REGIONAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

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The Maldives and the impact of expected climatic changes

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Preface

The environmental problems associated with the potential impact of expected climate changes may prove to be among the major environmental problems facing the marine environment and adjacent coastal areas in the near future. Therefore, the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC) of UNEP launched, co-ordinated and financially supported a number of activities designed to assess the potential impact of climate changes and to assist Governments in the identification and implementation of suitable policy options and response measures which may mitigate the negative consequences of the impact.

In 1987, Task Teams on Implications of Climatic Changes were established for six regions covered by the UNEP Regional Seas Programme (Mediterranean, Wider Caribbean, South Pacific, East Asian Seas, South Asian Seas and South-East Pacific regions) with the initial objective to prepare regional overviews and case studies on the possible impact of expected climate changes on the coastal and marine ecological systems, as well as on the socio-economic structures and activities of their respective regions. Two additional Task Teams (for the West and Central African region and for the Eastern African region) were established in 1989, and the establishment of Task Teams for the Black Sea and the Kuwait Action Plan region is under consideration. The original terms of reference for all Task Teams and their composition are shown in appendix 1 and 2 of this annex.

The regional overviews and case studies were planned to be presented to the intergovernmental meetings convened in the framework of the relevant Regional Seas Action Plans in order to draw the countries' attention to the problems associated with expected climate change and to prompt their involvement in the development of policy options and response measures suitable for their region. The site-specific case studies were planned to be presented to national seminars.

The preliminary results of the regional overviews of the Task Teams were already considered by meetings convened under the Mediterranean, Caribbean, South Pacific, South-East Pacific and East Asian Seas Action Plans. One site-specific case study (the Nile Delta) was presented at a national seminar (December 1988). Two additional seminars are planned for mid-1989 (Delta of Po and Thermaikos Gulf).

A special intergovernmental meeting will be convened in the Marshall islands (Majuro, 16-20 July 1989) for the island States and territories of the South Pacific to consider their policy options, suitable response measures and additional site-specific case studies to be developed.

Once the initial objective of the Task Teams (impact studies) is achieved, they will concentrate on providing assistance to national authorities in defining and implementing specific policy options and suitable response measures.

The development of climate scenarios for the Mediterranean region has been initiated. They are planned to be completed in 1990 and to be used in connection with the revision of the Mediterranean regional study.

On a global scale a review on the interaction of the oceans and greenhouse gases and atmospheric aerosols was completed and published, a bibliography on effects of climate change and related topics was prepared by the Mediterranean Task Team, and the launching of a globally co-ordinated programme for monitoring of climate related changes relevant to the marine and coastal environment is being negotiated with IOC and WMO.

The second meeting of national focal points on development of an action plan for the protection and management of the South Asian Seas, convened by the Executive Director of UNEP in Bangkok, 7-11 December 1987, considered the progress made in the work of the Task Team established to examine the implications of climatic changes in the South Asian Seas region and recommended "that Maldives should be considered for a specific in-depth case study analyzing the full ecological and socio-economic implications of expected climate changes as well as the management and policy options available to mitigate or avoid the negative effects of these implications."

Subsequently, a request from the Government of the Maldives was received by UNEP for the preparation of such a study. In response to that request, in consultation with the Government of the Maldives and with the assistance of UNDP, a mission was sent to the Maldives (4-10 December 1988) to prepare a report which may become the basis for the in-depth study.

The report of the mission was presented by UNEP to the Government of the Maldives in March 1989.

The Government of the Maldives endorsed in general the findings and recommendations of the report, and agreed that the report could be published, with the understanding that the implementation of the project proposed by the report will be further discussed between the interested parties and modified as deemed appropriate.

The present document is the reproduction of the report submitted to the Government of the Maldives in March 1989, with minor editorial modifications.

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1. BACKGROUND

1.1. The virtual certainty that predicted climatic changes, including the concomitant sea-level rise, will profoundly affect low-lying islands was considered at the second meeting of National Focal Points on the development of an action plan for the South Asian Seas region, held in Bangkok, 7-11 December 1987. Therefore the meeting recommended that "Maldives should be considered for a specific in-depth case study analyzing the full ecological and socio-economic implications of expected climatic changes as well as the management and policy options available to mitigate or avoid the negative effects of these implications" (UNEP(OCA)/SAS WG.1/7, para 46).

1.2. This recommendation was subsequently endorsed by the first planning meeting of the Regional Task Team on the implications of climatic changes in the South Asian Seas region (UNEP(OCA)/WG.2/23 para 32) held in Islamabad, 28-30 June 1988.

1.3. On 19 June 1988 the Ministry of Foreign Affairs of the Republic of the Maldives informed UNEP that "the Government of Maldives fully support this recommendation and will extend its support and co-operation to the team which will be charged with the preparation of such a study".

1.4. In order to respond to the recommendation of the Bangkok meeting and to the request received from the Republic of Maldives, proposals for carrying out the study were solicited by UNEP from competent organizations. Two specific proposals were received (from Delft Hydraulics and MARC) and were submitted on 9 May and 15 August 1988 respectively to the authorities of Maldives for comments. In the meantime UNDRO's report on "Special assistance to Maldives for disaster relief and strengthening of its coastal defences" (A/43/703) and the Commonwealth Secretariat's possible involvement in a study of climatic effects on the Maldives were brought to the attention of UNEP.

1.5. In view of the two parallel proposals on which no detailed substantive comments were received from the Maldives, as well as of UNDRO's study and the study which may be carried out by the Commonwealth Secretariat, UNEP felt that a more precise insight was needed of the real problems and requirements of the Maldives before a full scale study is launched. Therefore, on 21 October 1988, a suggestion was made by UNEP to the Ministry of Home Affairs and Social Services of the Maldives for "sending a two man preparatory mission to the Maldives to determine, in close co-operation with the relevant national authorities, the scope of a study highlighting the problems which may be faced by the Maldives due to expected climatic changes and identify response options suitable and applicable to the Maldives".

1.6. The reply to the suggestion was received at UNEP through UNDP on 25 October 1988, indicating that "His Excellency Mr. Maumoon Abdul Gayoom, President of the Maldives, has asked (UNDP) to convey the Government's agreement to proposal to field the two person mission to determine scope of the study to which the Government accords the highest priority".

1.7. The authorities of the Maldives and UNEP agreed in ensuing correspondence to the terms of reference of the mission (Annex 1 to this report) and the consultants participating in the mission (Prof. John C. Pernetta and Prof. Giuliano Sestini).

1.8. The mission to the Maldives took place between 4 and 10 December 1988. Details of the mission's itinerary and discussions are attached in Annex 2. In all a total of 16 Government Officials from 11 Government Departments were consulted; two meetings of the National Environment Commission were addressed and a public lecture (televised) on climatic change and sea-level rise was delivered.

1.9. In accordance with the terms of reference a summary of the major findings of the mission, together with the recommendations for proposed follow-up activities (Annex 3 to this report), were presented to a meeting of the National Environment Commission for their discussion and approval.

1.10. This report has been prepared as envisaged by the terms of reference of the mission, duly taking into account the comments and suggestions of the officials of the Maldives consulted during the mission.

1.11. The mission wishes to express its appreciation for the co-operation, assistance and hospitality extended to it by all officials of the Maldives met during the mission, as well as by the staff of the UNDP Office in Malé.

2. FACTORS WHICH MAY BE RELEVANT TO OR AFFECTED BY THE POTENTIAL IMPACT OF EXPECTED CLIMATIC CHANGES

2.1. The current status of the marine environment and environmental problems of the Maldives are reviewed in several publications (UNEP/RSRS 13; UNEP/RSRS 82; UNEP/RSRS 76) and a detailed current account is provided in Annex 4 to this report.

2.2. The current problems stem in large part from the high population density (650/Km^2) which is aggregated onto relatively few islands within each atoll. The problems of Malé (the capital) have reached a critical level in terms of environmental management, in particular, management of freshwater resources; coastal infrastructure development; solid waste disposal; rainwater runoff; sewage disposal; and population pressure.

2.3. In all areas and atolls environmental problems are locally severe and the consequences of environmentally unsound developments have been recently highlighted by the impacts of storm generated long distance swells which have caused widespread flooding of reclaimed areas and weakening and/or destruction of coastal structures.

2.4. Live coral mining for construction and road surfacing is considerably reducing the wave energy absorption capacity of the reefs and altering local current and sediment patterns. It may adversely affect the capability of the reef system as a whole to respond to sea-level rise.

2.5. Land reclamation, particularly on the oceanic sides of the islands, increases vulnerability and is frequently associated with harbour dredging and construction, activities which are presently undertaken without data on local currents and sediment movements.

2.6. Construction of coastal infrastructure, including sea walls, breakwaters, jetties, piers, groynes and harbours, without prior investigation of local current patterns and patterns of sediment erosion and deposition, not only increases their vulnerability but also increases the total capital investment which is at risk.

2.7. Aquifer depletion and saline intrusion are a problem for several islands, however the Malé situation is compounded by compaction of the road surface preventing rain from permeating and recharging the aquifer. In the case of Malé the aquifer will be depleted long before sea-level affects its volume unless remedial action is successfully implemented.

2.8. High population growth and urban drift (3.2% per annum for the country; 7.0% per annum for Malé) increase vulnerability by straining already limited resources and result in aggregation of human and capital resources into a few locations, hence increasing the risk of catastrophic impacts through episodic events.

2.9. The current environmental problems are exacerbated by: a lack of mechanisms within government for taking environmental problems into consideration in the planning process; a lack of guidelines and procedures for the evaluation of environmental issues; a lack of an adequate in-country data base covering many physical and biological parameters; and a shortage of trained manpower at all levels.

2.10. Economic impacts will be most intensely felt if the tourist industry is adversely affected. The present "resort-islands" represent a considerable investment in infrastructure on the land and coastline of very small islands which is at risk from increased sea-level and episodic events, such as storm generated wave surges.

2.11. The current, environmentally unsound development practices will increase the susceptibility of the country to changes predicted to occur as a consequence of global climatic changes.

3. VULNERABLE COMPONENTS OF NATURAL ENVIRONMENTS AND OF SOCIO-ECONOMIC STRUCTURES AND ACTIVITIES

3.1. Assuming a mean global sea-level rise of 20 cm by the year 2025, those islands in the archipelago which have been structurally modified can expect increased rates of erosion and coastal alteration. The impacts of "high waves" will be greater with greater mean sea-level and continued land reclamation reducing the wave energy absorption capacity of the reef system.

3.2. Changes to aquifer volume may be expected under higher sea levels with increased saline intrusion exacerbating the already critical situation in some islands with high density human populations.

3.3. Increased temperatures may lead to increased demand for air conditioning and hence energy requirements, thus indirectly affecting the economy of the country.

3.4. Coral growth may be adversely affected by increased temperature, particularly in the more enclosed lagoons and atolls. Recent evidence of coral bleaching and death under increased lagoon temperatures ($2^{o}C$ above normal) underlines the importance of this potential impact.

3.5. Social impacts arising from inter-island migration resulting from changes to island stability and/or habitability are likely to be extensive given the nature of Maldivian society which is characterized by generally low mobility and strong attachment to individual atoll/islands.

3.6. The present "resort-islands" represent a considerable capital investment which is highly vulnerable to increased sea-level and episodic events such as storm generated wave surges.

3.7. Changes in reef growth and productivity combined with changes in local current patterns may adversely affect tuna production and the distribution of stocks with consequent implications for the siting of fish processing facilities.

3.8. The aggregated distribution of human settlements (only 202 of the 1,300 islands are inhabited) increases their vulnerability since high density settlements inevitably result in extensive coastal modification, hence the overall vulnerability of the entire Republic is increased.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. It is the view of the mission that the Maldives represent a critical case where assistance in planning sustainable development and developing an in-country capability for coping with climate change, sea-level rise and environmental management is urgently required.

4.2. Any programme of activities designed to address the planning/policy issues related to climate change and sea-level rise must seek to strengthen the existing national mechanisms and structures concerned with environmental planning and assessment in the country.

4.3. The combination of present environmental problems in the Maldives together with the numerous reports of visiting experts which remain largely unimplemented might suggest, on superficial examination, that the Republic either lacks the capacity or the will to implement change. It is the opinion of the authors of this report, however, that neither of these reasons is correct. The authors were struck by the clearly articulated and frequently expressed concern of many Maldivians about current environmental problems. It seems clear that the problems of planning sustainable development in the Maldives stem mainly from the highly sectoralised approach to planning which appears to operate at present.

4.4. Individual advisors/consultants produce reports and recommendations on industrial development, on manpower planning, on agriculture, fisheries, water management, transport, conservation and disasters without consideration of an holistic approach to planning and management. A country as physically limited as the Maldives can only be treated as a single entity, since changes and developments in one area have automatic links and impacts with all other areas of the economy and environment. Sustainable development in the Maldives can only be achieved by a careful and simultaneous consideration of all aspects of these islands' fragile environment.

4.5. Given the clearly expressed desire of the Government of the Maldives to initiate the process of sustainable development, including an adequate consideration of environmental issues in development planning, it is imperative that UNEP respond promptly if the current enthusiasm and commitment is to be successfully harnessed.

4.6. The best way to achieve a lasting input into the planning process of the Maldives, which would take into account the potential effects of expected climatic changes, is not by preparing another study by foreign experts who, though well meaning and highly qualified, most frequently fail to perceive the socio-economic context and the national aspirations of the country seeking their assistance.

4.7. Unless the Government structures, national administrators, planners, policy-makers and experts directly participate in the preparation of such a study, it will remain one of the already too many misunderstood studies littering the developing countries and considerably contributing to the deforestation of the globe.

4.8. Therefore, as one of the <u>basic principles</u>, the authors of this report are proposing that the assistance which may be provided by UNEP to the Maldives should primarily be in the form of national manpower development in the subject areas related to:

(a) the understanding of problems which the Maldives may face due to expected climatic changes; and to

(b) the development of national capabilities in identifying and implementing strategies suitable for sustainable socio-economic development under the conditions which will be created by expected climatic changes.

4.9. The objectives of UNEP's assistance could be defined as follows:

Long-term objective:

- to assist the Government and administration of the Republic of the Maldives in identifying and implementing strategies for coping with the impacts of global climatic change and sea-level rise.

Medium term objectives:

- to examine in detail the impacts of global climatic change and sea-level rise on the physical environment, coastal ecosystems, agriculture and fisheries production of the Maldives;

- to examine in detail the consequent impacts of changes to the resource and physical base of the Republic on the social and economic structures (in particular the tourist industry) within the country;

- to raise the awareness of the Government and administration of potential problems resulting from climatic change and sea-level rise and assist in the development of alternative policy/planning options;

- to ensure that the potential consequences of global climatic change and sea-level rise are taken into consideration in planning future developments within the country; and

- to strengthen the capability of the Government and administration of the Republic in data and information management (including analysis and interpretation), environmental impact assessment and comprehensive development planning.

Short-term objective:

- to follow-up the mission's findings and recommendations through further direct discussions with the Government of the Republic in order to determine the details of a project document which would become the formal framework for UNEP assistance to the Maldives.

4.10. The achievement indicators for the proposed objectives are:

for the long-term objective:

- implementation of a comprehensive development plan for the Republic.

for the medium-term objectives:

- improved awareness amongst development planners of the possible consequences of global climatic change and sea-level rise for the ecosystems and economy of the Maldives;

- inclusion of consideration of possible environmental impacts and the consequences of global climatic change and sea-level rise in planning future developments;

- increased public awareness of the potential problems resulting from global climatic change and sea-level rise.

- effective co-operation between the various political and administrative structures of

the Republic on the development of a comprehensive, non-sectoral development plan, taking into account the potential impact of expected climatic changes.

training of nationals of the Republic in subject areas relevant to the assessment of the expected impacts of climatic changes and to the formulation of policy options to cope with these impacts.

4.11. The outputs which may result from UNEP's assistance include:

(a) Several sectoral technical reports relative to assessment of specific areas of potential impacts of climatic change and identifying policy options to cope with these impacts.

(b) A consolidated cross-sectoral report on the same subject.

(c) A popular booklet, written in Divehi and English, providing general information on the causes and effects of global climatic changes and sea-level rise, with specific reference to their expected implications for the Maldives Islands.

(d) Nationals of the Republic trained in environmental impact assessment and comprehensive development planning, with specific reference to the impact of expected climatic changes.

4.12. Crucial to the success of the proposed UNEP assistance to the Maldives will be the establishment of a proper institutional framework for the delivery of that assistance and for its absorption by the institutional structures of the Republic.

