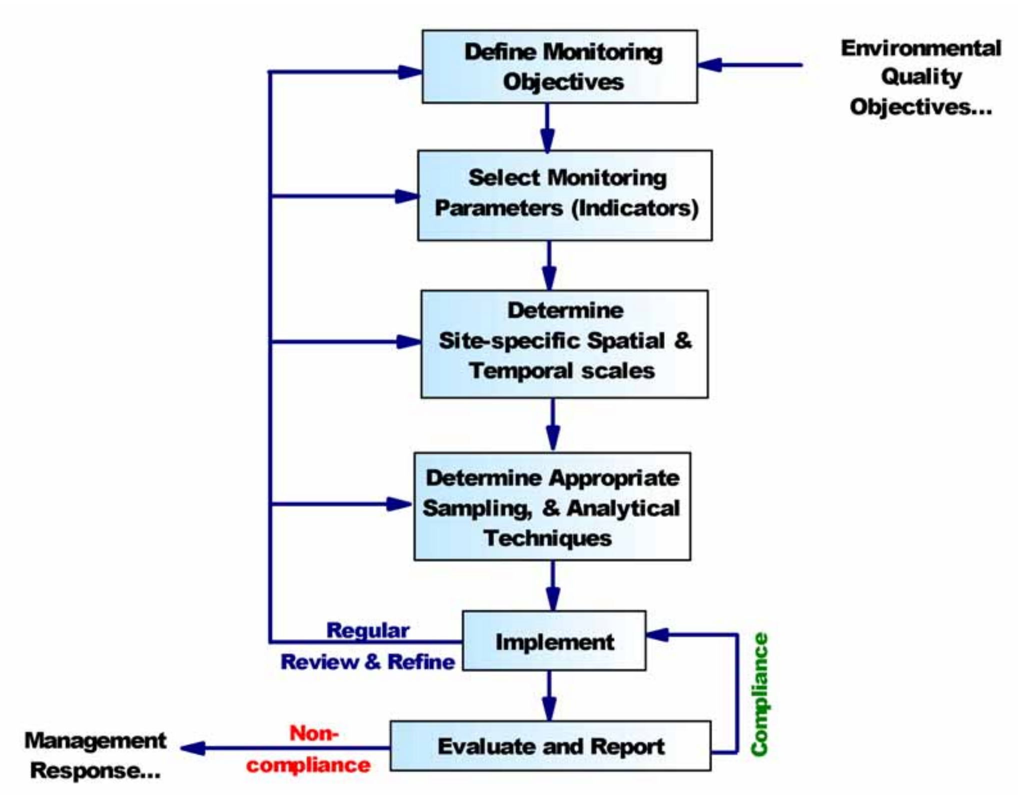


Figure 2.7: Key aspects to be addressed as part of long-term monitoring programmes

i. Monitoring Objectives

Measurable site-specific monitoring objectives are a key component of a sound long-term environmental monitoring programme. Such clear objectives make it possible to design a focused and cost-effective monitoring programme. These objectives can also be translated into hypotheses that could be proved statistically.

Usually, monitoring objectives are distilled from the environmental quality objectives which, in turn, are based on site-specific management goals for the protection of marine aquatic ecosystems and designated uses in a particular area – in many instances these objectives will have been derived using national (or regional) water and sediment quality guidelines.

Monitoring objectives can also be specified in terms of biological parameters (e.g. species diversity, abundance and community composition) that incorporate some 'acceptable change' from a baseline data set and/or an appropriate control site.

ii. Selection of Monitoring Parameters

The selection of measurement parameters (or indicators) is site-specific and should be able to quantify whether monitoring objectives (as defined above) are being complied with. Key determining factors in the selection of monitoring parameters are, for example:

- characteristics of marine pollution sources
- anticipated impacts on water and sediment quality, and subsequently on the health of aquatic ecosystems and other beneficial uses.

Depending on the anticipated impacts, monitoring can be conducted either in the water column, in sediments and/or in biological components. Selecting monitoring parameters in an environmental component in which there is usually high natural variability, such as the water column, may require high resolution sampling frequency, often with high cost implications. It is therefore usually more appropriate (and cost effective) to focus on those environmental components that tend to integrate or accumulate impacts or change over time, such as sediments and organisms. For example, filter feeders (such as mussels and oysters) are internationally recognized as suitable indicators for trace metal and hydrocarbon accumulation in the marine environment (Cantillo, 1998). These organisms filter food from the water in which they live and tend to retain contaminants that often accumulate to high concentrations in their tissues, thus reflecting changes in water quality over time. Their sedentary nature also prevents confusion about where a filter feeder might have accumulated a particular chemical compound.

