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**THE SOCIETAL VALUE OF GEOSCIENCE
INFORMATION IN LESS DEVELOPED COUNTRIES –
THE COASTAL ZONE OF EASTERN AFRICA**

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Front cover illustration: Freshwater issuing from Pleistocene coral limestone in the intertidal zone at Diani, Mombasa, Kenya.

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SUMMARY

This report identifies, through consultation with a range of coastal scientists and coastal management practitioners, those coastal management issues to which geoscience knowledge and understanding have relevance. It assesses the importance of these issues, reviews the state of existing knowledge and proposes research and applications agendas with a view to delivering societal benefit, both through the development of appropriate national policies for sustainable development in coastal areas and through the implementation of effective management practice at national to community-based levels. The study focuses on the coastal areas of Eastern Africa, in particular, Tanzania.

A prime role for the geoscientist is to provide strategic knowledge of the geological and hydrogeological resources of the coastal zone and the processes which affect them; also to deliver an understanding of the dependencies of the various ecosystems on those resources and, in some cases, *vice versa*. The greatest societal benefit deriving from this knowledge will accrue from its application where demand on the resources is greatest - in most instances this means in and around urban areas.

The surveying and management of groundwater resources is probably where geoscience can bring the most significant benefit, with the potential to deliver value to the coastal community, rural and urban, even over the short term. Over the longer term, the application of geoscience to the problems of the siltation and pollution of coastal areas from land-based sources is likely to lead to societal benefit, though this may be difficult to quantify because of the complexity of the resources involved. Although coastal erosion is perceived by coastal managers to be an important issue, and one for which geoscience is relevant, benefits from geoscience research are likely to be restricted to site-specific developers, over the short term at least.

The report highlights a need to raise the level and breadth of scientific awareness in coastal policy-making and management, including knowledge of the geological resource inventories and the processes that affect or control them – both crucial components of environmental assessment for sustainable development in the coastal zone. The delivery to coastal management, both at the public institutional and the community levels, of relevant and accessible information on the geoscience-related resources, their values and the processes acting on them should be a key input to the integrated management of the coastal zone.

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1. INTRODUCTION AND BACKGROUND

The overarching aim of this project is to develop and test cost-benefit analysis methodologies for national geoscience surveying projects in government institutions in developing countries. Part of the aim focuses on issues for which such methodologies might be relevant within the coastal zones of countries within the SADC region of Africa. This study relates mainly to Tanzania, to a lesser extent to Mozambique, and with incidental coverage outwith the region in Kenya.

The contribution to coastal area management and sustainability that knowledge of geoscience and geoscience processes makes is already recognised in principle at the intergovernmental levels (e.g. the Intergovernmental Oceanographic Commission of UNESCO), at governmental levels in many countries, and by some of the major national and international donor and research-funding agencies (e.g. The World Bank). In many cases, however, the rationale for such recognition is poorly described or inadequately presented in the context of coastal area policy and management, particularly in relation to issues concerning living resources and socio-economics. This shortcoming applies not only to considerations of resources or resource valuation in coastal areas but also to a wide range of environmental assessments which could, indeed should, be substantiated by an understanding of geoscience, and geoscience-related, processes - physical, chemical and biological.

The resource that is implicit in the geology of the coastal zone is fundamental, not just in terms of its potentially useful non-living materials, but, more importantly, because of the substrate or host function that it provides both for the coastal ecosystem at large, and its associated hydrological, hydrogeological and oceanographic interactions. The processes acting on the geological resource are complex, whether on account of natural forcing pressures or human intervention. The effective appraisal of the impacts of such processes, a prerequisite for appropriate policy formulation and management action, demands a thorough knowledge of the resource and the processes that affect it.

Sustainability in the coastal zone implies the maintenance of its *natural capital* (Goodland and Tillman, 1996) - the total resource. Coastal areas are special in the very wide range of resources they contain, and thus the wide range of opportunities that they present to the ecosystem. Assuming an anthropocentric view of resource valuation, the aim of integrated coastal management is to at least maintain the total resource value, and preferably enhance it, for the benefit of future generations - the concept of *intergenerational equity* (Adger, 1997). The translation of resource value into societal benefit is complex and subject to many variable factors. In particular the resource value is a function of usage or demand and thus varies both spatially and temporally. Despite these constraints, there is merit in considering the value of specific resources (not least geological resources), and the possible changes in their value with time, so that management responses may be prioritised for the benefit of society.