4.13. The following is proposed as a suitable institutional framework for UNEP's assistance to the Republic:

(a) A project document signed between the Government of the Maldives and UNEP, specifying the substantive details and the modalities of their co-operation.

(b) A Project Team established in the Maldives and consisting of

- Project Co-ordinator (a Maldivian, selected and appointed by the relevant authority of the Republic as a full time member of the Team);

- Scientific Advisor (selected in consultation between the relevant authorities of the Republic and UNEP, formally recruited by UNEP);

- Technical Experts - international (selected in consultation between the Project Co-ordinator, the Scientific Advisor and UNEP, formally recruited by UNEP);

- Technical Experts - Maldivian (selected in consultation between the Project Co-ordinator and the Scientific Advisor, seconded to the Project Team by the relevant authorities of the Republic); and

- Supporting staff and trainees (locally recruited or seconded to the Project Team by the relevant authorities of the Republic).

(c) The Ministry of Planning and Environment of the Maldives is suggested as the most suitable framework in which the Project Team should be physically established and operated. The Ministry is also suggested as the body which should provide the Project Team with the necessary administrative and technical support (office space and equipment, communication and transport facilities, secretarial assistance, etc.).

(d) The National Environment Commission of the Maldives is suggested as the appropriate body supervising and guiding the substantive work carried out by the Project Team. The Project Co-ordinator should report directly to the Commission which, in turn, should ensure the input from and co-operation of all relevant sectors of the Maldivian administration with the Project Team.

(e) Substantive supervision and guidance to the Project Team provided through the Oceans and Coastal Areas Programme Activity Centre of UNEP.

4.14. Communications between UNEP and the Republic should be with:

- the National Environment Commission on major policy matters relevant to the project and the work of the Project Team;

- the Project Co-ordinator and the Scientific Advisor on matters relevant to substantive supervision and guidance of the project's implementation;

- the Ministry of Planning and Environment on administrative and financial matters relevant to the project (assuming that the Ministry will be designated by the Government of the Maldives as UNEP's counterpart, i.e. as the "supporting organization" of the project).

4.15. It is assumed that the Project Team will also have a direct communication link with the national structures represented in the National Environment Commission as well as with other Government structures relevant to the work of the Project Team but not represented in the Commission (e.g. Department of Meteorology).

4.16. Furthermore, it is strongly recommended that the Project Team establish effective direct working relationship with the UNEP Task Team on the implications of climatic changes in the South Asian Seas region, with specialized international and intergovernmental organizations having projects and activities relevant to the objectives of the present project (e.g. IOC, UNESCO, UNDRO and IUCN), as well as with projects such as the South Malé Breakwater project.

4.17. The objectives suggested in this report could be achieved, using the envisaged institutional framework, according to the following <u>workplan and timetable:</u>

(a) Submission of the Mission's report, with UNEP's, comments, to the Government of the Maldives for comments and clearance before 1 March 1989.

(b) Negotiation of a project document between UNEP and the Government of the Maldives: March - June 1989.

(c) Signing of the project document and appointment of the Project Co-ordinator (for terms of reference see Appendix I): June/July 1989.

(d) Appointment of the Scientific Advisor to the project (for terms of reference see Appendix II): July/August 1989.

(e) Identification of national and international Technical Experts of the project (for terms of reference see Appendix III-X): July - October 1989.

(f) Appointment of national and international Technical Experts of the project (while in the Maldives each of the international Technical Experts will work in close co-operation with his Maldivian counterpart and produce with him a joint sectoral report before leaving the Maldives (for schedule of their work see Appendix XI): August 1989 - January 1990.

(g) Collection, collation and analysis of existing data by the Technical Experts, under the guidance and with the assistance of the Project Co-ordinator and Scientific Advisor: August 1989 - January 1990.

(h) Field surveys and analysis of data collected through these surveys by the Technical Experts, under the guidance and with the assistance of the Project Co-ordinator and the Scientific Advisor: August 1989 - January 1990.

(i) Preparation of sectoral reports by the Technical Experts, under the guidance and with the assistance of the Project Co-ordinator and the Scientific Advisor: September 1989 - January 1990.

(j) Preparation of the consolidated report by the Project Co-ordinator and the Scientific Advisor: November 1989 - February 1990.

(k) Monthly joint progress reports of the Project Co-ordinator and the Scientific Advisor to the National Environment Commission of the Maldives and to UNEP: July 1989 - February 1990.

(l) Joint mid-term review of the project's progress by the National Environment Commission and UNEP: November 1989.

(m) Popular booklet on the potential implications of the expected climatic changes printed and widely distributed in the Maldives: February 1990.

(n) Draft terminal report of the Project Co-ordinator, prepared on the basis of sectorial reports and in co-operation with the Scientific Advisor, presented to the National Environment Commission and to UNEP: March 1990.

(o) Joint review of the draft terminal report by the National Environment Commission and UNEP: April 1990.

(p) Terminal report of the Project Co-ordinator, prepared on the basis of the review, presented to UNEP: May 1990.

4.18. No attempt was made by the mission to prepare a budget of the proposed activities. However, assuming that the Maldivian staff attached to the Project Team and the local support (office space and equipment, communication and transport facilities, secretarial support, etc.) will be provided to the project as the in-kind contribution of the Government of the Maldives, and that the cost of the Scientific Advisor, the internationally recruited Technical Experts and some incidental costs will be covered by the Environment Fund of UNEP, or by funds raised by UNEP, the mission's estimate is that UNEP would have to raise about US $250.000 to provide for the cash requirements of the project.

Appendix I

TERMS OF REFERENCE: PROJECT CO-ORDINATOR

Under the substantive guidance of UNEP, and in close liaison with the Ministry of Planning and Environment and with the Scientific Advisor of the project, the Project Co-ordinator will have overall responsibility for the implementation of the project. Specifically, he will be responsible for:

- establishment of a detailed workplan for all project activities and co-ordination of their implementation;

- liaison with the Government structures represented in the National Environmental Commission, other Government structures as well as with relevant international and intergovernmental organizations in order to ensure their substantive input into and co-operation with the project;

- guidance and supervision in the preparation of sectoral reports of the project by the Technical Experts;

- preparation of the monthly progress reports on the project to the National Environmental Commission and to UNEP;

- preparation of the consolidated report of the project;

- supervision, guidance and participation in the work carried out by the Technical Experts;

- identification of the Maldivian Technical Experts and arranging for their appointment as members of the Task Team by appropriate national authorities;

- participation in the identification and selection of the international Technical Experts;

- organization and supervision of the printing of the project's reports, including the popular booklet on implications of the climatic changes for the Maldives;

- liaison with the Ministry of Planning and Environment on all administrative and financial matters relevant to the project; and

- arranging for the administrative support to be provided by the Government of the Maldives to the project.

Appendix II

TERMS OF REFERENCE: SCIENTIFIC ADVISOR

Under the substantial supervision and guidance of UNEP, the Scientific Advisor will assist the Project Co-ordinator in the implementation of the project. Specifically, he will:

- advise the Project Co-ordinator on all matters relevant to the scientific and technical aspects of the project's implementation;

- develop detailed programmes of work for each of the international and Maldivian Technical Experts;

- co-ordinate, guide, supervise and participate in the work of the Technical Experts, including the preparation of sectoral reports;

- participate in the preparation of the monthly progress reports on the project to the National Environmental Commission and to UNEP;

- participate in the preparation of the mid-term and consolidated report on the project;

- participate in the identification and selection of international Technical Experts;

- supervise and foster the transfer of scientific knowledge and expertise from the international Technical Experts to their Maldivian counterparts;

- collect, collate and analyse all scientific and technical reports relevant to the project and ensure their appropriate interpolation into the sectoral, mid-term and terminal report of the project; and

- participate in the mid-term and terminal review meeting of the project.

Appendix III

TERMS OF REFERENCE: PHYSICAL OCEANOGRAPHER

A. INTERNATIONAL EXPERT

Under the guidance of the Project Co-ordinator and the direct supervision of the Scientific Advisor, the expert will visit the Maldives as a member of the Project Team and will perform the following tasks:

- assemble published and unpublished information relevant to the oceanography of the Indian Ocean, with special reference to the Maldives area;

- prepare and undertake a programme of field observation and measurements at selected sites to examine the impacts, if any, of natural and artificial coastal structures on local current patterns;

- prepare and undertake a programme of field work which will provide basic training for the national expert in measurement of tidal movements, sea currents and sediment deposition;

- collaborate with other experts of the Project Team in the preparation of integrated site assessments of the physical environment in coastal and lagoon waters; and

- prepare in collaboration with the national experts a sectoral report on oceanographic conditions relevant to the Maldives, including an assessment of current vulnerability of the country to "high wave", storm surges and flooding a review of the potential impact of climate change and sea level rise on the oceanographic characteristics of Maldivian waters and recommendations for monitoring, assessment, planning and policy activities by the Maldives Republic.

B. NATIONAL EXPERT

Under the general guidance and supervision of the Project Co-ordinator and the Scientific Advisor, the Expert will work as a member of the Project Team and as the national counterpart of the international expert. Specifically, he will:

- assist in collection of relevant national data;

- ensure direct liaison of the Project Team with the relevant national authorities;

- facilitate and participate in the field work carried out by the international expert;

- participate in the preparation of the sectoral mid-term and terminal reports; and

- participate in the mid-term and terminal review of the project's results.

Appendix IV

TERMS OF REFERENCE: MARINE BIOLOGIST/REEF ECOLOGIST

A. INTERNATIONAL EXPERT

Under the guidance of the Project Co-ordinator and the direct supervision of the Scientific Advisor, the expert will visit the Maldives as a member of the Project Team and will perform the following tasks:

- assemble published and unpublished information relevant to the coral reefs, fisheries, and marine fauna and flora of the Maldives;

- prepare and undertake a programme of field observations and measurements at selected sites to characterize the nature of the biological communities in relation to physical parameters and anthropogenic influences;

- in liaison with the Marine Research Section of the Ministry of Fisheries design and undertake a field monitoring programme which will provide basic training for the national expert in biological monitoring and assessment techniques;

- collaborate with other experts of the Project Team in the preparation of integrated site assessments of the environment in coastal and lagoon waters; and

- prepare, in collaboration with the national expert a sectoral report on the marine ecosystems and resources of the Maldives, including a review of the potential impacts of climatic change and sea-level rise on these ecosystems, with special reference to the potential effect of temperature stress on reef growth under changed climatic conditions.

B. NATIONAL EXPERT

Under the general guidance and supervision of the Project Co-ordinator and the Scientific Advisor, the Expert will work as a member of the Project Team and as the national counterpart of the international expert. Specifically, he will:

- assist in collection of relevant national data;

- ensure direct liaison of the Project Team with the relevant national authorities;

- facilitate and participate in the field work carried out by the international expert;

- participate in the preparation of the sectoral mid-term and terminal reports; and

- participate in the mid-term and terminal review of the project's results.

Appendix V

TERMS OF REFERENCE: GEOLOGIST/COASTAL GEOMORPHOLOGIST/SEDIMENTOLOGIST

A. INTERNATIONAL EXPERT

Under the guidance of the Project Co-ordinator and the direct supervision of the Scientific Advisor, the expert will visit the Maldives as a member of the Project Team and will perform the following tasks:

- assemble published and unpublished information relevant to the geology, coastal geomorphology and sedimentology of the Maldives;

- prepare and undertake a programme of field observations and measurements at selected sites to examine the impacts, if any, of natural and artificial coastal structures on patterns of sediment deposition and coastal erosion;

- prepare and undertake a programme of field work which will provide basic training for the national expert in coastal geomorphology, sediment sampling and analysis;

- collaborate with other experts of the Project Team in the preparation of integrated site assessments of the physical environment in coastal and lagoon waters; and

- prepare in collaboration with the national expert a sectoral report on the geology, geomorphology and sedimentology of the Maldives, including the assessment of the vulnerability of the Archipelago to erosion at the present time, the potential impacts of future climatic change and sea-level rise on the coastal geomorphology of the islands and recommendations for monitoring, assessment, planning and policy actions by the national authorities.

B. NATIONAL EXPERT

Under the general guidance and supervision of the Project Co-ordinator and the Scientific Advisor, the Expert will work as a member of the Project Team and as the national counterpart of the international expert. Specifically, he will:

- assist in collection of relevant national data;

- ensure direct liaison of the Project Team with the relevant national authorities;

- facilitate and participate in the field work carried out by the international expert;

- participate in the preparation of the sectoral mid-term and terminal reports; and

- participate in the mid-term and terminal review of the project's results.

Appendix VI

TERMS OF REFERENCE: METEOROLOGIST/CLIMATOLOGIST

A. INTERNATIONAL EXPERT

Under the guidance of the Project Co-ordinator and the direct supervision of the Scientific Advisor, the expert will visit the Maldives as a member of the Project Team and will perform the following tasks:

- assemble published and unpublished information relevant to the meteorology/climatology of the Indian Ocean, with special reference to the Maldives area;

- in liaison with the Department of Meteorology and the national expert, examine existing data collections and programmes and recommend how these might be extended to provide a more comprehensive data base for assessing the climatic changes affecting the Maldives;

- using existing data sources indicate possible scenarios of Maldivian climatic changes under the influence of greenhouse gas forced warming, in particular an assessment of the likely changes to storm/strong wind frequency, precipitation, relative humidity and other aspects of climate, including the impacts of such changes on human comfort levels, if any; and

- prepare, in collaboration with the national expert, a sectoral report on the climate and meteorology of the Indian Ocean with special reference to the Maldives, including a review of potential change, under conditions of greenhouse gas warming, and recommendations for monitoring and assessment of climate related factors which may be needed for planning, and policy decisions on the part of the Maldives Government.

B. NATIONAL EXPERT

Under the general guidance and supervision of the Project Co-ordinator and the Scientific Advisor, the Expert will work as a member of the Project Team and as the national counterpart of the international expert. Specifically, he will:

- assist in collection of relevant national data;

- ensure direct liaison of the Project Team with the relevant national authorities;

- facilitate and participate in the field work carried out by the international expert;

- participate in the preparation of the sectoral mid-term and terminal reports; and

- participate in the mid-term and terminal review of the project's results.

Appendix VII

TERMS OF REFERENCE: HYDROLOGIST

A. INTERNATIONAL EXPERT

Under the guidance of the Project Co-ordinator and the direct supervision of the Scientific Advisor, the expert will visit the Maldives as a member of the Project Team and will perform the following tasks:

- assemble published and unpublished information relevant to the hydrology of the Maldives;

- prepare and undertake a programme of field observations and measurements at selected sites to examine the current status of aquifer resources in terms of their potability, volume, and exploitation;

- prepare and undertake a programme of field work which will provide basic training for the national expert in water resource assessment and management;

- collaborate with other experts of the Project Team in the preparation of integrated assessment of the terrestrial environment;

- prepare, in collaboration with the national expert a sectoral report on the state of knowledge of the aquifer resources of the Maldives, including a review of the potential impacts of climatic change and sea-level rise on these resources and recommendations for monitoring and assessment of factors which may be needed for planning and policy decisions by the Maldives Government; and

- participate in the preparation of the mid-term report of the project.

B. NATIONAL EXPERT

Under the general guidance and supervision of the Project Co-ordinator and the Scientific Advisor, the expert will work as a member of the Project Team and as the national counterpart of the international expert. Specifically, he will:

- assist in collection and analysis of relevant national data;

- ensure direct liaison of the Project Team with the relevant national authorities;

- facilitate and participate in the field work carried out by the international expert;

- participate in the preparation of the sectoral, mid-term and technical reports; and

- participate in the mid-term and terminal review of the project's results.

Appendix VIII

TERMS OF REFERENCE: TERRESTRIAL ECOLOGIST

A. INTERNATIONAL EXPERT

Under the guidance of the Project Co-ordinator and the direct supervision of the Scientific Advisor, the expert will visit the Maldives as a member of the Project Team and will perform the following tasks:

- assemble published and unpublished information relevant to the terrestrial ecology, including agriculture, of the Maldives;

- assess the status and stability of the terrestrial ecosystems, including the agricultural production, using existing data and field surveys, as well as data from aerial photography and satellite imagery;

- prepare and undertake a programme of research and field observation which will provide basic training for the national expert in assessment of terrestrial biological resources and changes in the status of these resources which may occur under the impact of climatic changes;

- collaborate with other experts of the Project Team in preparing an integrated assessment of the state of the terrestrial environment;

- prepare, in collaboration with the national expert, a sectoral report on the state of the terrestrial environments of the Maldives, including a review of the potential impacts of climatic change and sea-level rise on the terrestrial ecosystems, including agriculture, and recommendations for monitoring and assessment of factors which may be needed for planning and policy decisions by the Maldives Government; and

- participate in the preparation of the mid-term report of the project and in the mid-term review of the project's results.