However, an instance in which monitoring of the water column is considered to be the most appropriate, is the monitoring of microbiological indicators (e.g. Enterococci or *E. coli*) at recreational or marine aquaculture areas. Management of such areas requires near real time data to ensure that potential risks to human health are mitigated timeously. As a result, data need to be collected at weekly or two-weekly intervals, and even daily during the peak holiday season.

Monitoring parameters can also include marine organisms, by means of which species diversity, relative abundance, and community structure and composition of the biological communities in a study area are monitored. As it is often very expensive to conduct detailed biological monitoring programmes that measure entire biotic communities, indicator species are often selected as proxies for evaluating ecosystem health. In studies throughout the world and also in South Africa, macroinvertebrate communities have been used successfully in assessing ecosystem health (ANZECC, 2000b). Meiofauna distribution patterns, in conjunction with related biogeochemical parameters, have also been used successfully in this regard, e.g. in intertidal areas along sandy beaches (Skibbe, 1991; Skibbe, 1992). In South African estuaries, macrophytes have also been used successfully as long-term indicators of ecosystem health (CSIR, 2003). Other biotic parameters that have also been used are fish (ANZECC, 2000b), particularly in areas that support resident populations, such as estuaries, shoals, reefs and settlements on moored substrates.

Where the boundaries of the study area include areas that support biotic species of economic importance (e.g. the prawn populations on the Thukela banks off the KwaZulu-Natal coast), the distribution and abundance of these species are also effective monitoring parameters as part of ongoing long-term monitoring programmes.

It is, however, important that scientifically sound reasons are provided for the selection of specific biotic indicator species in a particular study area. Before choosing a particular taxonomic group(s) as a monitoring parameter of ecosystem health, it is important to also test it against the following criteria (ANZECC, 2000a &b):

- Sensitivity to potential impacts for waste inputs
- Response will reflect the overall ecological condition or integrity of the study area
- Approaches to sampling and data analysis can be highly standardised
- Response can be measured rapidly, cheaply and reliably
- Response has some diagnostic value.

A useful checklist that can be used to assist in the selection of suitable measurement parameters, in general, is provided in Table 2.1 (ANZECC, 2000b).

TABLE 2.1: Checklist for selection of measurement parameters (from ANZECC, 2000b)

Relevance	Does the measurement parameter reflect directly on the issue of concern?
Validity	Does the measurement parameter respond to changes in the environment and have some explanatory power?
Diagnostic value	The measurement parameter must be able to detect changes and trends in conditions for the specified period. Can the amount of change be assessed quantitatively or qualitatively?
Responsiveness	Does the measurement parameter detect changes early enough to permit a management response, and will it reflect changes due to the manipulation by management?
Reliability	The measurement parameter should be measurable in a reliable, reproducible and cost-effective way.
Appropriateness	Is the measurement parameter appropriate for the time and spatial scales that need to be resolved?

iii. Refinement of spatial and temporal scales

Setting spatial boundaries for a monitoring programme is important because inappropriate boundaries might focus efforts away from driving or consequential factors (ANZECC, 2000b). The anticipated influence of marine pollution sources therefore needs to be taken into account in the specification of the spatial boundaries of a long-term monitoring programme. This influence, in turn, depends on the transport and fate of pollutants, both in the near and far field, as well as potential synergistic effects associated with other anthropogenic activities that may affect water and sediment quality in the study area.

Sampling locations can also be dictated by the location of designated beneficial use areas. For example, recreational beaches and marine aquaculture farms will be logical sampling locations if located in areas where marine pollution sources, and associated pollutants, pose potential risks to human health.

The temporal scale of a monitoring programme (i.e. sampling frequency) largely depends on the:

- variability in the load of contaminants from marine pollution sources
- variability in processes driving transport and fate in the receiving environment
- temporal sensitivity of the ecosystem to pollutant loading, i.e. exposure time versus negative impact.

The sampling interval or frequency should at least resolve the main source of natural variability of the constituent under investigation. Scales of change over time differ widely in the water column (minutes – days) compared, for example, with sediments (days – seasons – decades). Non-periodic events, such as storms, can also have a dramatic influence that needs to be taken into account where appropriate.