This report explores the relation between geoscience knowledge and information and societal benefit as applied to the coastal areas of Eastern Africa. It is based in part on published sources, but largely on consultations with, and advice from, scientists and administrators within the region during September–October 1998. A listing of

published sources, but largely on consultations with, and advice from, scientists and administrators within the region during September–October 1998. A listing of organisations and individuals consulted is given at Appendix A. Appreciation of some specific issues was supplemented by reconnaissance study in the field. The report makes recommendations for the enhancement and stronger application of strategic geoscience information for a number of key issues of concern in the management of the coastal areas of the region, with a view to benefitting society at all levels, including the least advantaged.

2. GEOGRAPHIC AND SOCIO-ECONOMIC OVERVIEW

The coast of Eastern Africa is a passive continental margin, with a narrow continental shelf except in central and southern Mozambique and locally in Tanzania where major rivers discharge to the sea. Northern Mozambique and nearly all of the Tanzanian coast are characterised by Pleistocene coral limestones which overlap the older continental rocks and form a number of pronounced geomorphic terraces. The limestone coasts form fringing, largely intertidal platforms which, together with reefs at their seaward margins and a number of coast-normal, partially submerged palaeovalleys, provide the substrates for productive and diverse ecosystems including coral, seagrass and mangrove. The coasts of central and southern Mozambique, in contrast, are dominated by deltaic sedimentary deposits and characterised by sand spits, beach ridge plains and associated swamps.

Except in the extreme south, the climate is tropical humid to sub-humid with two monsoon seasons, the north-east monsoon from November to February and the south-east from April to September. Offshore Tanzania is affected by the northward-flowing East African Coastal Current, and Mozambique, by the southward-flowing Mozambique Current. Maximum tidal range varies from 2 to 6 metres.

The coastal zone of Tanzania (800 km long) has a population of 4.6 million, concentrated largely in and around Dar es Salaam; that of Mozambique (2770 km long) has a population of 6.5 million (UNEP, 1998b). Both countries have a population growth rate of 2.8%/yr overall, higher in the coastal areas, the growth rate in Dar es Salaam being 7.8%/yr, and that in Maputo even higher (UNEP, 1998b). Both countries are heavily dependant on their coastal environments as sources of food and employment. Fisheries are of widespread importance, both through commercial involvement offshore and at the artisanal level inshore. The principal ports of Dar es Salaam and Beira serve the extensive hinterland, with smaller facilities at Tanga, Nacala and Maputo. Industrial development in the coastal zone is low; products include cement (from Pleistocene limestones), salt (from coastal salt pans) and industrial minerals (from mined mineral sands). Subsistence agriculture is practised throughout, and there are extensive sisal estates in northern Tanzania. Natural gas is being developed on the island of Songo Songo in Tanzania. Tourism is becoming increasingly important, with the island of Unguja in Zanzibar showing by far the greatest rate of development. Overall, tourism in both Mozambique and Tanzania lags well behind that of Kenya in its development.

3. INSTITUTIONAL ARRANGEMENTS FOR COASTAL MANAGEMENT

3.1 Tanzania

The Tanzanian Coastal Management Partnership (TCMP), based in Dar es Salaam, was founded in 1997 as a joint venture between the Government of Tanzania, through its National Environmental Management Council (NEMC), and USAID, the United States Agency for International Development. USAID is represented by experts from the Coastal Resources Center of the University of Rhode Island (URI). TCMP seeks to embrace Integrated Coastal Zone Management (ICZM). It is one of a number of environmental initiatives supported by USAID grouped under the title of *EPIQ*.

TCMP is concerned with the development of national policy for ICZM, addressing perceived problems and issues at the national scale. It has an integrating role, providing linkage between a number of existing local, sectorial, management-orientated projects, supported by a range of different donors; also promoting effective connections between scientists, policy-makers and managers. It is concerned with capacity building – developing ICZM at the national policy, as opposed to the project, level. After South Africa, Tanzania is the first African country to implement this objective. TCMP aims to provide policy assistance to Government in specialist fields such as mariculture, and to prepare policy guidelines for emerging resource opportunities. It is seeking to build Environmental Assessment policy at the strategic or national level.

The TCMP includes all the main coastal management projects currently being implemented within the country. It also includes stakeholder representatives as partners.

3.2 Mozambique

The *National Inter-agency Working Group on the Coastal Zone* of the Ministry for Co-ordination of Environmental Affairs (MICOA), with its headquarters in Maputo, has aims similar to those of TCMP, though compared with TCMP it is less developed. MICOA was formed in 1996 with the principal role of co-ordinating environmental management issues. With Danish assistance (DANIDA) it has so far established one of several proposed regional offices, in Nampula in the north of the country, and, like TCMP, is seeking to develop commitment from stakeholders as well as from NGOs and commercial interests. Another working group has been formed to deal with coastal management issues specifically in Xai Xai, in the south of the country, where there are strong development pressures.