B. NATIONAL EXPERT

Under the general guidance and supervision of the Project Co-ordinator and the Scientific Advisor, the expert will work as a member of the Project Team and as the national counterpart of the international expert. Specifically, he will:

- assist in collection and analysis of relevant national data;

- ensure direct liaison of the Project Team with the relevant national authorities;

- facilitate and participate in the field work carried out by the international expert;

- participate in the preparation of the sectoral, mid-term and technical reports; and

- participate in the mid-term and terminal review of the project's results.

Appendix IX

TERMS OF REFERENCE: ECONOMIST/PLANNER

A. INTERNATIONAL EXPERT

Under the guidance of the Project Co-ordinator and the direct supervision of the Scientific Advisor, the expert will visit the Maldives as a member of the Project Team and will perform the following tasks:

- assemble published and unpublished information relevant to the economic development of the Maldives;

- in liaison with the Ministry of Planning and Environment and in collaboration with the national expert, examine the past, present and planned development plans, both sectoral and national, and provide an overview of the current state of the economy and its possible future development;

- examine, in close co-operation with other experts of the Project Team and with the national expert, the prospects of the present and planned development activities from the standpoint of sustainable development;

- evaluate, in close co-operation with the expert on sociology and with the relevant national experts, the socio-economic impacts of present and planned developments;

- prepare, in collaboration with the national expert, a sectoral report on the state of knowledge and potential impacts of climate change and sea level rise on the economy of the Maldives, including recommendations for future planning and policy decisions by the Maldives Government which may avoid or mitigate the potential impact of expected climatic changes on the future economic development of the Maldives; and

- participate in the mid-term review of the project's results and in the preparation of the project's terminal report.

B. NATIONAL EXPERT

Under the general guidance and supervision of the Project Co-ordinator and the Scientific Advisor, the expert will work as a member of the Project Team and as the national counterpart of the international expert. Specifically, he will:

- assist in collection and analysis of relevant national data;

- ensure direct liaison of the Project Team with the relevant national authorities;

- facilitate and participate in the field work carried out by the international expert;

- participate in the preparation of the sectoral, mid-term and technical reports; and

- participate in the mid-term and terminal review of the project's results.

Appendix X

TERMS OF REFERENCE: SOCIOLOGIST

A. INTERNATIONAL EXPERT

Under the guidance of the Project Co-ordinator and the direct supervision of the Scientific Advisor, the expert will visit the Maldives as a member of the Project Team and will perform the following tasks:

- assemble published and unpublished information relevant to the sociology of the Maldives:

- in liaison with the Ministry of Planning and Environment and in collaboration with the Departments of Home Affairs and Social Services, Health and Education and the national expert, examine the past, and current social trends and their possible future developments;

- examine, in close co-operation with other members of the Project Team, prospects of the present and foreseeable social trends from the standpoint of sustainable development, as well as the socio-economic impacts of the present and planned economic development of the Maldives;

- prepare, in collaboration with the national counterpart expert and with other members of the Project Team, a sectoral report on the social and cultural environment of the Maldives, including the analysis of the potential effects of climatic change and the sea-level rise induced impacts on this environment, and relevant recommendations for future planning and policy decisions by the Government of the Maldives; and

- participate in the mid-term review of the project's results and in the preparation of the project's terminal report.

B. NATIONAL EXPERT

Under the general guidance and supervision of the Project Co-ordinator and the Scientific Advisor, the expert will work as a member of the Project Team and as the national counterpart of the international expert. Specifically, he will:

- assist in collection and analysis of relevant national data;

- ensure direct liaison of the Project Team with the relevant national authorities;

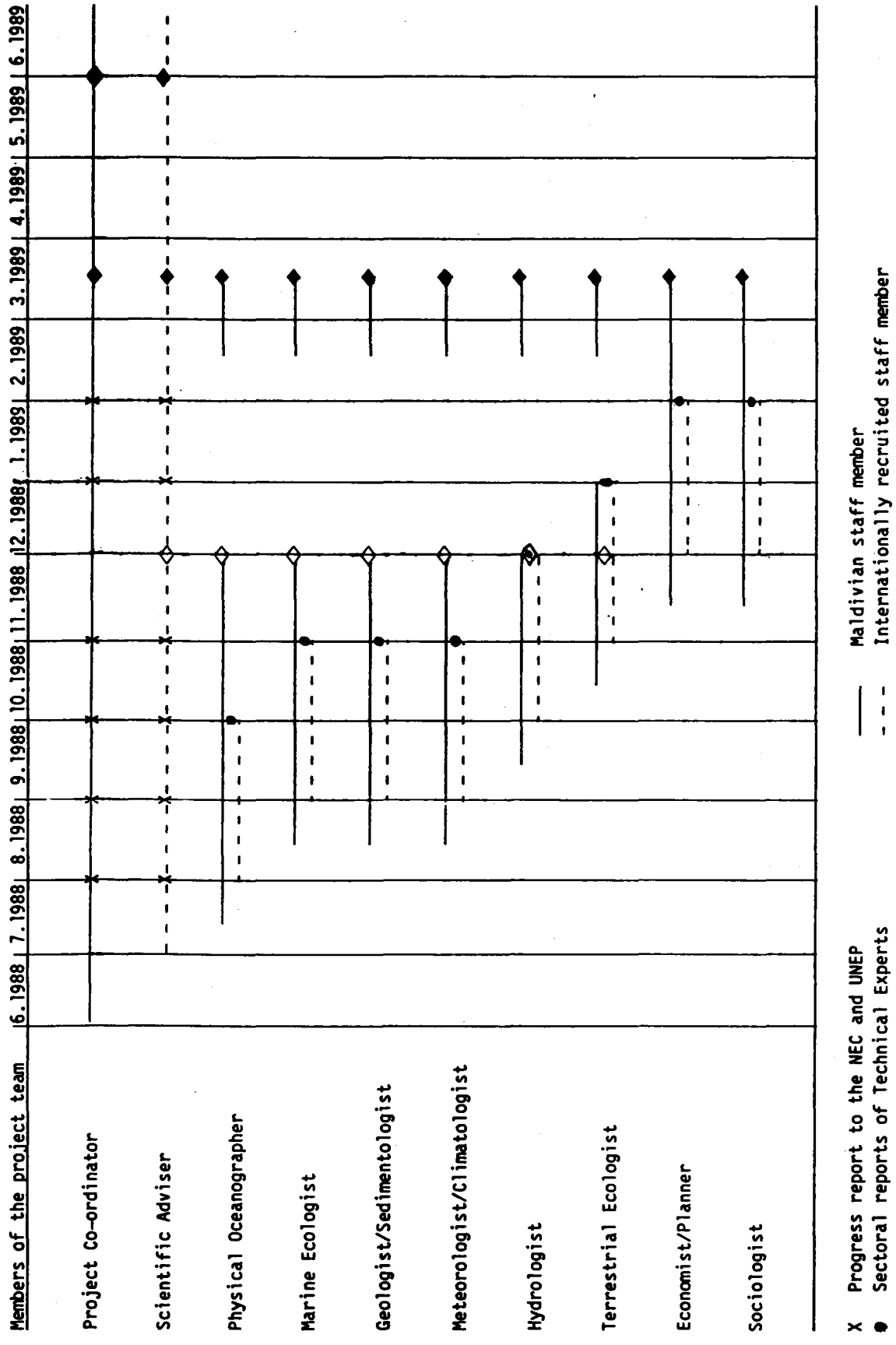
- facilitate and participate in the field work carried out by the international expert;

- participate in the preparation of the sectoral, mid-term and technical reports; and

- participate in the mid-term and terminal review of the project's results.

Appendix XI

WORKPLAN AND TIMETABLE FOR THE PROJECT TEAM



ANNEX I

TERMS OF REFERENCE FOR THE MISSION TO
THE REPUBLIC OF THE MALDIVES

1. Under the general supervision and guidance of the Director of Oceans and Coastal Areas Programme Activity Centre a two-man UNEP mission will visit the Maldives for approximately 7 days. The main purpose of the visit is to prepare, in close co-operation with national counterparts identified by the Government of the Maldives, a proposal for an in-depth study of the potential impact of expected climatic changes (primarily sea level and temperature rise) on the natural environment and the socio-economic structures and activities of the Maldives, including the identification of response options which may be suitable and available to avoid or mitigate the expected negative impact of climatic changes.

2. Specifically, while in the Maldives the mission, consisting of two high level UNEP consultants, will:

(a) examine and evaluate the available information concerning the physical and biological environment (terrestrial and marine) of the 22 atolls comprising the Maldive archipelago;

(b) examine and evaluate the available demographic, social (including archaeological and cultural) and economic data;

(c) present to the national authorities, organizations, institutions and experts the results of relevant UNEP-sponsored studies, specifically those conducted in the Pacific region, outlining the potential applicability of these studies to the case of the Maldives;

(d) discuss with the national authorities, organizations, institutions and experts their perceptions of the consequences of the potential impact of climatic changes and seek their views on the suitable response options; and

(e) identify national authorities, organizations, institutions and experts which may participate in the in-depth study expected to follow the mission, and determine the modalities of co-operation between the legal and administrative structures of the Maldives with the team which will be in charge of the in-depth study.

3. On the basis of the activities referred to in paragraph 2 above, as well as information collected by the consultants prior to their mission to the Maldives, the consultants will prepare a joint report containing:

(a) a general overview of the climatological, oceanological, geological, biological and socio-economic factors which may be relevant to or affected by the potential impact of expected climatic changes;

(b) preliminary identification of the most vulnerable components and sites of the natural environment, as well as of those socio-economic structures and activities which may be most critically affected by expected climatic changes;

(c) detailed proposal for an in-depth evaluation of the potential impact of expected climatic changes on the natural environment and the socio-economic structures and activities of the Maldives, including the identification of policy or management options suitable to avoid

or mitigate the impact of climatic changes; the proposal should identify the workplan, timetable and financial requirements of the in-depth evaluation as well as the possible institutional arrangements for carrying out the evaluation.

4. The mission, before leaving the Maldives, will present to, and discuss with the authorities identified by the Government of the Maldives, the outline of the proposal for the in-depth evaluation, as well as the main findings of the mission. The comments and suggestions of the authorities identified by the Government of the Maldives will be duly taken into account in preparing the final report of the consultants.

5. The final report of the consultants, prepared as specified in paragraph 3 above, will be submitted to UNEP as the consultants' joint report.

6. The final report of the mission will be transmitted by UNEP to the Government of the Maldives with comments of UNEP and will be used as the basis for UNEP's envisaged assistance to the Government of the Maldives in formulating and implementing suitable response options to the expected impact of climatic changes.

ANNEX 2

ITINERARY AND SUMMARY OF DISCUSSIONS HELD DURING THE MISSION
MALDIVES, 4-10 DECEMBER 1988

The mission was undertaken by the two Consultants on behalf of UNEP and stemmed from the urgent request of the Government of the Republic of the Maldives for assistance in planning for climate change and sea level rise. Given the timing of this request the two Consultants had no opportunity to discuss the details and workplan prior to their separate arrival in Malé.

G. Sestini travelled from Italy arriving in Malé on the morning of 4 December and held preliminary meetings with the UNDP Resident Representative, Ms. M. Olson and with the Director of Environmental Affairs of the Ministry of Home Affairs and Social Services, Mr. H. Shihab. J. Pernetta travelled from Papua New Guinea arriving in Malé on the afternoon of 4 December and was briefed by Sestini on these initial contacts.

Monday 5 December:

0800 The mission met with the UNDP Resident Representative and her Deputy, Mr. H. Hiratsuka and was briefed on the structure of Government and the need for Environment Planning in the country. In turn the mission briefed the UNDP representatives on the purposes of the mission.

0915 Ministry of Home Affairs. Initial discussions on the mode of operation of the mission with Mr. H. Shihab.

1000 The meeting was joined by Mr. M. Ali, Assistant Undersecretary of the Ministry of Home Affairs and Social Services, and a general discussion on the environmental problems of the Maldives ensued.

1130 The mission was formally presented to the Honourable Minister for Home Affairs Mr. U. Zahir, during which meeting the mission formally requested and received an assurance that the Government of the Maldives was prepared to extend its full co-operation to UNEP in undertaking any programmes which might eventuate as a result of the mission's visit.

1200 - 1400 Continued discussions with Messrs Shihab and Ali during which it was agreed that two meetings of the National Environment Commission would be called; the first to brief representatives of Government Departments on the work of the mission and the second to discuss and approve the proposed work plan and activities.

1700 - 1800 The mission met with Ms. Olson to brief her on the work plan of the mission.

Tuesday 6 December:

0090 Ministry of Home Affairs. Messrs Shihab and Ali. Detailed discussions of development issues in the Maldives.

1000 Meeting of the "National Environment Commission" (see attached list of participants). The mission provided the meeting with a copy of its brief, following which J.C. Pernetta briefed the meeting on the technical aspects of climatic change and sea-level rise, the work of UNEP and the role of the regional task teams. In particular examples from the UNEP/Association of South Pacific Environmental Institutions (ASPEI)/South Pacific Regional Environment Programme (SPREP) Task Teams case studies were presented. G. Sestini then briefed the meeting on the work of the Mediterranean task team.

1130 Office of Physical Planning and Design. Mr. H. Shafeeg, Deputy Director and Mr. A. Haidhar. The mission was briefed on the work of the Office and the perceived difficulties in taking environmental issues into consideration in the planning process. The mission was informed that generally the Office was not involved in the selection of sites for future developments but merely informed which islands should be developed for different purposes. The team was shown plans for a future "over spill" housing development as part of the Selected Atolls development project. The mission was asked for suggestions and guidelines on how to carry out environmental impact assessments and how environmental considerations should be incorporated into physical plans.

1230 - 1345 Department of Tourism. Mr. A. Zahir, Director General. The Director General briefed the mission on the role of tourism in the economy of the country; plans for future development and indicated some of the constraints under which his Department has to work. The Director outlined the criteria for tourist resort development (current Tourist Development Master Plan) and how the final choice of implementation rested with Government, and involved criteria other than the technical ones followed by the Department. He also expressed the concern of his Department that adverse and sensationalist reports of the impacts of climatic change might adversely affect the tourist industry and the confidence of investors.

Wednesday 7 December:

0830 Department of Public Works and Labour. Mr. A. Kamaludeen, Director. The Director outlined the major developments currently being undertaken by his Department, as well as his Department's capabilities and equipment and indicated that his Department was viewed by many as the "Destroyers of the Environment". It was clear to the mission however that major development projects had been undertaken on the advice of outside experts. The Director is in fact appreciative of the environmental problems which had resulted from coastal infrastructure development and was open to any advice and assistance which would reduce the detrimental environmental impacts of his Department's development activities.

0930 - 1030 Ministry of Home Affairs. Messrs Shihab and Ali. The mission reviewed their major findings to date and agreed with Messrs Shihab and Ali on the objectives for UNEP's proposed future collaboration with the Republic of the Maldives.

1030 Ministry of Agriculture, Mr. A. Azeez, Director of Agricultural Services. The mission was briefed on current projects on Agricultural development, and was informed that the Ministry of Agriculture was to merge with the Ministry of Fisheries in the near future. The team took the opportunity of examining satellite images of the Maldives and a set of RAF air photographs that cover a large proportion of the country recently acquired from the British Government.

1200 Department of Meteorology, Mr. A. Majeed, Director and Deputy Director. The Director expressed concern that his Department was not represented on the National Environment Commission but indicated that his Department would be more than happy to collaborate with any long-term monitoring and/or evaluation programme concerned with climatic change and sea-level rise, he indicated that they are already collaborating with the University of Hawaii in the TOGA programme.

2030 - 2230 Islamic Centre. A public lecture was delivered by the mission presenting in non-technical language a review of the "greenhouse effect" and its possible impacts. The talk drew heavily on the work of UNEP and in particular the findings of the South Pacific and Mediterranean task teams. The meeting was attended by about 120 people including the Ministers for Home Affairs, Agriculture and Health and was televised for later public broadcast.