In the water column, high frequency physical processes, such as tides, currents, wind and waves, mainly control variability. A sampling frequency that is too low relative to the underlying natural variability will, therefore, result in biased data that will make it difficult to separate a human-derived impact from a natural anomaly. In the same way, sampling at a frequency that is too low relative to the variability in waste inputs may result in marked negative impacts being missed. In order to resolve the problem of the variability in the water column, sampling frequencies generally have to be high (e.g. hourly-daily-weekly). As a result, the use of water column measurement parameters as part of monitoring programmes is usually not cost-effective.

Sediment sampling frequency is strongly linked to the time-scale within which the sediments act as ‘particle traps’. As with sampling of the water column, sediment sampling at a frequency that is lower than the periodic re-suspension events will make trends difficult to interpret and could lead to spurious conclusions. Therefore, where cost constraints necessitate limitations on sampling frequencies, it will be inappropriate to select sampling locations that are situated in areas reflecting short-term variability. In such instances, longer-term depositional areas should rather be targeted. For example, because sediment processes often show strong seasonal trends, sampling is often confined to a particular season. Depositional sites can be designated both long- and short-term. For example, an open coast site may be a depositional site for a period of days to weeks whereas an estuary may be such for a period of months to years. The ecological impact of both does not have to be linearly related to the persistence. Both provide important insights into the sediment and pollutant dynamics of the coastal and estuarine environments and are key to the design of optimal monitoring programmes, particularly in terms of sampling frequency.

Another commonly used technique to partially overcome the problem of high frequency variability is to measure seasonal variability of pollutants in biological tissue (e.g. flesh of filter feeders). It is, however, important to realise that the body mass of these organisms also has a strong seasonal variability related to spawning cycles. Natural variability therefore needs to be separated from potential long-term signals caused by human interference. To address this issue, the following are required as a minimum:

- Samples need to be taken at regular six-monthly intervals
- Long-term sampling needs to be undertaken within a narrow time window each year to reduce seasonal uncertainty.

Traditionally, long-term monitoring programmes included intensive sampling grids to overcome the inherent uncertainties of the spatial (and temporal) variability of a system. However, with the use of numerical modelling, many of the inherent problems of the traditional approach can be overcome. Numerical modelling has proven to be very useful in enhancing the design of long-term monitoring programmes and improving the interpretation of the results of monitoring. Such numerical models provide the process links that enhance the ability to diagnose problem areas, as well as anticipating problems through their predictive capacity. The benefits of numerical modelling in the design of long-term monitoring programmes include:

- Definition of the most critical space- and time-scales of impact in the system: Important insights are provided by the combination of the synthesis of the existing understanding of the key processes and the model assumptions and inputs
- Improved interpretation and understanding of the monitoring results in the context of a dynamic environment that determines the transport and fate of pollutants.

The aim, therefore, is to use the capability of numerical models to reduce uncertainties in relation to system variability, key processes and how these influence the transport and fate of contaminants. Because this increased understanding provides greater confidence in the predicted outcomes, the investment in the monitoring can be limited to only a number of critical parameters measured on critical time and spatial scales.

Although long-term monitoring programmes may, initially, still require relatively intensive spatial (and temporal) scales to address uncertainties in a system's response, over a number of years, these can be reduced to only a few selected points through an iterative process, as the predicted responses of the system are verified. These high sensitivity points, however, need to be justified on the basis of specific criteria, such as high concentrations of mud and silt that indicate a long-term depositional area.

iv. Sampling and analytical techniques

The choice of sampling and analytical techniques to apply in a monitoring programme is largely dependent on the selection of monitoring parameters and the output that is required to properly evaluate whether monitoring objectives are complied with.

Key requirements that need to be stipulated in a sampling programme include:

- Sampling technique
- Number of replicates (determined by the statistical technique used in analysis)
- Sample handling and storage.

It is strongly recommended that an appropriately accredited analytical laboratory conduct chemical analyses of marine biogeochemical parameters.

v. Data Evaluation and Reporting

In the evaluation of monitoring data, the following are important aspects that need to be considered:

- *Data qualification*. The required accuracy and precision of data need to be clearly defined before embarking on data acquisition exercises. Rounding-off and the number of significant figures must be defined for each type of data. A high level of confidence with regard to data accuracy is essential for any further analysis.
- *Appropriate (Statistical) techniques*. Computers and statistical software are valuable tools for the evaluation of environmental data. However, they are only tools: the ultimate assessment depends on scientific expertise, as well as a proper understanding of statistical procedures and their applicability to environmental data. Where statistical expertise is limited, commercially available software packages (or the techniques described in the following section) must be used cautiously. Statistical techniques that are applied inappropriately can result in erroneous results or interpretations.