3.3 Regional

The Secretariat for Eastern African Coastal Area Management (SEACAM) was founded in 1997, based in Maputo, Mozambique, in response to the recognition at intergovernmental level within the region of the need to accelerate the implementation of ICZM. SEACAM's work programme, which has a lifespan of two and a half years, is based on stakeholders in ten countries of the region, including Kenya, Tanzania and

Mozambique. It has a role of capacity building and information sharing as they relate to the coastal zone. There is an emphasis on management issues, notably mariculture and tourism development, though there is presently little emphasis on research. The principal financial support comes from Sweden (Sida/SAREC), with contributions from the World Bank and IOC of UNESCO.

4. EXISTING SCIENTIFIC RESEARCH AND MANAGEMENT PROJECTS

In its review of donor activity in the coastal zone of Sub-Saharan Africa, the World Bank concluded that 'rather than having resolved the issues..., development efforts (including those of the World Bank) in the coastal zone have generally contributed to them (Hatzios et al., 1994). The review stressed the narrow, sectorial view taken by donors, with little attention paid to planning and building technical and institutional capacity as important components of management. The results of consultations carried out as part of the present study suggest that, while many donors continue to take a sectorial view, there is a growing awareness of the potential benefits accruing to the intended beneficiaries of coastal projects - the coastal communities - through taking a more integrated approach to policy and management issues.

A common complaint voiced by consultees involved with coastal management projects was a lack of scientific data to support policy formulation and management action. Another was the recognition by some scientists interviewed of the difficulties of achieving cross-disciplinary linkage in addressing research issues in the coastal zone. Only in a few cases had there appeared to be a planned cross-disciplinary approach to management problems, considering the wider scientific perspective.

It is clear that in general there is a need to raise the level and breadth of scientific awareness in coastal management, the need to know about inventories, about processes - both crucial components of environmental assessment for development in the coastal zone. It is also clear from the consultations that many resource management projects were being carried out without any substantial knowledge or understanding of the relevance of geoscience resources and processes to specific sectorial interests.

With a few exceptions, the science (including the geoscience) that is accessible to coastal management projects, whether at the regional or site specific scale, falls well short of what is required, or at least desirable, for sound assessment and planning decisions, decisions that are usually taken with the best intentions of producing societal benefit. Very few current projects are concerned with resource valuation, other than in the most general terms. This is a shortcoming that makes problem identification difficult and the prioritisation of relevant research effort haphazard to say the least. While the current scientific and management projects within the region still tend to focus on the living resources of the coastal zone - coral reef and related fisheries ecosystems, seagrass meadows, mangroves and mariculture, there is a growing trend, as shown particularly by SEACAM, towards capacity building.

Current and recent projects dealing with non-living resources are concerned largely

with coastal erosion. Surprisingly little effort is being, or has been, devoted to the causes (or sources) and impacts of siltation and related contaminants, and to the paramount twin issues of water supply and water quality in the coastal zone. Exceptions are the DFID-funded Land-Ocean Contamination Study (LOCS), which included an assessment of contemporary sediment and pollutant fluxes in the estuaries of Dar es Salaam and Mombasa, in Kenya (Rees et al., 1996); also a current regional research project, funded by the European Union, in which institutes in Kenya, Tanzania and Mozambique, as well as The Netherlands and Belgium, are examining groundwater in the coastal zone, principally in respect of the implications of human-induced changes in its outflow, and outflow quality, on the ecosystems of the nearshore zone.

While there are published geological survey maps and reports covering the coastal areas of both Tanzania and Mozambique (e.g. Stockley, 1928), they are generally not produced to modern standards and their scales and levels of detail are inadequate for applications in coastal planning and management. More useful (though not products of national geological surveys) are specific studies of Quaternary coastal geology and geomorphology such as that in Zambesia province in Mozambique (Jaritz et al., 1977) or in Zanzibar (Arthurton et al., in press). Some coastal aquifer mapping and hydrogeological assessment has been carried out in Tanzania, through the University of Dar es Salaam, and in Kenya, through the Geological Survey of Kenya.

An atlas of coastal resources, living and non-living, is planned to cover the eastern African region, produced by the United Nations Environment Programme with the support of the Government of Belgium. The first part of this atlas, covering the coastal zone of Kenya, has been published (UNEP, 1998b); its accompanying report provides a useful overview of the physical characteristics of the coastal environment, including general information on geology and geomorphology, and hydrology (including groundwater resources); also a section dealing with minerals and energy resources. Production of the part covering Tanzania is in progress and coverage of Mozambique is planned.

A listing of the principal current and recent scientific research and coastal management projects in the region (including Kenya) is given at Appendix B.