Thursday 8 December

0830 Marine Research Section, Ministry of Fisheries. Mr. H. Maniku, Senior Fisheries Development Officer. The mission was briefed on the current work of the section which falls into three main areas; fish stock assessment; resource management; coral reef biology and ecology. The latter programme is concerned with monitoring 18 sites on 6 atolls in the categories of; no exploitation; fishing only; coral mining. Mr. Maniku indicated that his section was establishing linkages with overseas institutions (IOC/UNESCO and Newcastle University) to assist in research and monitoring work.

1000 Home Affairs. The mission checked the draft document for submission to the National Environment Commission.

1030 UNDP. Ms. Olson and Mr. Hiratsuka. A short debriefing meeting was held during which the mission indicated the broad outline of the proposed recommendations to UNEP.

1145 Ministry of Foreign Affairs. Mr. A. Hameed, Assistant Undersecretary. The mission outlined their proposed recommendations to UNEP; sought and received assurance that the Ministry of Foreign Affairs saw the matter of sustainable development and sound environmental planning as a high priority of the Government, and was assured that the proposed collaboration with UNEP would receive the support and assistance of the Ministry. Mr. Hameed expressed his concern that the proposed activities should be within the capabilities of the country to support and that UNEP would consider favourably the recommendations and proposals of the mission.

1200 - 1330 National Environmental Commission Meeting, attended by UNDP Deputy Resident Representative Mr. Hiratsuka. The mission presented a draft paper (Annex 3) outlining those areas which they saw as of immediate and future environmental concern to the country; the objectives of a collaborative programme with UNEP support; and the proposed activities. The meeting discussed the document at length, proposed various minor amendments and additions and approved the various proposals. A recommendation was made by Commission members that representatives of both Foreign Ministry and Meteorology Departments should be part of the Commission. At the suggestion of Mr. H. Maniku it was agreed that an initial workshop would be held if the programme was implemented, during which the various government departments would consider how they could support the programme and review their existing relevant data and programmes with a view to linking these with the proposed activities.

1430 - 1800 Visit to Maafushi Island (South Malé Atoll) harbour development and fish handling centre. At the invitation of the Director of Public Works, Mr. Kamaludeen, the mission was taken on a tour of inspection of the dredging operations, land reclamation and fish centre on South Malé Atoll. During the course of the visit the mission was informed that the work had been initiated without a full environmental impact assessment being undertaken, but had been implemented as an urgent attempt to decentralize some activities and reduce the current pressures on Malé. Mr. Mayabushi, the engineer in-charge of the South Malé Breakwater construction, accompanied the Director and the mission availed themselves of the opportunity to discuss the manufacture of the 'tetrapods' and the details of these defensive structures.

Friday 9 December:

The mission worked at the UNDP office from 0930 - 1530 consulting documents in the UNDP library. Access was kindly provided by Mr. Hiratsuka. In the afternoon G. Sestini made a tour of the land reclamation and of existing and in-construction coastal defence structures on the South and East sides of Malé Island. J. Pernetta departed Malé at 0045 on 10 December while G. Sestini had further consultations with Ms. Olson and Mr. Shihab on the morning of 10 December prior to departing at 1200 hours.

LIST OF PARTICIPANTS AT THE MEETING OF NATIONAL ENVIRONMENT COMMISSION OF THE REPUBLIC OF MALDIVES, 6 DECEMBER 1988

1. Mr. Ahmed Zahir, Director General, Department of Tourism.

2. Mr. Abdulla Rasheed, Director of Planning, Ministry of Education.

3. Mr. Abdul Hameed Ahmed Didi, Projects Director, Ministry of Atolls Administration.

4. Mr. Hassan Maniku, Senior Fisheries Development Officer, Marine Research Section, Ministry of Fisheries.

5. Mr. Abdul Azeez Abdul Hakeem, Director of Marine Affairs, Ministry of Transport.

7. Mr. Abdulla Kamaludeen, Director, Department of Public Works and Labour.

8. Mr. Hussain Shihab, Director of Environmental Affairs, Ministry of Home Affairs and Social Services.

9. Ms. Maxine Olson, Resident Representative, UNDP.

10. Mr. Mohamed Ali, Assistant Undersecretary, Ministry of Home Affairs and Social Services.

11. Mr. Mohamed Shafeeg, Deputy Director, Office for Physical Planning and Design.

12 Mr. Abdul Hameed Zakariyya, Assistant Undersecretary, Ministry of Foreign Affairs.

13. Mr. Ali Haidhar, Office for Physical Planning and Design.

ANNEX 3

SUMMARY PRESENTED TO A MEETING OF THE NATIONAL ENVIRONMENT COMMISSION OF THE REPUBLIC OF THE MALDIVES MALE, 8 DECEMBER 1988

CURRENT ENVIRONMENTAL PROBLEMS IN THE MALDIVES

The current environmental problems of the Maldives are in large part the result of the high density population (650/Km^2) which is aggregated onto relatively few islands within each atoll.

The problems of Malé have reached a critical level in several areas increasing the island's susceptibility to episodic events such as storm generated high waves. In other areas/atolls the problems are also locally severe increasing the susceptibility of such areas to future climatic change and sea-level rise. This increased susceptibility is due to:

(a) Coral mining for construction and road surfacing;

(b) Land reclamation particularly on the seaward edges of islands;

(c) Construction of coastal infrastructure including sea walls, breakwaters, jetties, piers, groynes and harbours; and

(d) Aquifer depletion and saline intrusion.

All of the current environmental problems are exacerbated by:

(a) High population growth;

(b) A lack of mechanisms within Government for taking environmental problems into consideration in the planning process;

(c) A lack of guidelines and procedures for the evaluation of environmental issues;

(d) A lack of an adequate in-country data base covering many physical and biological parameters; and

(e) A shortage of trained manpower at all levels.

IMPACTS OF SEA-LEVEL RISE AND CLIMATIC CHANGE

The current, environmentally unsound, practices will increase the susceptibility of the Maldives to changes predicted to occur as a consequence of global warming and the "Greenhouse Effect".

Assuming a sea-level rise of 12-18 cm by the year 2030 one might anticipate profound effects on those islands of the Maldives which have been structurally modified, since the normal processes of sand genesis, deposition, removal and flux between sinks have been altered by changes to the micro-climate and current regimes.

The impacts of "high waves" will be greater with greater mean sea-level and such increases must be taken into consideration in planning future coastal infrastructure.

Changes to aquifer volumes may be expected under higher sea levels, however such changes will be less important on islands where the aquifer is not currently over-exploited. Saline intrusion will be exacerbated in those aquifers which are heavily used for human consumption.

Increased temperatures (1.5°C by 2030) will affect the human environment; agricultural production and marine ecosystems. Given the countries proximity to the equator the Maldives can expect a lower than average temperature rise which may have little impact on the human environment but may be expected to result in some increased demand for air conditioning.

Agricultural production and terrestrial ecosystems are likely to be less affected than marine organisms such as corals, many of which are currently growing at temperatures close to their upper thermal tolerance limits.

Perhaps the area of greatest current concern to the Maldives is the possibility of an increased frequency of storm-generated swells and high waves, particularly given the experiences of the country during 1987. Analysis of meteorological patterns in the Indian Ocean is urgently required to predict the possibility of an increased frequency of such events.

Social impacts arising from changes to island stability and/or habitability are likely to be extensive given the nature of Maldivian society which is characterized by generally low mobility and strong attachment to individual atolls and islands.

Economic impacts will be most intensely felt if the tourist industry is adversely affected. The present structure of the tourist industry is based on "resort islands" which are essentially self-contained and as a consequence pack considerable infrastructure on the land and coastline of very small islands. The present tourist industry is concentrated in the Central Maldives hence increasing the risk to this sector of the economy in the event of detrimental effects being felt differently within the country.

AN INTEGRATED STUDY OF THE IMPACTS OF CLIMATE CHANGE AND SEA-LEVEL RISE ON THE REPUBLIC OF THE MALDIVES

Long-term objectives

1. To assist the Government and administration of the Republic of the Maldives in identifying strategies for coping with the impacts of global climate change and sea-level rise.

Medium-term objectives

1. To examine in detail the impacts of global climatic change and sea-level rise on the physical environment, coastal ecosystems, agriculture and fisheries production of the Maldives;

2. To examine in detail the consequent impacts of changes to the resource and physical base of the Republic on the social and economic structures (in particular the tourist industry) within the country;

3. To raise the awareness of the Government and administration of potential problems resulting from climatic change and sea-level rise and assist in the development of alternative policy/planning options; and

4. To ensure that the potential consequences of global climate change and sea-level rise are taken into consideration in planning future developments within the country.

Short-term objectives

1. To initiate discussion at a governmental level of the possible consequences of global climate change and sea-level rise in the Maldives islands; and

2. To identify the requirements of the Government and administration in the country in terms of environmental impact assessment, future work programmes, information flow and planning assistance.

Achievement indicators for long and short-term objectives

1. Improved awareness amongst development planners of the possible consequences of global climate change and sea-level rise for the ecosystems and economy of the Maldives;

2. Inclusion of a consideration of the possible environmental impacts and the consequences of global climate change and sea-level rise in planning future developments;

3. Use of technical reports by scientists, managers and policy makers; and

4. Increased public awareness of the potential problems resulting from global climate change and sea-level rise.

Programme activities

(a) Review of existing information

Selected reviews will be undertaken based on data both within and outside the country to evaluate the present status and potential impacts of climate change and sea-level rise on the following areas:

1. Geology, geomorphology, tectonic stability;
2. Marine biology and ecology;
3. Settlement patterns, demography and mobility;
4. Meteorology and climate of the Indian Ocean and the Republic;
5. Economic activities and future development plans; and
6. Terrestrial environment and aquifer resources.

This activity will result in the provision of a data-base of previously published materials for the Ministry of Planning and Environment. (The National Environment Commission agreed that in the event of UNEP initiating the programme it would wish to hold an in-country workshop to discuss the relevance of existing in-country data and the role of Government Departments in supporting the implementation of the programme).

(b) Case Study of a selected atoll

A detailed on-site investigation of a selected atoll in terms of specific geographic, physical and biological parameters to augment the data used in (a) above. This work will involve extensive support and participation of National Institutions and Organizations.

(c) Provision of educational booklet on climate change and sea-level rise

On the basis of information derived from (a) and (b) above a short popular booklet on the potential impacts of climatic change and sea-level rise will be published in Divehi and English.

(d) Government meeting

Towards the end of 1989 a workshop will be held in the Maldives at which the findings of the reviews and case study will be evaluated and plans laid for the direction of future work, planning and policy making.

Modality of operation

It is clear that the appropriate Department of Government to direct and co-ordinate this work is the Ministry of Planning and Environment. The National Environment Commission will play a significant role in guiding the programme during its implementation and in co-ordinating the inputs of Government Departments to the work programme.

ANNEX 4

A PRELIMINARY REVIEW OF THE ENVIRONMENT, RESOURCES, CURRENT AND FUTURE ENVIRONMENTAL PROBLEMS OF THE REPUBLIC OF THE MALDIVES

Contents

A. PHYSICAL ENVIRONMENT

GEOGRAPHY

The Republic of the Maldives consists of a chain of coral atolls, 80-120 Km wide stretching for 860 Km from Lat. 7°06' N to Lat 0°42' S, along the 73°E meridian (Figure 1). There are 19 major atolls. Although the area of the State amounts to 107,500 Km^2 and there are about 1300 islands, of which 202 are inhabited, the land areas totals only 298 Km^2, and no island is larger than 10 Km^2.

The linear atoll system rises above a flat submarine ridge 300-450m deep which falls abruptly at the margins to sea floor basins 2600-3000m deep in the East, 1800 to 9000m deep in the West (Figures 2 and 3). The atolls are separated by E-W channnels that cut deeply (to more than 1000m) to the top of the plateau.

The atolls vary in shape and size from oval, eliptical or pear-shaped, to circular (Figure 4). Within the lagoons water depths range from 40 to 60m. Atoll types vary from open structures with numerous islands, faros, patches, and knolls in the atoll lagoon (e.g. Malé: Kaafu and Ari: Alifu atolls) to almost closed ones with few lagoonal knolls and patches. The outer edges of the more open atolls are composed of elongated islands, faros, and patches, while the outer edges of more closed atolls may have a ribbon reef structure and/or a series of islands developed along the peripheral reefs for much of their length (Figures 5, 6 and 7).

The faros are ring-shaped reefs, each with its own lagoon; the reef patches are coral structures that rise 40m above their base, with steeply inclined slopes (45°), many supporting a sandy island capped by vegetation; while knolls are submerged structures that rise 20-30m above the lagoon floor, but do not reach the sea surface.

The atoll margins may be interrupted by channels as deep as the lagoon itself. A recent bathymetric survey conducted by the Institute for Marine Research, Bergen (UNDP/FAO, 1983) found that the inter-atoll channels; mainly the N-S one which is generally 250 - 350m deep and the deeper transverse ones, have smooth uniform bottoms. Uneven to very rough sea floor occurs within the lagoons and in the vicinity of the atoll outer slopes.

There are various types of islands, or cays, with different shapes, according to their location; at the seaward atoll edges, at the lagoon margin, or within the lagoon. Generally oval or club shaped; the largest islands are very elongated. In several atolls (e.g. Malosmadulu, Alifu, Dhaalu) a majority of reef structures and islands, both at the margins and within the lagoon, have an E-W or ENE orientation.

Many islands have raised edges and depressions in the middle, although most islands are flat, and about 1m high. No islands have an elevation greater than 3 meters. The inhabited islands vary in size from 0.5 to 10 Km^2, most being 1-2 Km^2, while those that are uninhabited range from mere sandbanks a few hundred m^2 to as much as 10Km^2.

No topographic surveys of any island with the exception of Malé have been made. Apart from the Admiralty Charts of individual atolls, the most accurate morphological information is provided by RAF air photographs at a scale of about 1:25,000.

Although the Maldivian atolls have been described by various travellers and visiting scientists, the morphology of an atoll and its components, is known in some detail only for Addu atoll at the South end of the chain (Stoddart et al, 1966) (Figure 8, 9).

GEOLOGY

The Maldives archipelago lies above the Laccadives-Maldives-Chagos submarine ridge system which extends into the Central Indian Ocean from the SW coast of India. The geological nature of this feature is still not precisely known. The tectonic evolution of the Indian Ocean, is characterized by the NW drift of the Indian Plate and by Oceanic expansion between Somalia, Arabia, the Seychelles and India since Cretaceous times. The Laccadives Maldives Ridge may be more related to the latter than to the mid-oceanic Carsberg Ridge. In fact South of Addu Atoll the ridge (which to the north is clearly defined down to the 2000m bathymetric contour) looses identity as depths increase to over 3600m. The mid-oceanic ridge, of which Chagos is a part, morphologically swings NW towards the Carsberg Ridge. In addition, in contrast to the latter, the Maldives Ridge is notably aseismic; the presence of continental basement has been suggested by magnetic anomalies (HMS Owen 1962, Survey). The presence of volcanics has not been demonstrated; rather, strong negative gravity anomalies along the entire chain of atolls has indicated the presence of a thick accumulation of sediments, presumably organically formed limestones, up to a few thousand meters. From what is known of the continental margin of India, this succession could be of Eocene age onwards.

Detailed subsurface geological surveys have been carried out in the Maldives by at least two petroleum exploration companies. (Esso and Elf Aquitaine in the 1970's). Both led to the drilling of two test wells, which failed to discover commercial hydrocarbons, but certainly have produced scientifically valuable information on the geological constitution and history of the islands. The reflection seismic surveys conducted by the companies prior to drilling would provide an exact picture of the structure of the Maldives Ridge. Although such information is generally held to be confidential, it could be released to the Maldives Government, and efforts should be made to obtain it.

The more superficial geology of the islands and their more recent (Pleistocene-Holocene) history are no better known. The atolls are entirely made of biogenic sediments, the coral reef system (which includes many other skeleton-building organisms, besides coral colonies) and the products of its mechanical disintegration by biological agents and by wave impact. The atoll cays are made of coral-bioclastic sand and reef gravel lying on a bed of coral rock. On several islands there are outcrops of cemented sand: cay 'sandstone' (a limestone layer 0.3-0.5m thick lying at 1-1.2m depth, formed near the fresh water table) and beach rock (cemented inter-tidal sand and gravel); as well as of reef rock (e.g. Addu, Heva, Midu, Kulu Hera, Mwlikadu, Maradu).

The beach sands are fine grained and well sorted; in the reef flats between the islands and their surrounding living reef edge, coral rock (cemented reef limestone) is overlain by a veneer of poorly sorted fine to coarse bioclastic material. The lagoon floors, for example Addu Atoll, (Stoddart et al., 1966) are made of fine-grained, poorly sorted, calcareous sediments.