To be useful from a management perspective, it is crucial that monitoring results be reported in a clear format to provide the appropriate scientific (and engineering) knowledge for informed and effective decision-making. Often the most effective manner in which to communicate environmental data and information is through graphical presentation, in that large data sets can be illustrated effectively. Graphical presentation is also effective in showing qualitative aspects (such as correlations and trends) and quantitative aspects (such as outliers). It is also a user-friendly means of communicating complex numerical and statistical outputs.

The frequency of reporting is also important. For example, compliance monitoring (referring to monitoring of composition and volumes of marine pollution sources) requires near 'real-time' (i.e. as close as possible to the time of sampling) reporting to ensure that mitigating measures are implemented timeously. Environmental monitoring programmes require less frequent reporting, e.g. usually six-monthly or annually.

In general, a Monitoring Report needs to include:

- A list of monitoring objectives (or hypotheses) and how these relate to the overall Environmental Quality Objectives specified for the study area
- Details of the design and implementation of the monitoring programme (also indicating the relationship between selected measurement parameters and monitoring objectives)
- An evaluation of the monitoring data in relation to the monitoring objectives (or hypotheses). This evaluation should make use of data summaries and graphical presentations in order to enhance readability
- A statement on whether the monitoring objectives have been met
- In the event of non-compliance, possible reasons for the non-compliance
- Management strategies and actions required to address non-compliance
- Recommendations on refinements to the monitoring programme
- Appendices containing cruise and laboratory reports, raw data tables and other relevant background information.

Various other communication routes can be utilised to communicate findings to wider stakeholder groups, which may not have the relevant scientific or engineering background, such as Pamphlets, Stakeholder meetings, Internet websites and Media reporting.

Monitoring data are expensive to collect and require substantial investments of both human and financial resources. As a result, such data must be made as usable, useful and retrievable as possible. The sheer volume of data generated as part of ongoing monitoring programmes dictates that computer-based data management systems must provide the basis for data storage and management. A good data management system should have (ANZECC, 2000b):

- Reliable procedures for the recording of analytical and field observations
- Procedures for systematic screening and validation of data (quality control)
- Secure storage of information
- Simple retrieval system
- Simple means of analysing data
- Flexibility to accommodate additional information.

SECTION 3.
PRELIMINARY IDENTIFICATION OF KEY STAKEHOLDERS INVOLVED IN MANAGEMENT OF LAND-BASED MARINE POLLUTION SOURCES IN THE BCLME REGION

An important secondary objective of this project was to initiate the establishment of a BCLME coastal water quality network that will provide a legacy of shared experience, awareness of tools, capabilities and technical support. This network will be supported by an updatable web-based information system that provides guidance and protocols on the implementation of the generic management framework, as well as a meta-database on available information and expertise.

This network should include managers/government officials and scientists who are:

- Involved in the management of land-based pollution sources to the marine environment
- Knowledgeable on potential effect of water and sediment quality on the biota and beneficial uses in the coastal waters of the BCLME region
- Responsibilities in terms of setting legislative policies and procedures related to waste disposal to the marine environment as well as protection of the Namibian marine environment.

Preliminary lists of key stakeholders who are involved in the management of marine pollution, in each of the three countries, are provided in Table 3.1 to 3.3 respectively.

The list of key stakeholders will be captured in an updatable, web-based information system (another deliverable on this project), accessible to users in the BCLME. It is envisaged that these lists will grow as the coastal networks expand in the different countries.

TABLE 3.1: Preliminary list of key stakeholders in Angola

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TABLE 3.2: Preliminary list of key stakeholders in Namibia

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SECTION 4.
DESKTOP ASSESSMENT STUDIES ON EXISTING INFORMATION PERTAINING TO MANAGEMENT OF LAND-BASED SOURCES OF MARINE POLLUTION

Another key objective of this project was to prepare an inventory and critical assessment on the available data and information relevant for the management of land-based pollution sources in the BCLME region. To conduct such desktop assessments in the time and budgetary constraints of this project, effort was focused on the main development nodes in the BCLME region. The nodes that were included in the desktop assessment studies are listed in Table 4.1 (also indicated in Figure 4.1)