5. THE GEOSCIENCE-RELATED MANAGEMENT ISSUES IDENTIFIED

5.1 Resources and pressures

Geoscience information can contribute to ICZM in two important ways. Both of these concern the resources of the coastal zone, renewable and non-renewable. The first concerns the *resource inventory*, or more specifically the geological and geomorphological aspects of that inventory. It aims to define the dimensions of the resource, whether in terms of volumes or of the substrates (or accommodation areas) available for exploitation or development by the coastal ecosystem and the various goods and services. The second concerns the *pressures* to which the coastal resources are subject, whether these resources are living or non-living. This involves an

understanding of processes, in particular the geoscience-related processes such as sedimentation, erosion and groundwater flow, and the ways in which those processes may change with time.

The pressures affecting coastal resources may be generated locally by human activities such as beach sand abstraction or waste disposal, or they may be the result of human activities distant from the coastal zone such as land-use changes and irrigation schemes in the adjoining drainage catchment, these in turn causing changes in the rates of water and sediment discharge at the coast. Alternatively the pressures may result from naturally induced events or changes such as extreme climatic events, which may result, for example, in severe coastal erosion and the destruction of coastal infrastructure.

ICZM is concerned primarily with the pressures on resources generated by human activities in the coastal zone itself, and seeks to maintain the natural capital of those resources. These pressures need to be distinguished from those generated externally for policy and management action to be effective, and this applies particularly to the impacts of geoscience-related processes, such as the sediment-associated delivery of pollutants from land-based sources to coastal waters. In practice, coastal managers may have little control over, say, human activities in the catchment, but awareness of the total flux – water, sediment and pollutants – and its changes over time may have important implications for a range of coastal resource users.

5.2 Water supply and quality (including groundwater)

Concern over the supply and quality of freshwater for use in the coastal zone emerged from the consultations as being the most important issues facing coastal communities.

The problem is widespread and is subject to seasonal variation. It affects urban and rural communities alike, whether on the mainland or the offshore islands. There is a particularly urgent need for groundwater management in urban aquifers, to meet an increasing demand for potable water in the face of unplanned and increasing domestic sewage disposal and the danger of saline intrusion, whether of natural occurrence or induced by over-abstraction.

In 1996 the Government of Tanzania commenced an emergency programme of groundwater exploration in an attempt to alleviate a severe water shortage in Dar es Salaam resulting from a prolonged drought. A recent research project in the Kenyan coastal zone south of Mombasa (Adams, 1986) identified a substantial groundwater resource, with a view to supplementing the established supply to Mombasa from the hinterland at Mazima Springs. There are currently moves to develop this resource for the benefit of Mombasa and local coastal hotels, but not, it is understood, for the rural community. Recurrent problems of groundwater pollution with a frequent incidence of cholera were reported around Zanzibar Town, particularly during the dry season (September-March), while pollution was also seen as an impediment to setting up successful fish-rearing operations on the Tanzanian mainland.

5.3 Coastal erosion

Although very restricted in its impacts on coastal communities, coastal erosion was cited by a number of consultees as being an important management issue. The problem has also been recognised at the intergovernmental level, with a current regional IOC project aimed at producing guidelines for coastal managers in the assessment, monitoring and management of the problem. TCMP sees erosion as being one of the big issues in Tanzania, though this is mainly in respect of its impact on private investment schemes, usually tourism related. The Kunduchi Integrated Coastal Area Management Project (Sida/SAREC) is one of the few management projects encompassing the issue of erosion, which has threatened substantial hotel infrastructure along this shore. Attempts have been made at Kunduchi to stabilise the beach sands by the installation of quarried-rock groynes, but generally these have been unsuccessful. Another project, funded by the Government of The Netherlands (Mohamed and Betlem, 1996), assessed the problem on the islands of Zanzibar, where private tourism investment was similarly threatened. Studies at Nungwi, at the northern tip of Unguja island, using aerial photographs taken over the period 1947-1977 showed that the shoreline had retreated by 1.2 km over that 30-year period. One consultee quoted instances of villages on mainland Tanzania, near Tanga, that had been forced to move inland as a consequence of coastal erosion.

The consultation identified uncertainty as to the causes of the erosion. In some cases human intervention, such as sand mining from the beach, was taken to be responsible; in others, climatic variation causing changes in the direction in which waves impact the beach, or changes in the volumes of sediments discharged from rivers to the shore were considered to be the determining factors. In Tanzania the responsibility for environmental assessment of coastal development sites rested with the developer, but such assessment was seldom carried out.