The stability of the faros, patch and linear reefs and of the related islands, depends on general and local factors, such as the overall geological subsidence of the system; on the rate of growth of the reef-constructed mass and on the rate of sand-gravel production; on the degree and direction of dispersal of the bioclastic sediments by waves and currents.

The shallow subsurface geology of the islands is known in a limited way only in Malé from boreholes drilled for construction projects (Binnie & Partners, 1975; 1983): coral rock lies at a depth of 8 to 10m under shell-coral debris and sand. In parts (e.g. near the Islamic Center) soft to very soft 'coral clays' are met with at 25m depth.

This information is insufficient, not only for technical purposes, but also in shedding any light on the development of the atolls during the Pleistocene eustatic changes of sea level. Some indirect indications of the reef growth process is provided by erosional notches at depths of 20-35m incised on the outer reef wall in Malé (DPWL - Engineering Geology Ltd., 1987) and elsewhere (Hass, 1961, Eibl-Eibesfeldt 1964); by abrupt slope changes; and by the average depth

of submerged reef knolls (15-25 fms, Stoddart et al., 1966) (Figures 10, 11). These features are probably related to standstill stages in the late Pleistocene-Holocene rise of sea level (100-120m since 18.000 years B.P.), or possibly to previous events.

Other, still indirect, signs of the relative stability of the islands are the elevated coral rock occurrences (0.5 - 1.5m above MSL), mentioned above and buried pre-islamic archaeological remains in the southern Maldives. While the latter suggest subsidence, the former on the contrary may indicate higher sea levels or uplift (a raised rock in Sri Lanka 1m above MSL was dated to 3000 yr. BP, and similar but older examples are known in the Pacific region. Stoddart et al., 1966).

SOILS

Soils in the Maldives islands are in general young and thin, being only a few to 20 cm deep, often retaining the parental coral rock and sand. They consist of a top layer of organic material below which lies a sandy loam, about 15 to 75 cm thick, whose colour varies from light grey in low-humus areas to blackish brown in high humus areas. The sub-soil is comprised of hardened and compressed yellowish sand or sandstone 4 to 5 cm thick, often with a thick clayey layer in the middle. Below this again is the yellow, soft sand and coarse to gravelly sand just above the water level. The soils improve in humus content from the periphery to the middle of the island which is often lower-lying with dense vegetation. The soils, except in the low-lying swampy areas which contain heavy deposits of organic matter, are extremely poor in water-retaining capacity.

The soils are highly alkaline due to the excess of calcium from the basic coral rock, with a pH between 8.0 and 8.8, average of 8.5. In the low-lying areas with plenty of organic matter, the pH varies from 7.0 to 7.75. Quantitive chemical analyses have indicated that the soils in general are deficient in nitrogen both in the form of ammonia and of nitrate; very low to low in potash (except in humus-rich soils); but are fairly rich in phosphorus, calcium and magnesium; manganese and aluminium are lacking, but there is no deficiency of iron. (Butany, 1974).

This situation affects agricultural production and expansion; large quantities of potash and nitrogen need to be supplied. Excess calcium in the soil interferes with the uptake of potash, and turns the iron into an insoluble form which is not available to certain species of plants, especially leguminosae, causing fatal chlorosis in most plants.

GROUNDWATER

Beneath the larger islands and many of the smaller ones a freshwater lens exists that changes in volume each season. Several detailed accounts are available regarding groundwater, and water resources assessment and use, though 75% of them refer to the situation in Malé (Binnie and Partners, 1983; Hadwen, 1986).

The thickness of the freshwater lens depends upon the rate at which it is replenished by rainfall; the size of the island; the permeability of the substration and hence its capacity to prevent mixing with saline water below; and on the rate of withdrawal from the wells. A transition zone of a few meters thickness lies between the accumulated fresh water above, and the sea water on which it floats below. The top of the freshwater aquifer is one-half to two meters below the land surface and changes continuously with the tide. Well water levels measured at increasing distances from the sea, display progressively less tidally influenced variation and a progressively greater time lag.

Groundwater resources have not been determined in any more than 200 islands. Islands several Km^2 in size could have freshwater lenses over 25m thick. On the other hand, in the North several islands particularly the smaller ones are known to possess no groundwater resources.

Qualitatively all the underground waters are alkaline due to excess calcium from coral sand and occasionally due to excess sodium salts. The average pH in different atolls varies from 7.8 to 8.3. The pH is near neutral in non-brackish waters from above-ground lakes and ponds, and also in some low-lying swampy areas. Chemical analysis of water samples indicates that the water is generally brackish, but in fact groundwater appears to be of relatively lower salinity in the southern islands. There are also seasonal variations. Many wells in the North turn brackish in the hot dry season, but their water is non-saline during the southwest monsoon. Wells near the seashore have brackish water more often than those located towards the middle of the island.

In the more densely populated islands (outside, Malé) water quality has also been affected by poor waste disposal and hygiene conditions, as the permeable soil allows pathogens to infiltrate easily and frequently, and spread in the groundwater. In Haa Alifu for example, a high incidence of endemic diarrhoeal disease, and cholera and shigella epidemics in 1978 and 1982, underlie the seriousness of this problem.

In Malé island groundwater availability and quality have deteriorated in the last decade, due to the increased population density (Figures 12, 13, 14), to increased extraction and to decreased aquifer re-charge. Originally the freshwater lens may have been over 20m thick. High rainfall and natural soil permeability allowed regular groundwater re-charge with a complex flow (generally towards the center of the island) and complex relations to saltwater and tidal oscillations. The boundary with the sea appears to be much less permeable, so that outflow and losses are restricted. Borings and electrical conductance measurements made in 1982-83 indicated that instead of an expected thickness of 21m, the fresh water lens was only 13m. There was a decline in gross freshwater storage from 6.14 million m^3 in October 1983, to 4.84 million m^3 in February 1986; the yearly rate being a decline of 560.000 m^3/year (Figure 15).

The water balance (Figure 16) estimated by Binnie and Partners for 1983, showed that 85% of the rainfall volume was lost through surface evaporation, runoff and evapotranspiration; of the remaining 15% seeping under ground, 7% was extracted.

Table 1: Water Balance, Malé

Item	Amount (mm)
Average annual rainfall	+ 2017
Less losses from surface of ground and roof	- 1107
Less evaporation from trees and vegetation (their roots being in the groundwater)	- 571
Less flow to the sea and other unaccounted for losses	- 144
Average amount available for use	201
Yield from 132 hectares in Malé	725 cubic meter per day
Less losses through sewers	- 2780 cubic meter per day
Average daily over draw	2055 cubic meter per day

Consumption has definitely become greater than re-charge due also to sewerage schemes which discharge waste waters directly to the sea, and to reduced infiltration, due to the increasing

impermeability of road surfaces. The quality of groundwater was good up to about 1967, progressive pollution and salinization have occurred since then. The rate of groundwater storage is expected to continue to decrease, that of salinity to increase, although not uniformly over the whole island.

CLIMATE

Located just north of the equator to 7° Lat N, the Maldives have a tropical climate with an annual mean temperature of 28°C and a great deal of sunshine. Daytime high temperatures reach 32°C, nighttime lows do not drop below 25.5° (Table 2). Over the period of the last six years variations in the average lowest temperatures have been greater (1°C) than those between the highest temperatures (0.5°C). During the last 20 years the lowest recorded temperature was 22°C, the highest 36°C. There is not much seasonal variation in temperatures.

In the Maldives instrumental records of meteorological variations began to be kept in the late 1940's. Continuous records are available at the National Meteorological office from 1966, for Malé. Data for Addu Atoll (Gan) extend from 1942 to 1962 and from 1980 onwards (Anon, 1987)

Table 2: Malé Climate Statistics

	Annual Max.	Min	Mean	Monthly Mean	Daily Mean
Temperature °C	31	25	28		
Rainfall mm	2280	600	1927	161	
Evaporation mm (open water)	-	-	2000	180	6
Relative Humidity %	85	75			
Wind Speed m/sec			4.7		
Sunshine hrs	280	140		209-250	

The weather is dominated by the two monsoon periods: the SW monsoon from April to November, the NE monsoon from December to March, when winds blow predominantly from either of these two directions (Table 3).

Table 3: Wind Directions Malé. Percentage of time from each direction based on 6 years observation

	N	NE	E	SE	S	SW	W	NW	CALM	Mean Wind speed kts.	No of days of gales+	fog	thunder
JAN	16	51	13	1	1	2	4	9	3	7	1	0	2
FEB	25	45	11	1	1	3	5	7	2	8	1	0	2
MAR	23	24	4	4	7	1	8	20	9	8	1	0	4
APR	6	3	2	2	6	18	36	20	20	8	1	0	2
MAY	2	2	2	1	6	25	46	12	4	9	1	0	2
JUNE	2	1	1	6	13	29	29	12	6	8	3	0	3
JULY	2	1	2	9	17	33	23	7	6	8	1	0	2
AUG	2	1	1	7	9	17	42	13	8	7	1	0	1
SEP	3	1	1	4	7	21	36	19	8	8	1	0	1
OCT	5	1	1	5	8	13	37	23	7	9	1	0	2
NOV	12	3	2	1	5	14	28	29	5	8	1	0	1
DEC	15	30	6	8	1	6	9	20	5	7	1	0	2
MEANS	9	14	4	4	7	15	25	16	6	8	-	-	-
TOTAL	-	-	-	-	-	-	-	-	-	-	14	0	24

Source: Meteorological Office, Bracknell. + Force 7 in gusts; 0 Rare

Air circulation is controlled by the N-S migration of the belt of the equatorial westerlies along with that of the sun. This part of the Indian Ocean lies between the NE trades of the northern hemisphere and the SE trades of the Southern hemisphere. Along the boundaries between these regimes lie zones of convergence which give rise to unsettled rainy weather (the so-called Northern Shear line). Prolonged spells of unsettled weather are associated with the N-S shift of this zone, especially in the southern part of the archipelago (Stoddart et al., 1966) (Figure 17).

Strong winds and gales are relatively rare; Cyclones are unknown. At Malé winds during a wet spell can blow for several days; in June-July maximum velocities can reach 25-30 m/sec (50-60 knots).

Rainfall is well distributed through out the country; on average it amounts to 1950 mm/annum, but there has been considerable inter-annual variability: from 1530 mm to 2700 mm over the last 20 years (excluding exceptional years, total annual rainfall varies by 500-800 mm between years). The wettest months are May, August-September and December, the driest January-April (Figure 18).

Open water evaporation is in the range of 6 mm per day and transpiration from vegetation is also high. It is estimated that 85% of the total rainfall is lost through evapotranspiration.

OCEANOGRAPHY

Waves

There are no general studies of wave directions and regimes made for the area of the Maldives, except for recent observations and measurements relating to harbour and shore defence structure construction in Malé. Wind generated waves and oceanic swells are conditioned by the monsoon wind directions, with long fetch distances (Figure 19). Waves generated by the SW monsoon in the Indian Ocean North of the Equator, 2-3 m high with periods of 18-20 secs, have been recorded in Sri Lanka.

Ocean wave conditions control wave energy and approach at the outer margins of the atolls. Atoll arrangement and configuration should cause considerable wave refraction and interference. Because of the abrupt drop off to depth at the edge of the external reefs and the wide fringing reefs, wave attack on beaches is much reduced. Deepwater swells are known to penetrate the Malé atoll, causing problems for ships and barges. Manual wave calculations have suggested that swells with periods over 5 sec could occur inside the lagoon 5-6 % of the time, having heights of 0.5m. Waves generated within the lagoon, given the depth and the limited fetch, could be 1.4m high with periods of 4.5 secs for a wind speed of 20m/sec (Posford, Parzy & Partners, 1987).

The exceptional April 1987 (Figure 20) event of flooding of the South Malé reclaimed area, (Figure 21) as well as of Hulule airport, and other islands NE of Malé (including tourist resorts) and in other atolls to the South, has been attributed to long period ESE swells generated in the South Indian Ocean West of Australia (Goda, 1988) (Figure 22).

Wave measuring devices have now been operating for at least a year on the South side of Malé atoll (Givarura island).

Sea-level variations

Precise and long-term data on tidal range and patterns of flow are scarce or absent (ref. U. S. Navy Hydrographic office, Admiralty Indian Ocean Pilot). Tidal variation averages 1 m less in the Southern Maldives; mean HW intervals (Mukunde Atoll) are said to be 10h 20'.

Tidal gauges have operated in Malé from February-June 1987 (University of Hawaii) and again from April 1988 to the present (Lanka hydraulic Laboratory) - recording 1.1m variation between spring tides (variations in the lows being 0.7-0.8m, between high tides 1.1-1m).

Situations of high sea-level at the coast of the atolls are caused by storm surges and wave setup. A degree of coastal flooding due to high tides has been experienced in the past at various places. Recent flooding has been made more noticeable by its impact on constructions such as sea walls and houses near the shore and on low-lying reclaimed land.

The July 1988 high water situation at Thulhadhoo (Malosmadulu Atoll) was caused by high SW waves (2-2,5m high, periods 12-15 sec.) in association with high spring tide and a SW wind. The damage caused was enhanced by the absence of beaches and the presence of vertical low seawalls which magnified overtopping and flooding (Lanka Hydraulic Ltd., 1988.)

These events are a reminder that occasional natural events of long distance swells and high water levels due to wave surge and/or high tides, would in themselves cause little damage to the Maldives atolls, were it not for the mismanagement that has taken place in recent years. This mismanagement includes stripping the islands of the natural defences afforded by the outer reefs, the reef flats and the beaches.

Currents

Ocean currents generally flow eastwards during the SW monsoon period, westwards during the NE monsoon (Figure 23); velocities may reach 1m/sec. In the northern part of the Maldives constant currents move westwards from December to April, towards the East from May through August.

Information on tidal currents is still scanty and only qualitative. Generally the tidal flood moves eastwards, the ebb westwards. Malé atoll tidal currents are said to be much less strong than oceanic currents, though they cause velocity variation in the flows. Strong tidal flow occurs at atoll passages and tidal streams may be quite irregular due to the reefs and sandy shoals, and in areas with many islands. Wave and wind-induced currents would also arise during storm conditions.

Clearly, basic information needs to be collected on tidal and other currents, within the atolls, in order to investigate sand movements and sediment budget, both for evaluations of island stability and port developments.

Hydrography

The hydrographic conditions around the Maldives islands are characterized by a seasonally fluctuating mixed layer of relatively saline water from the Arabian Sea (about 36°/oo), and less saline water from the Bay of Bengal (about 34°/oo).

Two hydrographic sections were surveyed in 1983 by the Institute of Marine Research, Bergen (Norway), one in the Kudahuvadhoo and one in the Kaashidhoo channel. They showed no anomalies in respect to the general features of the region. The surface temperature varies between 28 and 29°C with a slightly decreasing gradient from South to North.

A rapid downward decrease in temperature to below 20°C occurs at 90-100m depth. All salinities observed down to 500 m depth fell within the range 35-36°/oo, and at 500m the oxygen content was 1.2ml/l, the minimum value observed. Oxygen does not seem to be a limiting factor in the area surveyed.

B. BIOLOGICAL ENVIRONMENT

TERRESTRIAL ECOSYSTEMS

Descriptions of the vegetation and lists of plant species are found in various scientific

reports including those of Willis and Gardiner (1901) Fosberg (1957) Fonseka & Balasubramanian (1984) and Adams (n.d). To date five hundred and eighty three species of plants are recorded from the Maldives of which 55% (323) are cultivated. The numbers of species vary on islands according to land area and the vegetation patterns follow a basic atoll conformation with salt tolerant species forming a fringe surrounding the forest dominated natural vegetation of the islands centre. Localised stands of mangrove, including Pemphus acidula, Sonneratia, Brughiera, and Rhizophora are found, usually on low-lying marshy areas of the lagoon side of larger islands.

The original woodland has been cleared on many islands being replaced by grassland, coconut groves and agricultural gardens. Sigee (1966) provides a description of the vegetation of Gan which included dry grassland; sedge marsh; woodland; marshland and open scrub; shoreline communities and ecotones. On Hitaddu, this author describes dense Pandanus woodland which also contains some Hibiscus tiliaceous. Pandanus has been well collected and four species are endemic to the Maldives (St. John, 1961).