TABLE 4.1: Development nodes selected for the BCLME region

ANGOLA	NAMIBIA	SOUTH AFRICA
Cabinda Soyo Ambriz Luanda Lobito Namibe	Henties Bay Walvis Bay/Swakopmund Luderitz Oranjemund (diamond mining areas)	St Helena Bay Saldanha Bay/Langebaan Lagoon Cape Peninsula (western section) False Bay Walker Bay (Hermanus) Mossel Bay Knysna Estuary

Figure 4.1: Development nodes selected for the BCLME region

The desktop assessment reports provide inventories on:

- Existing legislation, policies and management strategies related to the management and control of land-based marine pollution (these are usually set by national or regional government authorities)
- Known marine pollution sources (particularly focusing on the land-based sources), for which available and easily accessible estimates on waste loads will also be provided.
- Important marine aquatic ecosystems, as well as the designated beneficial uses of the marine environment. Beneficial use areas that should be identified are mainly related to:
  - Tourism and recreation areas
  - Marine aquaculture (including important fisheries)
  - Industrial uses of seawater (e.g. for fish processing and cooling water intake)
- Available or published information sources on physical, biogeochemical, and biological characteristics and functioning of the marine environment adjacent to the development nodes (relevant to understanding and predicting the transport and fate of pollutants)
- Inventory of existing monitoring initiatives related to the management of land-based pollution sources.

The desktop assessment studies for South Africa, Namibia and Angola are provided in Appendices A, B and C, respectively.

The inventories of information, generated as part of the above-mentioned desktop assessment studies will be captured in the updatable, web-based information system (another deliverable on this project), accessible to users in the BCLME (temporary web address: www.wamsys.co.za/bclme).

SECTION 5.

THE WAY FORWARD

The primary purpose of this project was to standardize on the approach and methodology with which land-based pollution sources in the BCLME region are managed. This was achieved through the preparation of a generic (draft) management framework for the management of such sources, including protocols for the design of baseline measurements and long-term monitoring programmes.

It is important to realize that, although it is possible to put forward a generic management framework for such a large region, the implementation of the management framework will ultimately be more site-specific.

An important secondary objective of this project was to initiate the establishment of a BCLME coastal water quality network to provide a legacy of shared experience, awareness of tools, capabilities and technical support. The establishment of this network was facilitated through work sessions held in each of the three countries to which key stakeholders were invited. At the work sessions, the proposed management framework was introduced and participants were given the opportunity to provide their input. This was followed by training workshops in each of the three countries, where key stakeholders were given preliminary training in the application of the management framework. The updatable web-based information system, which was also developed as part of this project, should be a valuable tool supporting the BCLME coastal water quality network in future, provided that it is maintained and updated regularly.

The following points relate to the way forward:

- The proposed framework for the management of land-based marine pollution sources in the BCLME region is largely based on a framework that was developed for the Department of Water Affairs and Forestry (South Africa) as part of their *Operational Policy for the Disposal of Land-derived Wastewater to the Marine Environment of South Africa* (RSA DWAF, 2004a&b). However, the proposed framework still needs to be **officially approved and adopted** by responsible government authorities in Namibia and Angola. It may well be that individual countries require further refinement or adjustment of the management framework to meet requirements specific to their own countries.

- The management framework developed as part of this project is **closely link to the recommended water and sediment quality guidelines** for the coastal areas of the

BCLME region (developed as part of another BCLME project – BEHP/LBMP/03/04). In particular, the guidelines will assist in the initial establishment of environmental quality objectives.

In the interim, until such time as a management framework and quality guidelines have been incorporated in official government policy, it is proposed that the management framework developed as part of this project, together with the recommended water and sediment quality guidelines (referring to Project BEHP/LBMP/03/04), be applied as preliminary tools towards improving the management of the water quality in coastal areas of the BCLME region.

- The **updatable web-based information system** (temporary web address www.wamsys.co.za/bclme), developed as part of this project, can also be a very useful decision-support and educational tool for marine pollution management in the coastal areas of the BCLME region. However, its usefulness in the future will strongly rely on the system being maintained and updated regularly. It is therefore important that a dedicated 'administrative home' for the system be provided once this project is terminated. In the short to medium term, it is recommended that one or more of the BCLME offices within the three countries take on this responsibility.

- Although training workshops did form part of this project, they targeted only a limited number of stakeholders in each of the three countries. To facilitate wider capacity building in the BCLME region on management of marine pollution in coastal areas, it is strongly recommended that the output of this project be included in a **training course**. In this regard, the *Train-Sea-Coast/Benguela Course Development Unit* is considered the ideal platform through which to develop and present such training (www.ioisa.org.za/tsc/index.htm).

SECTION 6.
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