The extent of the problem of coastal erosion in Mozambique is beyond the scope of this report. However, Mozambique's central and southern coasts are built of terrigenous sediments, largely discharged from major rivers such as the Zambesi. Increasingly, these rivers draining the African hinterland are being impounded for electric power and irrigation schemes, with the result that the flux and discharge of water and sediment at the coast are diminishing. Over the coming years there may be a tendency for the existing accretionary regimes at the shoreline to be replaced by erosional ones, particularly around the main delta lobes.

5.4 Siltation

The effects of the deposition of silt from suspension, and the related high levels of turbidity in coastal waters resulting from river discharge, are known to degrade sensitive coral reef ecosystems. The problem is widely recognised and known to be most acute during the rainy season, with sediment-charged plumes extending through inshore waters, controlled by the prevailing currents. Sediment turbidity is pronounced in the inshore waters off the Rufiji delta in Tanzania and along much of the southern and central Mozambique coasts, extending oceanwards to as much as 30 km in places.

The extent to which the discharge of suspended sediment and its plumed distribution, as observed in present-day rainy seasons, is exceptional is unclear from existing geological, historical and monitoring data. Little systematic work has been carried out in the region on changes in the distribution of siltation with time, either historically or geologically, nor is there reliable data on the long-term variability of sediments (including suspended sediments) carried to the sea by the major rivers of the region. Some experts claim that changes in agricultural practice or deforestation are increasing the sediment flux, while others point out that river impoundment is leading to a reduction.

5.5 Other issues

Making the best use of the non-living resources of the coastal zone is an accepted goal of ICZM. A prerequisite for this is information on the extent and quality of those resources, and knowledge of the options that are available for alternative sources or materials. This approach applies particularly to the assessment of industrial minerals, whether the Pleistocene coral limestones for cement manufacture and construction or beach or dune sands for mineral extraction. The management issue here is to ensure that extraction or exploitation is achieved in the most cost-effective way and without irreversible disruption or destruction of the surrounding ecosystem. In such cases geoscience information, including mineral assessment and groundwater data, needs to be integrated with ecological and socio-economic expertise at the planning stage.

One issue identified in the Nacala peninsula, in northern Mozambique (Burbridge et al., 1992), was that of the potential development problems arising from the reclamation of coastal marshland and mangrove soils. Oxidation of iron sulphide contained in these muddy sediments leads to the production of acid sulphate soils, which can prove to be unproductive and are often abandoned. Accurate geological mapping of the coastal zone should provide managers and planners with the information needed to avoid such problems.

6. RESOURCE VALUATION AND SOCIETAL BENEFITS

6.1 Societal value of geoscience-related resources

A prime role for the geoscientist in ICZM is providing knowledge of the geological and hydrogeological resources as well as delivering an understanding of the level of dependency of the various ecosystems on those resources. In order for this information to be translated in terms of potential or actual societal value or benefit, it is first necessary to place a value on the resource, in anthropocentric terms. This is a complex task and the results can seldom be anything more than indicative. The valuation of a marketable resource, such as a mineral sand, is perhaps the simplest to estimate. It relates to the use made of that resource (Adger, 1997). Valuation of non-marketable resources, such as coral reefs or intertidal platforms or limestone aquifers, is more difficult. For not only do such resources directly support a wide range of uses, but they also provide the host for other resources, which may or may not be marketable, and which may in turn provide opportunities for the development of

further resources, and so on.

6.2 Adding value through knowledge

The geoscientist has a potential to add value to a resource, either by drawing attention to its existence, by assessing or reassessing its quality, or by realising the importance of its hosting role for other resources. Any of these mechanisms can feed through to providing benefit to society, in the coastal context through the agency of ICZM. The case of a limestone aquifer serves to illustrate this point. By itself, it is simply limestone. It may have a value as an industrial mineral, but the limestone may be so common that this value is negligible. The geoscientist can enhance that value significantly by improving knowledge not only of its dimensions and nature, but also of the groundwater that it hosts. Thus the value of the limestone relates to the value of the groundwater. If the groundwater remains unused then it has no value; the greater the demand for that groundwater, the higher its value and the higher the primary resource value. It follows that the greatest societal benefits from this geoscience will accrue from its application where the demand is greatest – in the case of the coastal zone, in and around the urban areas.

6.3 Impacts of geoscience processes on resource value

In addition to the inventory information supplied through geoscience research, the understanding of processes is also important and can deliver significant societal benefit. Much of the process understanding that can contribute to the safeguarding of sensitive coastal resources relates to the way in which, and rates at which, materials move into, within and out of the coastal zone. Such knowledge applies to the management of beach erosion and coastal recession or accretion, to making the best use of groundwater resources in the coastal zone, and to developing appropriate policy and management responses to the problems of pollution in coastal and estuarine sedimentary environments. For example, the DFID-funded LOCS project (Rees et al., 1996) drew attention to the need to study the hydrodynamic and sedimentological processes of estuarine environments in order to understand the storage and flux of pollutants within them.