Woodland and timber use

On most islands the woodland community is dominated by Pandanus spp. Hibiscus tiliaceous with typical atoll genera such as Tournfertia, Scaevola and Guettarda being widespread. Timber commonly used in Dhoni construction includes some 15 species many of which are used for different parts of the construction (Brune, 1984). Artocarpus, Calophyllum, Cocos and Cordia are used as timbers in house construction; handicraft Hernandia, Barringtonia, and Pandanus; for firewood Scaevola, Pemphis and Hibiscus. "Wood" is in general getting scarce and imported timbers are now used for many purposes suggesting extensive modification of the natural vegetation (Brune, 1984). Considerable ecological damage has already been done to the ecology as a result of fuelwood and timber exploitation (Saini, 1987).

Agricultural activity

The total cultivable area is given as 46,766 acres (Anon, 1987) of which most is used for subsistence production. Agricultural production in 1984 involved less than 10% of the country's labour but accounted for 11.44% of the Gross Domestic Product. In 1985 however despite a 4.83% increase in GDP from agriculture this sectors' share of total GDP had fallen to 10.48 percent (Saini, 1987).

Crops include coconut, fruits, vegetables, tubers, coarse cereals such as millet and maize (Table 4). Production of bananas and chillies had increased from 1984 but lime and citrus production was adversely affected by cancer and dieback.

Over the period from 1969-1971 coconut production declined from an average of 12.5 to 10.5 nuts per tree (FAO, 1974) and problems of pests such as the rhinoceros beetle have received considerable attention from the department of agriculture. This pest is now controlled by means of viral, biological control.

Coconut production stagnated during the '70's and 80's due to rhinoceros beetle, bat and rodent damage and the high density of palms, whilst coarse cereal production, yam and cassava production declined as a result of the availability of cheap imported rice and wheat flour. It is interesting to note that the country is not self-sufficient in coconut with dried products being imported from Sri Lanka.

A UNDP/FAO Agricultural Development Project (AG:DP/MDV/80/003) between 1982 and 1987 sought to enhance agricultural production and hence encourage vegetable and firewood production, import replacement, extension, training and research, and develop a medium term sectoral plan.

Traditional staple energy sources included breadfruit (Artocarpus) and taro, Colocasia esculenta which have been largely replaced by rice and wheat flour which together constitute the

staples of the modern diet, particularly in Malé. In 1971 taro production was estimated at around 600 tons although production figures are highly unreliable given the absence of detailed survey data.

Data on areas cleared for cultivation and frequency of fallow appear to be lacking but could be estimated using comparisons of the 1966 RAF aerial photographs and ground surveys. Any changes in land-use will have consequent impacts on the natural vegetation. In most Pacific atolls the major source of disturbance to natural vegetation is subsistence agriculture with episodic destruction through hurricanes being important. It would appear that in the case of the Maldives the former cause is more important than the latter.

Table 4: Crop Production in Maldives in Metric Tonnes (From Saini, 1987)

Crop	1978	1979	1980	1981	1982	1983	1984	1985	1986
Maize	15.5	9.48	6.26	28.55	1.94	3.79	3.25	1.19	-
Sorghum	-	0.06	-	0.11	0.11	0.99	1.04	0.10	-
Fingermillets	37.76	38.52	9.34	55.06	3.23	5.25	0.75	0.19	-
Italian Millets	0.08	1.63	0.02	37.48	1.01	2.89	0.46	0.44	-
Colocasia	790.81	12,132.41	968.14	1373.71	1095.08	541.08	1882.42	1125.88	410.15
Alocasia	217.51	8,293.47	29.00	106.06	244.05	60.32	41.58	26.29	133.84
Cassava	12.60	6.14	1.09	19.59	16.54	8.92	34.67	13.56	27.07
Coconut/ million nuts	8.54	1.16	10.29	11.17	10.72	6.85	10.60	11.81	11.12
Arecanut	2.40	0.71	1.69	9.01	70.91	1.54	1.12	16.79	5.59
Banana	-	-	-	308.48	778.81	339.60	1838.63	886.88	852.09
Onions	2.54	1.79	1.67	2.94	0.78	1.38	0.46	1.64	2.34
Chillies	4.98	2.03	0.93	34.24	11.78	21.19	151.13	711.46	69.49

MARINE ECOSYSTEMS

The 19 atolls of the Maldives archipelago support a wide diversity of coral and soft substrate benthic communities. General descriptions of the reefs and reef systems are found in (IUCN/UNEP 1988; Gardiner, 1903-1906; Munch-Peterson, 1985; Stoddart et al., 1966). Few detailed studies have been undertaken of coral reef biology, although the Ministry of Fisheries is currently operating a monitoring programme at 18 sites on 6 atolls. An overview of published work on reef biota is provided in IUCN/UNEP (1988) which states that approximately 1000 reef fishes; 140 species of coral, 63 species of marine benthic algae and 11 to 14 species of nesting sea birds are known from the Maldives. Stoddart et al. (1966) provide descriptions of the major reef and lagoon habitats of Addu Atoll and these descriptions form the basis for much extrapolation to other atolls in the archipelago. Stoddart et al. (1966) recognized distinct communities based on depth and exposure, and followed Eibl-Eibesfeldt (1964) in defining seaward reef and slope communities; seaward reef edge; seaward reef flat; lagoon reef flat and slope: which differed in different parts of Addu Atoll, in terms of their community structure and species composition.

Reef exploitation

The marine ecosystems of the country provide the fundamental economic underpinning for the entire existence of the Nation. The reefs form the foundation on which the fragile islands perch; they provide sources of building and road surfacing materials; support food species of fish and hence provide directly some 70% of the export income of the country. Through the provision of areas of aesthetic natural beauty and high species diversity they provide the "raison d'etre" for the tourist industry. The major products derived directly from the reef are:

- Fish and marine food products;
- Coral for construction and road surfacing; and
- Sand for construction, roads and land reclamation.

The exploitation of tuna, other fin fish and shellfish for local consumption and export, appears not to be a major factor in environmental degradation although few data are available on the size of stocks and projected maximum sustainable yields. One programme of the marine research division of the Ministry of Fisheries is concerned with collecting such data. The Ministry of Fisheries has set and enforces an arbitrary limit on tropical fish export for the aquarium trade and is currently concerned with assessing the impacts of this activity.

The impact of coral "mining" has been comprehensively reviewed by Brown & Dunne (n.d.) who examined the mode of operation, the volumes harvested (Table 5), the use, species composition and recovery rates of mined areas. This report identifies problems which include the slow rate of recovery of mined areas with consequent reduction in wave energy absorption capacity of mined areas, reduction in abundance and diversity of corals and fish, and impacts on local current patterns and consequently erosion. They recommend two alternative methods of meeting construction needs, the first being total removal by mining of a single faro, the second the use of concrete blocks manufactured from dredged sand, which they state "is available in practically unlimited quantities".

Table 5: Extraction of Coral Rock (1980-1985)

Year	Bought in by DPWL*	Tourist Resort Building	Total Malé Receipts	Price RF/cu ft
1980	7,140	No figure	7,140	0.33
1981	46,417	No figure	46,417	0.96
1982	246,048	282,000	528,048	0.71
1983	225,000	246,000	471,000	0.77
1984	240,548	31,600	272,148	0.87
1985	269,730	152,273	422,003	1.10

Source: Department of Public Works and Labour; (US$ 1 = Rufiya 8.25)

Sand mining or dredging is currently undertaken on a small scale by individuals for brick construction and on a larger scale for harbour dredging when it is frequently used for land reclamation, as in the case of the Maafushi harbour and fish drying centre in South Malé Atoll. Removal of sand on a large scale affects local current patterns and could lead to accelerated erosion of existing land under some circumstances.

Fisheries

In 1986 fish and marine products provided the bulk of exports and included dried, frozen and canned fish, cowrie shells, sea cucumbers, shark liver oil and shark skin, and live tropical fish with frozen skipjack tuna to the value of 71 million Rufiya being exported (US$1=8.25 Rufiya) constituting the largest component of the total exports of 158 million Rufiya. Most fisheries products are exported to Thailand and Sri Lanka with Japan and West Germany being secondary markets. Local consumption of fin fish was estimated in 1986 at 23,200 metric tonnes, or around 39% of the annual catch. Total catch has risen from 26,000 tonnes in 1977-1979 to 60,000 tonnes in 1985-86 as a result of increased mechanisation of dhonis, improved buying and marketing arrangements and increased fishing effort.

Current marine related problems

Coral bleaching

In mid-1987 diving instructors first reported this with coral deaths occurring in May/June 1987, down to depths of 30 meters. At least 12 hermatypic coral species were affected together with soft corals and anemones. The coincident occurrence of lagoon water temperatures 2-3 degrees higher than normal, ear infections and red tides with associated fish mortalities was also noticed. (Anon, 1988). Indian Ocean surface temperatures were recorded as being 1.5°C higher than normal during May, June & July 1987. (Meteorological Office, Bracknell, UK. cited in Anon, 1988). Coral bleaching and death is attributed in this instance to temperature stress, and hence is a source of considerable concern, given the prediction of increased temperature resulting from the greenhouse effect.

Sewage Pollution

In some areas raw, untreated sewage is discharged onto or in close proximity to reefs (e.g. South side of Malé). The sewage is carried in freshwater hence causing localised changes to salinity combined with eutrophication, enhanced algal growth and hence impacting coral growth.

Solid waste disposal

Localised problems of garbage disposal are causing some impacts on reefs around Malé with living corals being covered with plastic bags and other rubbish, washing out from unconsolidated dumps near the high tide level.

Conservation issues

The problems of coral reef conservation and management have been addressed in a number of reports by outside experts. Of these Kenchingham (1985) is the most comprehensive, recommending extensive legislative and management structures for implementation in the country. Like many other sectorally oriented reports the recommendations are perhaps too detailed and the administrative structures too cumbersome to be implemented given the manpower constraints of the country. In part the recommendations regarding monitoring have been implemented by the Marine Research Section of the Ministry of Fisheries through their coral reef monitoring programme but unfortunately a national approach to coral reef management and conservation has yet to be implemented.

C. SOCIAL ENVIRONMENT

PREHISTORY

The prehistory of the Maldives is not well known although recent archaeological investigations (Heyerdahl, 1986) clearly indicate the existence of pre-islamic cultures extending back to at least 2,000 years B.P. Conversion to Islam occurred in 1153 before which time a Budhist culture had existed throughout the Maldives as evidenced by carvings and the remains of stupas on many islands in the archipelago. Evidence for a pre-Budhist culture is less well represented but petroglyphs and other structures are related by Heyerdahl (1986) to ancient Indus valley civilizations which thrived between 2,500 and 1500 BC.

Scattered evidence of pottery, shell and metal artifacts, attest to the important geographic position of the Maldives on the major sailing routes between Arabia and Sri Lanka, Chinese pottery and Roman coins of the first century AD have been found in the Maldives.

HISTORY

Maldivian modern history commences with the conversion to Islam in 1153 but as early as the

9th century AD. Arab traders had used the Maldives as an entrêpot taking on water, dried fish and coconuts although the major attraction was the cowrie Cypraea moneta. Between the twelfth and fifteenth centuries trade between the Maldives and mainland India largely depended on the muslem merchants on the Southwest coast of India. In the early sixteenth century the Portuguese were granted trading rights and in 1552 Sultan Hasan IX invited the Portuguese to take control of the islands. The bulk of the population resisted, before finally being over-run in 1558. In 1573 a popular revolt lead to the overthrow of the Portuguese and by the end of the Century the Dutch established diplomatic relations with the Sultan. In 1796 the Dutch ceded Sri Lanka to the British who established a regular trade between Malé and Colombo. By 1860 the Borah merchants of SW India controlled most import export trade and local business interests reacted by burning down the shops and warehouses. The British Governor of Sri Lanka then signed a treaty with the Sultan under which the Maldives sovereignty was recognized. The Maldives became a British Protectorate in 1887. Protectorate status was relinquished by the British in 1965, the last Sultan returned to Colombia in 1968 and the first President, Ibrahim Nasir, was elected. Between 1968 and 1978 foreign influence in the Maldives increased but economic problems, particularly escalating food prices and corruption lead to social and political unrest. Nasir retired in 1978 to be replaced by the second President, Maumoon Abdul Gayoom, who has recently been re-elected for a further term.

LANGUAGE

The language of the Maldives is Divehi which displays affinities to several languages (Maloney, 1980) from North India, Sri Lanka and S. E. Asia, and contains a number of Arabic, Hindu and English words. Written Divehi (Tauna) is based on a twenty four letter alphabet, the letters being derived from variants of 9 arabic numerals. Modern tauna was invented in the sixteenth century following the overthrow of the Portuguese and differs from earlier scripts in being written from right to left. Earlier writings from the twelfth century were incised on copper plates, a number of which survive and the earliest, dating from the twelfth century, has recently been translated.

CULTURE

Modern culture is islamic with the people belonging to the Sunni sect. The women do not observe purdah and the most severe punishment for criminal offences consists of banishment to an island or atoll at some distance from family and place of origin. The Maldives have the highest divorce rate among the nations of the UN (80%, Anon, 1987) with most Maldivians having been married several times, often to the same partner.

Society is stratified, with respect and status being determined by political connections, wealth and education. The largest peer group are the fishermen, with boatbuilders being accorded higher social status, equivalent to the healers or "Hakeem". Traditionally weaving of mats and production of coir rope was a woman's occupation, whilst the bulk of men were occupied as fishermen. Agricultural activities were traditionally undertaken by both men and women and appear to have been less prestigious than occupations associated with the sea.

Five calendar systems are used in the Maldives of which the Christian and Islamic calendars are most frequently used by educated Maldivians. The traditional "nakai" calendar with twenty seven divisions of 13 or 14 days each with a "predictable" weather pattern, is still in use and is based on the fishermen's division of the year according to climate and lunar cycles which affect the use of fishing grounds and fishing success.

EDUCATION

The Maldives has a high literacy rate with only around 6,000 people being classed as illiterate in 1986 (Anon, 1987). Education commences in village schools with reading and recitation of the Quran. In 1986 some 50,000 students (26,000 male and 24,000 female) were registered in Government and private schools mainly at the primary school level (72%), only 11%

were registered at the secondary school level and 1% at higher secondary (matriculation) level. General Certificate of Education, "ordinary" and "advanced" level examinations are taken externally through the University of London and although the pass rates are high, the absolute numbers of individuals receiving advanced level education is small (53 in 1986).

A number of Maldivians have received degree level training overseas but few have received post-graduate training and to date there are no people trained at Doctoral level.

DEMOGRAPHY

The population is large (estimated at 195,100 in mid-1987) when considered in terms of the countries resource base and land areas (298 Km^2). The sex ratio shows an imbalance; 52 % males, 48% females. Between 1900 and 1960 the population was relatively stable around 70,000, however, following improvements in health care and reduction in infant mortality since 1960 the population has shown an exponential growth. Growth rate, estimated on data for 1977-1985 is 3.2% per annum, placing a strain on the education and health services of the state (Figures 24, 25, 26).

Only some 202 islands are permanently inhabited and 25.5% of the total population is aggregated in the capital Malé. The population is therefore unequally distributed in relation to the natural resources, and urban drift is a response to the availability of health care and education. Several development programmes of Government are designed to alleviate this problem through the provision of services in areas away from Malé.

MANPOWER

A large number of reviews and manpower development plans have been produced by outside experts, most of which make reference to the time lags between employment opportunities and the response of the educational system. Khanjo (1988) discusses the "bond" system under which all those passing grade 7 and above are bonded to work for the Government for between two and four years. Employment opportunities, particularly in the private sector, have grown faster than the supply of trained manpower. As a consequence many government employees work also in the private sector and Khanjo suggests that there may be considerable under-employment in the Government sector.

In 1986 some 2,510 expatriate workers were employed in the Government and private sectors, not all having high educational qualifications (130 bartenders, 117 cooks, 289 factory workers, 230 labourers for example). In a number of cases imported labour is required for development projects due to the unavailability of local manpower, over 47% of which is engaged in fishing and agricultural activities on their own account. A quarter of the expatriates were employed in government and one third in the tourist industry. Three quarters of the expatriate work force was from South Asian countries and 65% from Sri Lanka.

The shortage of high level trained manpower in the Planning sectors of government imposes severe constraints on the implementation of advice and guidelines in various sectors of administration and development.

D. ECONOMY

GENERAL

Until the 1970's the Republic of the Maldives was rather isolated and its economy was based on fishing, shipping and the cultivation of coconuts. The situation changed with the advent of tourism which stimulated new activities and started a period of accelerated economic growth.