A major constraint in groundwater development in urban coastal areas, such as Dar es Salaam, is the threat of pollution arising from the widespread and indiscriminate discharge of domestic sewage into the aquifer. There is also the problem of saline intrusion – the over-abstraction of groundwater leading to the introduction of marine-derived salt water to the aquifer. Both of these pressures conspire to reduce the dimensions of the potable freshwater resource and thus its value to the community. With a knowledge of the hydrogeological processes, the geoscientist can model these pressures and make appropriate recommendations for resource management.

7. A GEOSCIENCE RESEARCH AGENDA TO BENEFIT SOCIETY

7.1 Perceptions of the relevance of geoscience

The consultations carried out for this report have highlighted the inadequacy of the presently accessible scientific information on which policy, planning and management decisions in the coastal zone are based. While many consultees did not initially consider geology or geoscience as being of particular relevance to ICZM, most needed no persuasion of the importance of knowledge of the materials forming the hosts or habitat substrates (e.g. beach sands, dune sands, muds or rock) supporting the various ecosystems in the coastal environment. The value of groundwater was widely appreciated, though knowledge of the total resource, its aquifer host and its susceptibility to pollution was generally sketchy in those without geological and hydrological training.

7.2 The geoscience-related resource inventory

The enhancement of knowledge on the geological and hydrogeological resource inventory would be a positive step in providing ICZM with basic information on the physical nature of the coastal zone and how those ecosystems relate to those physical attributes. This can be carried out at a range of scales, from detailed field mapping to interpretation of aerial photographs or satellite imagery, depending on the resolution required. The coastal classification implemented for Kenya in the Eastern African Coastal Atlas (UNEP, 1998b) is one approach to characterising the coastal environment, and there may be scope for adapting such a GIS-based scheme to incorporate the geological, geomorphological and hydrogeological inventory. Such inventory information can benefit many aspects of planning and management in the coastal zone, helping to promote development that is appropriate to the particular physical resources and constraints of a shoreline, and to discourage land-use and investment that is inappropriate.

7.3 Groundwater and the coastal aquifers

Probably by far the greatest societal benefit to accrue from knowledge of the geoscience inventory in coastal areas relates to the groundwater resource. The management of this resource has implications for many aspects of ICZM, not least in satisfying the coastal community's need for drinking water. The problems of freshwater supply and quality are currently most acute in coastal urban areas and this is where research is likely to produce the greatest societal benefit over the short term. However, development pressures in the coastal zone are likely to place increasing demands on the more extensive coastal groundwater resource. Taking a long-term view of development in the coastal zone, there is a strong case for a programme of strategic geological and hydrogeological resource assessment of the coastal aquifers throughout the region. Of particular interest is the possibility of research aimed at making better use of groundwater that presently issues directly to the sea in the intertidal zone along many of the limestone shores of the region.

The coastal groundwater resource is presently underdeveloped, there being a

significant surplus of natural recharge over abstraction. The acquisition of appropriate information on the groundwater inventory and its constraining processes, and its dissemination through the ICZM framework are seen as essential steps in improving the management of this resource and delivering value and benefit to the coastal community as a whole.

7.4 Siltation and land-sourced pollution

Research into siltation and pollutant storage and flux is likely to produce a less direct benefit to society but is nevertheless considered to be an important area in which to improve knowledge and understanding. For siltation, the options open to coastal managers may be very limited; for the discharge of sediment from rivers (from catchment sources) in the coastal zone is probably beyond their control, at least in the short term. As with the problem of pollution of coastal waters from land-based sources, however, siltation may have significant impacts on the biodiversity, and thus development potential (e.g. for tourism or recreation) of the coastal marine environment. Benefits accruing to society from research in this area are likely to be in the long term but difficult to quantify.

7.5 Coastal erosion

The problem of coastal erosion, identified in this report, concerns mainly private developments (including tourism infrastructure) sited without adequate environmental assessment on naturally dynamic shorelines. The sustainable development of shores that are susceptible to erosion by the sea requires the implementation of planning regulations which recognise that susceptibility, for example, by the prohibition of infrastructural development to seaward of an agreed set-back line. The geoscience information needed to manage this problem is that required by planners to determine a limit of set-back appropriate to the physical conditions of the site. While a case may be made for research aimed at understanding the causes of coastal erosion, and in particular seeking to distinguish natural (e.g. climate change) from human-induced (e.g. beach-sand mining) causes, it is likely that in most cases the coastal community, as distinct from individual investors or property owners, would gain little benefit.

8. INFORMATION DISSEMINATION

8.1 Informing national policy

There are a number of complementary ways in which knowledge gained from geoscience research in, or relating to, the coastal zone can deliver societal benefit within the framework of ICZM. At the national level, geoscience information can assist in problem identification, recognised by the World Bank as a key issue in ICZM in both Tanzania and Mozambique (Hatzios et al., 1994). Also at the national level, there is a need to inform policy-makers on the relevance and implications of such information. In the case of Tanzania and Mozambique, both countries have organisations (TCMP and MICOA, respectively) that are currently advising their respective governments on the formulation of policy for the sustainable development

of the coastal zone. Clear statements on the importance of geological resource and process information in the context of ICZM need to be conveyed to the policy-makers, together with the best possible advice on the implications of this information for coastal populations in short to long time perspectives. Dissemination or sharing of information relating to policy is also relevant at the regional, intergovernmental level, through the networks of organisations such as IOC and UNEP; an example is the overview of land-based sources of pollution affecting the coastal environment of the eastern African region (UNEP, 1998a).

8.2 Informing management

Raising awareness amongst ICZM practitioners of the relevance of geoscience information is another key objective in the delivery of societal benefit. This goal applies both to those involved in public sector management and to those engaged in community-based management. Organisations such as SEACAM (section 3.3), with a strong emphasis on capacity building, could form effective conduits in this process, enhancing knowledge and understanding, particularly for local NGOs and stakeholders. The provision of geoscience information for management needs to be tailored specifically to the users, and presented in a format that is accessible to those users. The understanding of its relevance to particular management issues is of paramount importance if its implications are to be translated into good practice, and, in turn, into benefit for the coastal community. The educational role of NGOs is likely to be valuable in this respect.

Awareness of resource values by those involved in coastal management may provide the necessary incentive for the adoption of sustainable practices, not only non-living resource values but also an understanding of resource interdependency in the community's use of goods and services supported by those non-living resources. Information leading to an appreciation of the value to the community of managing the pressures (natural and human-induced) affecting those resources is also important, as, for example, the pressures impacting on the coastal groundwater resource in urban areas. The delivery to coastal management, both at the public institutional and community-based levels, of relevant and accessible information on the geologically related resources, their values and the pressures acting upon them should be a key input to the ICZM approach.

9. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

- The accessible scientific information on which policy, planning and management decisions in the coastal zone are based is generally inadequate for sound decision-making.
- Projects dealing with non-living resources have been concerned largely with coastal erosion. Surprisingly little effort is being, or has been, devoted to siltation in coastal waters, and water supply and water quality in the coastal zone.
- The supply and quality of freshwater for use in the coastal zone are the most

important issues facing coastal communities. There is a particularly urgent need for groundwater management in urban aquifers. While many consultees had not considered geoscience as being of particular relevance to ICZM, the value of groundwater was widely appreciated.

- Little systematic work has been carried out on siltation, nor is there reliable data on the long-term variability of sediments carried by rivers to the sea.
- Coastal erosion was cited by a number of consultees as being an important management issue, though its impacts on coastal communities are limited.
- Geoscience information can contribute to ICZM through knowledge of the resource inventory and the pressures affecting those resources. The resources implicit in the geology of the coastal zone are fundamental both for their potentially marketable materials and for the (non-marketable) host function that they provide for coastal ecosystems.
- A prime role for the geoscientist in ICZM is providing knowledge of the geological and hydrogeological resources as well as delivering an understanding of the level of dependency of the various ecosystems on those resources.

9.2 Recommendations

- There is a need to raise the level and breadth of scientific awareness in coastal management, the need to know about inventories and about processes – both crucial components of environmental assessment for sustainable development in the coastal zone.
- The greatest societal benefits from geoscience will accrue from its application where the demand on resources is greatest – in the case of the coastal zone, groundwater in and around urban areas.
- At the national level, geoscience information can assist in problem identification. Clear statements of resource and process information and its relevance in the context of ICZM need to be conveyed to the policy-makers, together with the best possible advice on the implications for coastal communities.
- The delivery to coastal management, both at the public institutional and community levels, of relevant and accessible information on the geologically related resources of coastal areas, their values and the pressures acting upon them should be a key input to ICZM.
- Awareness of resource values by those involved in coastal management may provide an incentive for the adoption of sustainable practices; appreciation of the value to the community of managing the pressures (natural and human-induced) affecting those resources is also important.
- There is a strong case for a programme of strategic geological and hydrogeological resource assessment of the coastal aquifers throughout the region. Of particular interest is the possibility of research aimed at making better use of groundwater that presently issues directly to the sea.
- Research into coastal siltation and pollutant storage and flux is considered to be an important research area, though may be unlikely to produce a measurable benefit to society in the short term.