The Maldives, however, have a typical developing island economy, characterized by limited natural and human resources, an acute shortage of raw materials, heavy imports of most requirements, and an ever increasing demand on the Government to cater for the basic needs of the country. The per capita gross domestic product is only about $440.

Table 6: Distribution of population

Locality	1974 Both Sexes	1977 Both Sexes	1985 Both Sexes	1985 Male	1985 Female
Republic	128212	142832	180088	93482	86606
Malé	16246	29522	45874	25897	19977
Atolls (all)	111966	113310	134214 1/	67585	66629
North Thiladhunmathi	8775	8601	9899	4759	5140
South Thiladhunmathi	9709	9923	10850	5055	5795
North Miladhunmadulu	6147	6363	7509	3622	3887
South Miladhunmadulu	6252	6282	6864	3258	3606
North Maalhosmadulu	8136	7904	9416	4681	4735
South Maalhosmadulu	5488	5758	6960	3573	3387
Faadhippolhu	6000	5655	5939	2901	3038
Malé Atoll 2/	3796	4153	5619	3160	2459
Ari Atoll	5769	6219	7351	3662	3689
Felidhu Atoll	950	1078	1352	742	610
Mulakatholhu	3162	3095	3490	1725	1765
North Nilandhu Atoll	1773	1986	2148	1014	1134
South Nilandhu Atoll	3185	2999	3568	1759	1809
Kolhumadulu	6589	6214	6949	3371	3578
Hadhdhunmathi	5547	6090	7201	3565	3636
North Huvadhu Atoll	4897	4977	6054	3024	3030
South Huvadhu Atoll	8150	7717	8905	4229	4676
Foammulah	4117	4202	4983	2309	2674
Addu Atoll	13524	14094	14923	7013	7910

1/ The discrepancy between this figure and the total of 129980 for the individual atolls listed below is not commented upon in the 1987 Statistical Yearbook from which the figures in this table are taken (Anon. 1988).

2/ Excluding the capital city

The economy is based principally on three export activities: fishing, international shipping and tourism. The role of agriculture is naturally limited by the shortage of cultivable land and the poor quality of the soil. Industry is still in its infancy: the few modern mechanised enterprises reflect the desire for developing export promotions and import substitution. The two main contributors to industrial output, garments and fish canning, are both export-oriented; the prime potential for increasing export earnings appears to be in the processing of imported materials for re-export.

In the decade since 1976, and especially since the election of President Maumoon Abdul Gayoom in 1978, the economy of the Maldives has registered an impressive annual growth rate averaging 8.9%, thanks largely to the increase in receipts from tourism and fisheries, as well as to the Government push of infrastructural development. The latter has included projects in the areas of the capital island, such as the international airport, a new commercial harbour and land reclamation at Malé, (which has extended the limited surface of the island by around 50%) and the attendant coastal defence works. A major road upgrading and water sewerage scheme, designed also

to provide the city with safe drinking water; a 4 mW, 6 million dollar power station, and waste treatment and de-salinization plants, all located in the reclaimed areas of South Malé.

Major recent developments in the atolls have been government buildings and schools, electrification and completion of an airport at Khadhdoo in the middle of the country. This has considerably improved inter-island communications (as there are now three airports and two airstrips in the country); fisheries modernization; factories and new tourist resorts are also being developed.

The rate of growth for 1985-86 and the contribution of the different sectors of the economy are summarized in table 7.

Table 7: Gross domestic product by sector (1986)

Item	Millions of Rufiya	%	Rate of Growth
Gross Domestic Product	623.3		
Agriculture	78.9	12.0	3.83
Fisheries	141.7	22.6	
Coral & sand mining	7.2	1.3	
Construction	44.8	7.2	
Manufacturing & Electricity	30.9	5.0	
Distribution	61.0	9.8	
Transport	37.2	6.0	
Tourism	110.0	17.6	17.4
Real Estate	30.0	4.5	5
Services	37.6	6.0	
Government	43.0	7.0	2.4

US $ 1 = Rufiya 8.25

FISHERIES

The traditional mainstay of the Maldivian economy has been expanded through mechanization of the fleet (55% of the total boats in 1986), distributing fuel to fishermen in far out islands, and in collecting their fish catch promptly. Productivity has considerably increased with a doubling of the catches since 1984 to 61,900 tons in 1985 and 59,300 tons in 1986 (Figure 27).

The main products (about 90%) are tuna (largely skipjack) and 55% of the annual catch is exported, mostly to Thailand, (60%) to Sri Lanka (31%) and to Japan (6%). 95% of the exported fish is in the form of frozen skipjack and salted dry fish (tuna, shark and reef fishes), tuna represent the largest part of the remaining five percent.

This export contribution results from the establishment at Feliuaru of a fish processing plant. This facility, originally a foreign and Government joint venture, is now fully Maldivian owned and has been recently expanded to produce fish meal.

Other exported fish and marine products include shark skins and dried shark fins, shark liver oil, sea cucumbers, cowrie shell and aquarium fishes.

On the basis of the size of the catches and fishing fleet, the main fisheries are in the North Tiladhumanthi, South Maalhosmadulu, Malé, Kolhumadulu, Madhdhunmathi and South Huvadhu

atolls. To facilitate fish gathering and processing for export, and to prevent over-crowding of Malé harbour, three collection centres have been established at Maalhosmadulu, at Maafushi Island near Malé and at Madhdoumathi atoll in the South.

AGRICULTURE

Unlike many developing countries agriculture in the Maldives accounts for a mere 12% of the GDP and employs less than 8% of the workforce. Given the severe physical limitation to agricultural growth (lack of land, poor soil, climatic conditions) the Government can only emphasize the cultivation of coconuts and fruits and to a lesser extent vegetables for the provision of extra cash income and import replacement.

The main cultivated crops that are easily cultivated are vegetables (pumpkins, eggplant, beans, drumsticks,) cassava and sweet potatoes, chillies, watermelons and fruit trees (breadfruit, mangoes, lime, papaya and guava). The best agricultural areas are in the North and South of the country, where better soil conditions exist on some islands.

Coconut is adapted to the difficult soil conditions and is by far the most important crop, with an estimated one million trees. Production, however, is low and nuts tend to be small; many palms are said to be affected by disease.

INDUSTRY

In the Maldives industrial activities comprise a traditional, handicraft sector, and a modern, mechanized sector.

Manufacturing is the least impressive sector of the economy. Its annual average growth for the nine year period was only 7.7% although from 1982 to 1985 the growth rate jumped to 16%, as a result of the establishment of several new industries. In absolute terms it is the smallest sector, next only to "coral and sand mining" amounting to only 5% of the GDP. Yet, surprisingly, according to the 1985 Census, manufacturing provides 22% of all employment, right after the largest employer, fisheries with about 25% and twice that of tourism with 10%.

The traditional handicraft sector is more widespread and includes boatbuilding, thatch and rope-making, carpentry, tailoring, blacksmithing and the making of curios and souvenirs. The 1977 census reported that more than a quarter of the workforce, mostly women, were engaged in such activities, mainly on a part-time basis. The sector was estimated to contribute Rf. 15 million to the gross domestic product in 1984; and is being further developed by linking it with growing and more dynamic activities such as tourism.

The modern industrial sector includes the fish processing factory already mentioned, three garment plants that make tee shirts, knitwear, shorts and blouses entirely for the export market (mostly North America). Two are in the Island of Gan, the third at Kuladhoo. They are joint ventures involving private foreign and government interests and are dependent on totally imported materials and to a large extent imported labour. These factories contribute considerably to the country's exports and income but very little to the creation of new jobs for the growing population.

Other smaller-sized industries are located mostly in Malé and produce soft drinks, mi-sheeting, plastic tubing, packed chicken meat, books and other printed materials. A boat-yard at Alifushi Atoll established in 1982 makes about 200 modern fishing boats a year.

The output of the individual manufacturing sectors was Rufiya 133,7 million in 1986; the sectoral contributions are indicated in Table 8.

Table 8: Industrial production in the Maldives, 1986

	Millions of Rufiya	Percent
Fish Processing		
Tuna Canning	10	7.5
Salting/Drying	33	24.7
Beverages	3.8	2.8
Garments	60	44.9
Plastics	1.5	1.1
Printing	5	3.7
Boatbuilding	4.8	3.6
Woodworking	5.1	3.8
Metalworking	5.1	3.8
Handicrafts	5.4	4.1

US $ 1 = Rufiya 8.25

TOURISM

At 17 of gross domestic product tourism is the second largest contributor to GDP after fisheries and is set to remain a major sector of the national economy (Figure 28). There are now 58 resorts, mostly in small islands in the Kaafu (north and south Malé) and nearby Alif atolls, most are within a radius of 50 Km from Malé airport (Figure 29); size varies from 30 to 300 beds. These resorts were established on uninhabited islands, assigned to a contractor and developed on a 5 year lease. In 1986 they provided a total of 5,559 beds for 113,953 tourists; revenue was 42 million US$. There has been a slow increase in bed capacity over the last few years and an occupancy rate of about 51%; the rate has fluctuated considerably since 1980 and is seasonal, highest rates of 70% are in the period November-April. There is still room for an increase in visitor days before an expansion of resorts is undertaken.

The building and management of the resorts, relies heavily on the import of most equipment, facilities, foodstuffs and skilled labour. About 3000 Maldivians are employed overall in the resorts and tourism has spurred other activities such that at least 1 in 10 families derive some income from it. The Government's revenues are principally from the leases, import duties and airport taxes. The Government has imposed strict guidelines for the development of the resorts, especially in regard to water supplies and the protection of the environment. Most tourists (73%) come from Europe, especially Germany and Italy.

TRADE AND COMMERCE

Thailand the United States and Sri Lanka - in that order - continue to be the major export markets. Exports to Japan, which was the largest trading partner and sole buyer of Maldives fish until 1981, had halved by 1986. The trade balance, which has usually been negative, continued to show a deficit of US$31.1 million in 1986. Although services, mainly tourism, did bring in some US$21.2 million in 1986, the overall balance of payments remained precarious with net foreign reserves not exceeding more than one month's imports.

In 1987 the trade balance again amounted to -31.1 million US$, with imports at 59.9 million US$ against exports of 28.8 million US$. Main imports were consumer goods; foodstuffs, tobacco, beverages and manufactured goods (56%); petroleum products (15%); intermediate and capital goods mainly steel and chemical (29%).

The World Bank/IMF and foreign donor countries have appreciated the Maldives' liberal import policies, but continued to caution that a tighter fiscal policy would be needed to redress the balance-of-payments situation. For 1987 budget, expenditure at Rs 380.1 million outstripped total revenue of Rs 361.5 million. The aid component of the annual revenue was an estimated Rs 80 million. Fiscal and monetary pressure resulted in the Maldives' currency being devalued by about 40% in 1987.

ECONOMIC DEVELOPMENT AND ENVIRONMENTAL IMPACTS

At first sight the basic national resources of fishing and tourism should continue to support the Maldivian economy with the addition, probably on a moderate scale of manufacturing and food processing. The Government is well aware however of the weakness of the present economic system dominated by fishing, tourism and shipping. The economy in fact ran into rough waters in 1984, as tourist arrivals stagnated because of ethnic violence in neighbouring Sri Lanka. The early 1980's also saw a slump in the price of fish and at the same time the crisis in international shipping dashed the Government's hopes that it could make the State shipping sector a growth area.

While these problems, with the exception of shipping, have largely been overcome they also highlighted the unhealthy dependence of the country's economy on fishing and tourism, the fortunes of which are solely at the mercy of international forces well beyond the control of the Maldives. Therefore, by the mid-1980s the Government began to search seriously for ways to diversify the economy.

Due to unfavourable conditions it cannot be expected that agriculture will ever play a dominant role in the economy of the country, importance is given now to the development of industry. Industry alone could provide ever growing demand and supply possibilities for continued economic growth of the Maldives.

The strategy for industrialization will rely mainly on export promotion, secondarily on import substitution on foreign investment, given the lack of capital and technical skills in the country. The Government has already set aside industrial development 'poles' in Addu (Gan), Laamu, Maa Dhaalu and Madhdhunmathi atolls. Potential fields of manufacturing could include (UNDP 1987): textiles and garments, food processing, yacht building, building materials and several other products based on marine salts supplied from de-salinization plants.

In addition to industrial expansion, other development projects and/or likely development areas, are in fisheries (aquaculture, deepsea fishing beyond the 30 miles limit), urban expansion in the atolls, involving schools, hospitals, sanitation and new harbour infrastructures; and in tourism.

However, the promotion of the modern industrial sector in the Maldives is constrained by such factors as the extremely limited domestic market, the absence of a raw material base (except fish) for industrial development, the shortage of skilled and semi-skilled labour and the absence of a legal and institutional framework conducive to industrial investments.

Industrial and other expansion is also constrained by problems of water supply and building materials; by shortage of power and by transport difficulties. The exhaustion of the fresh water lens in the capital could be equalled by similar occurrences in other towns, if these are allowed to expand beyond the land capabilities of their island; a not unlikely possibility if the inevitable policy of slowing down the migration into Malé is pursued, by creating other poles of attraction. The water supply problem will be not so much a question of groundwater management, as of technological methods to tap the considerable rainfall, and probably also of increasing seawater de-salinization. Nevertheless the Malé situation of reduced rainwater infiltration into the soil due to roads compacted by motor traffic should not be allowed to occur elsewhere.

Building material resources are potentially not small, provided that appropriate surveys

are made of coral sand and gravel supplies and of coral rock for mining. The present methods of stripping live coral reefs for construction purposes is not only inefficient but also environmentally very dangerous.

Development activities that are in the same category of creating potential threats to environmental stability, especially in regard to coastal erosion, are projects of land reclamation based on the filling of reef flats. The recent flooding occurrences clearly indicated that the damage inflicted to buildings and physical infrastructure, by natural events that are not exceptional in themselves, was due to land reclamation and the construction of seawalls at the edge of the islands outer reef. In the case of of the South coast of Malé Island a "tetrapod" breakwater is under construction with Japanese Government assistance. This represents an expensive and "high-technology" solution which would not have been necessary if prior consideration of potential environmental impacts had been undertaken.

Any development, albeit necessary, that involves harbour construction, would require a careful assessment of environmental impacts. The alternative is the prospect of escalating costs of repairing infrastructres, of building more coastal defences - eventually weakening whatever natural mechanisms exist for adjustment to sea-level rise.

The combination of present environmental problems in the Maldives together with the numerous reports of visiting experts which remain largely unimplemented might suggest on superficial examination that the Republic either lacks the capacity or the will to implement change. It is the opinion of the present authors however that neither of these reasons is correct. The authors were struck by the clearly articulated and frequently expressed concern of many Maldivians about current environmental problems. It seems clear that the problems of planning sustainable development in the Maldives stem from the highly sectoralised approach to planning which appears to operate at present.

Individual advisors/consultants produce reports and recommendations on industrial development, on manpower planning, on agriculture fisheries, water management, transport, conservation and disasters without consideration of an holistic approach to planning and management. A country as physically limited as the Maldives can only be treated as a single entity, since changes and developments in one area have automatic links and impacts with all other areas of the economy and environment. Sustainable development in the Maldives can only be achieved by a careful and simultaneous consideration of all aspects of these island's fragile environment.