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APPENDIX A

LIST OF CONSULTEES

United Nations Environment Programme (UNEP), Nairobi

Mr Omar Vidal, Acting Coordinator, Global Programme of Action for the
Protection of the Marine Environment from Land-based Activities,
Water Branch

Mr Paul Akiwumi, GEF Biodiversity

Dr John Pernetta, GEF International Waters

Food and Agriculture Organisation of the United Nations (FAO), Nairobi

Mr Dixon Waruinge, Coordinator, EAF/5 Project

Mr Mwangi Theuri

University of Dar es Salaam (UDSM)

Dr Mutakyahwa, Lecturer in Geology

Dr Charles Kaaya, Lecturer in Geology

Tanzanian Coastal Management Partnership (TCMP), Dar es Salaam

Mr Jeremiah Daffa, Support Unit Leader

Dr Maria Haws (USAID Consultant, University of Rhode Island)

International Union for the Conservation of Nature (IUCN), Tanga

Dr Solomon Makoloweka, Project Leader, Tanga Coastal Zone Conservation
and Development Programme

Dr Trudy van Ingen, Chief Technical Advisor

Dr Chris Horrill, Technical Advisor

Mr Sam Peet, Technical Advisor

Secretariat for Eastern African Coastal Area Management (SEACAM), Maputo

Dr David Moffat, Senior Advisor

Dr Sten Engdahl, Associate Expert

4H International Rural Development Organisation, Tanga

Dr Marje Jorgensen, Resident Advisor

A group of coastal management trainees from various NGOs

Institute of Marine Sciences (UDSM), Zanzibar

Dr Nyandwi, Coastal Process Scientist

Dr A Muzuka, Marine Scientist

Kenya Marine and Fisheries Research Institute (KMFRI), Mombasa

Dr K K Kairu, Coastal Sedimentologist

Mr Johnson Kitheka, Hydrologist and Oceanographer

Dr Natalie Beenearts, Ecologist (Kenya-Belgium Project)

APPENDIX B

LIST (BY TOPICS) OF RECENT AND CURRENT SCIENTIFIC RESEARCH AND OTHER DONOR-SUPPORTED INITIATIVES IN COASTAL MANAGEMENT (non-exhaustive; funding source, where known, shown in parentheses)

Coastal classification

Eastern Africa Atlas of Coastal Resources (UNEP)

Information networking

RECOSCIX Regional Scientific Information Exchange based at KMFRI (Belgium)

Coastal management

World Bank – Africa: A Framework for Integrated Coastal Zone Management

World Bank, Sida – Integrated Coastal Zone Management in Tanzania

World Bank, Sida – Integrated Coastal Zone Management in Mozambique

SEACAM Secretariat for Eastern African Coastal Area Management

(Sida/SAREC, IOC, World Bank)

MICOA Mozambique Ministry for Co-ordination of Environmental Affairs

(DANIDA)

TCMP Tanzania Coastal Management Partnership (USAID)

IUCN Nacala peninsula, Mozambique (FINNIDA)

IUCN Tanga Coastal Zone Conservation and Development Programme,

Tanzania (IUCN, Irish Aid)

Tanzania Mangrove Management Programme (NORAD)

Tanzania Rural Integrated Project Support (FINNIDA)

Mafia Island Marine Park (NORAD, WWF)

Rufiji Environmental Management Programme (Netherlands)

Kunduchi Integrated Coastal Area Management (Sida)

Groundwater

Government of Kenya – BGS Tiwi Aquifer Study 1986 (ODA)

Dar es Salaam – Emergency Groundwater Study 1996 (?Japan, ?ODA)

Regional – Impacts of Groundwater Discharge on Coastal Ecology (EU)

Kenya – KMFRI Mida Creek Groundwater Study (?)

Land-based pollution

BGS LOCS – Land-Ocean Contamination Study (ODA)

Overview of Land-based Sources and Activities Affecting the Marine, Coastal and Associated Freshwater Environment of the Eastern African Region (UNEP, FAO, Sida)

Coastal erosion

Planning Workshop on an Integrated Approach to Coastal Erosion, Sea-Level Changes and their Impacts (IOC, UNEP, WMO, SAREC)

Guidelines for Assessment, Monitoring and Management of Physical Shoreline Change (in preparation, IOC)

Government of Zanzibar – Study of Coastal Erosion (Netherlands)
Government of Zanzibar – Study of Shoreline Change (Netherlands)