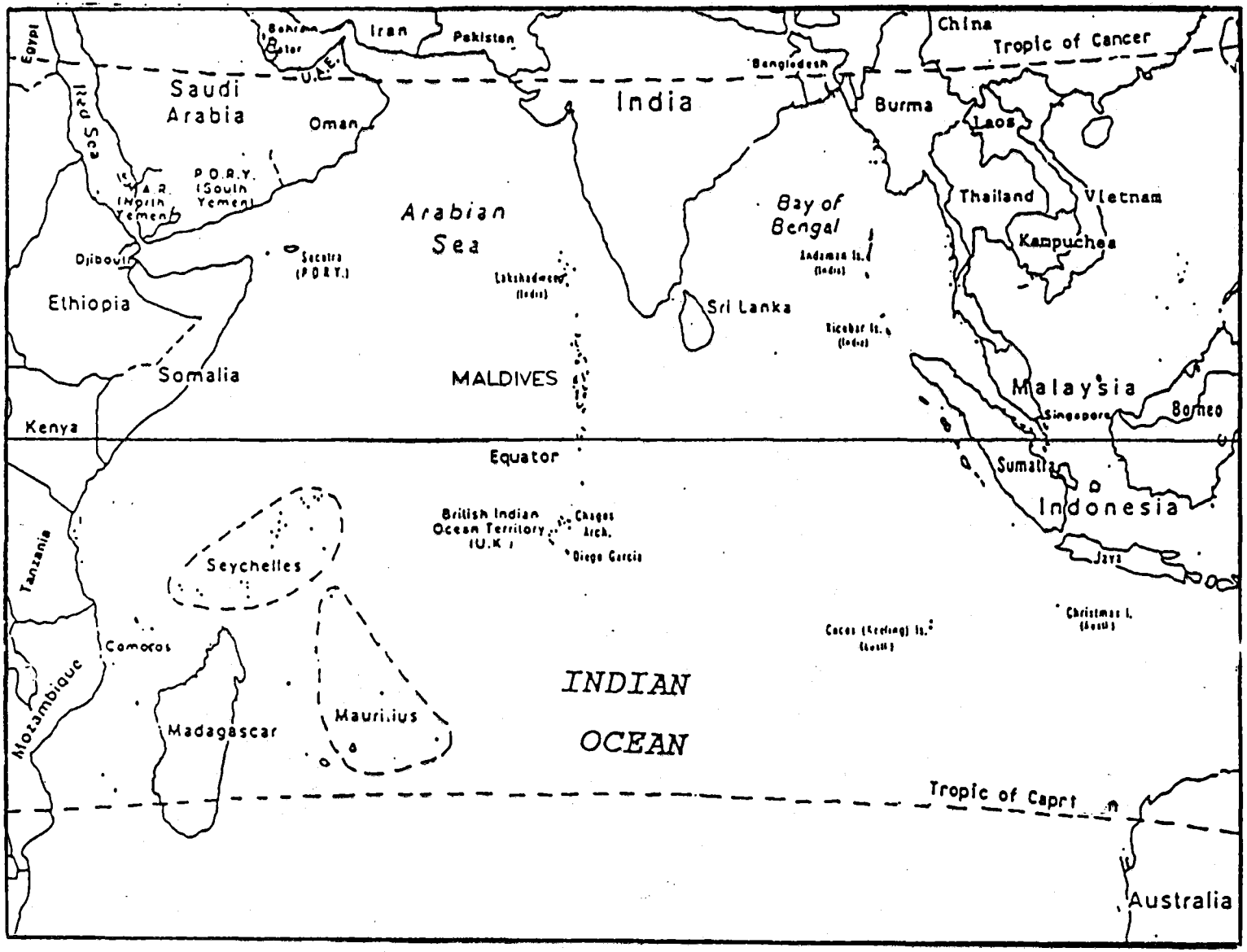


Figure 1. Location of the Maldives in the Indian Ocean.

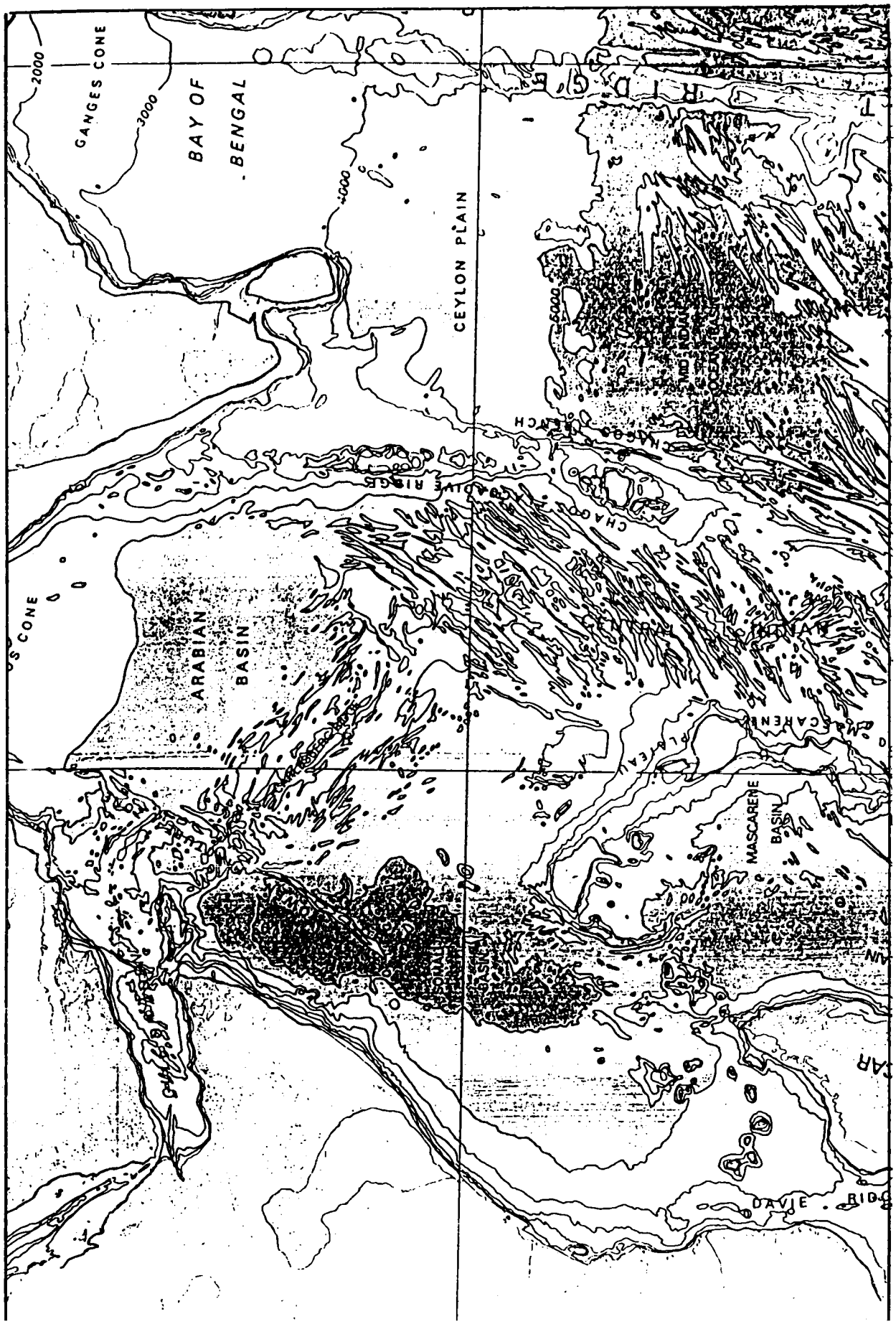


Figure 2. The Chagos-Maldives-Laccadive Ridge in relation to the Central-Carlsberg Ridge and adjacent basins

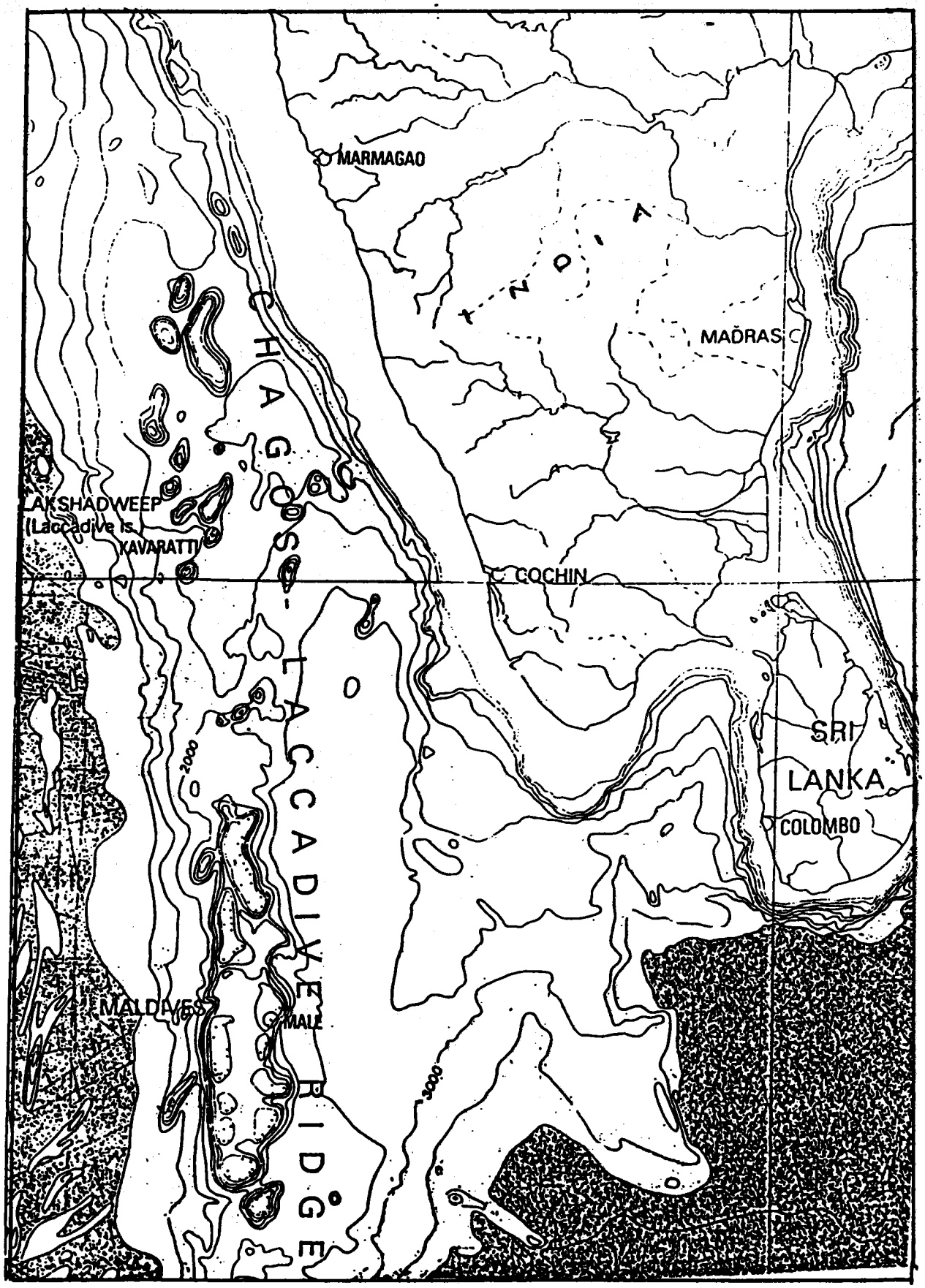
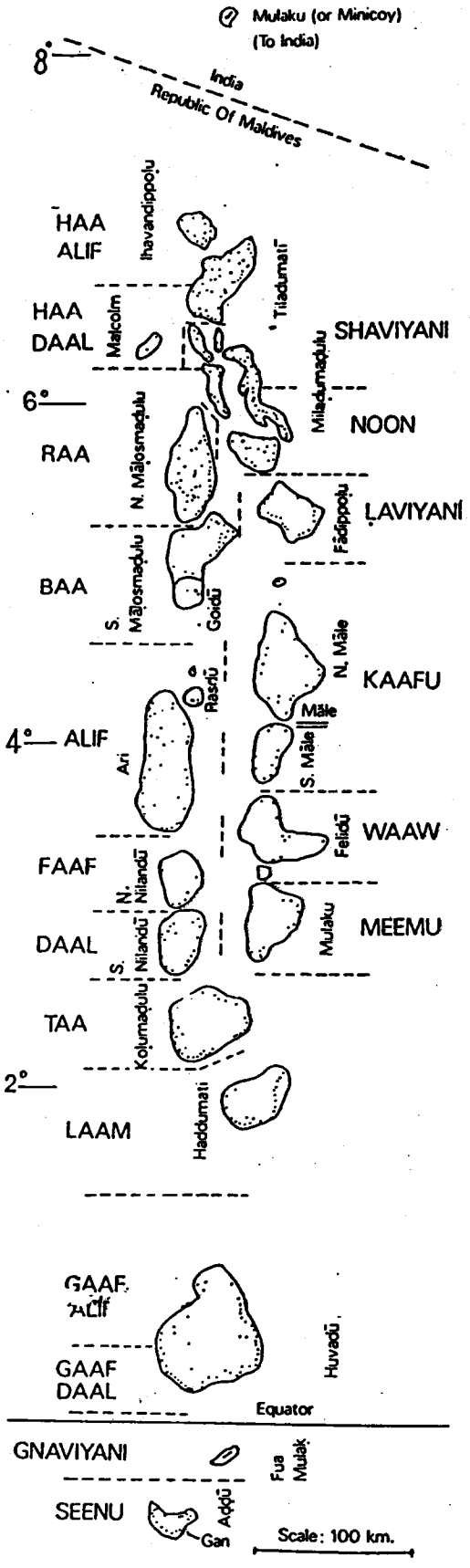
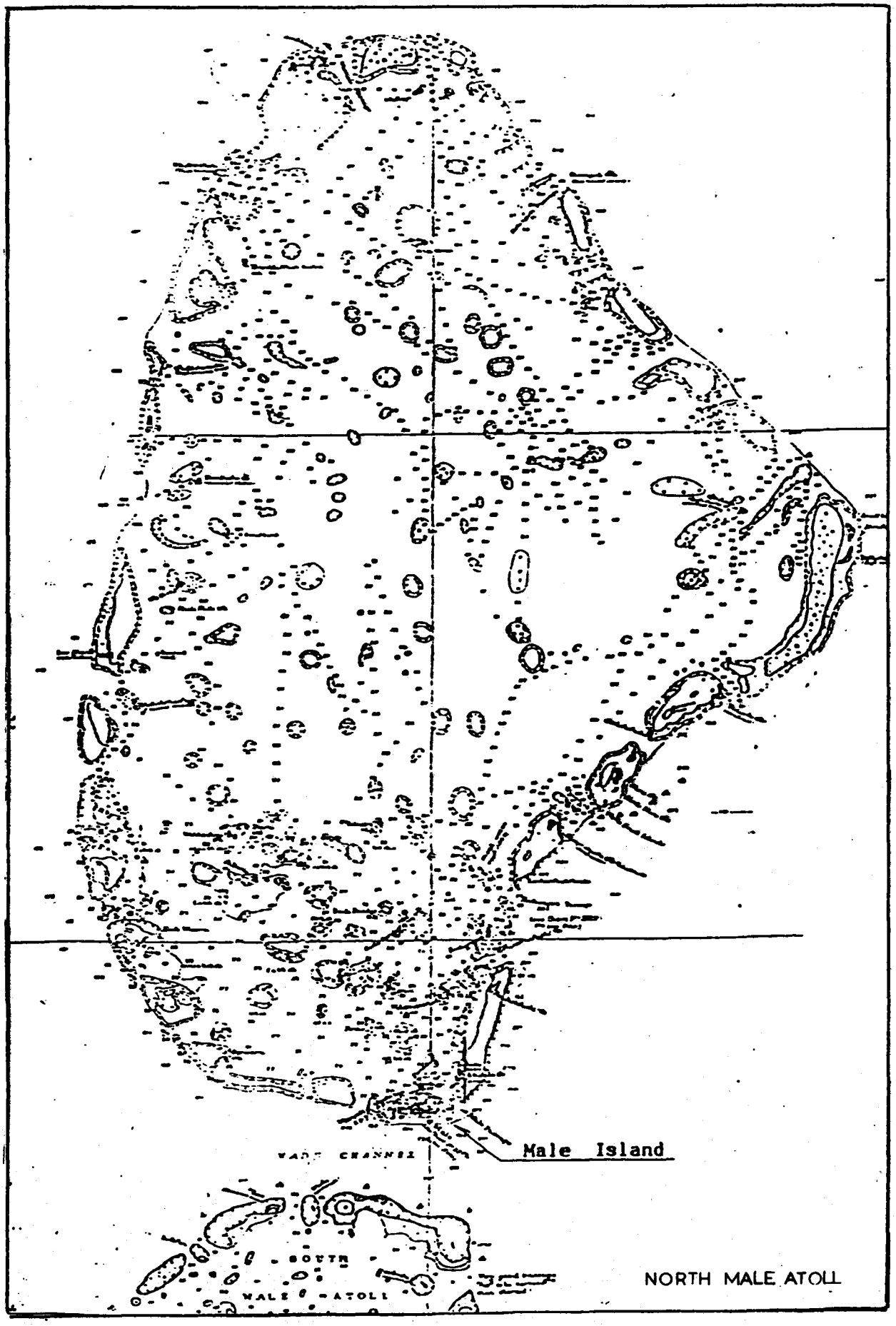


Figure 3. Generalized bathymetry of the Maldives Ridge

MALDIVE ISLANDS




Male Island
NORTH MALE ATOLL

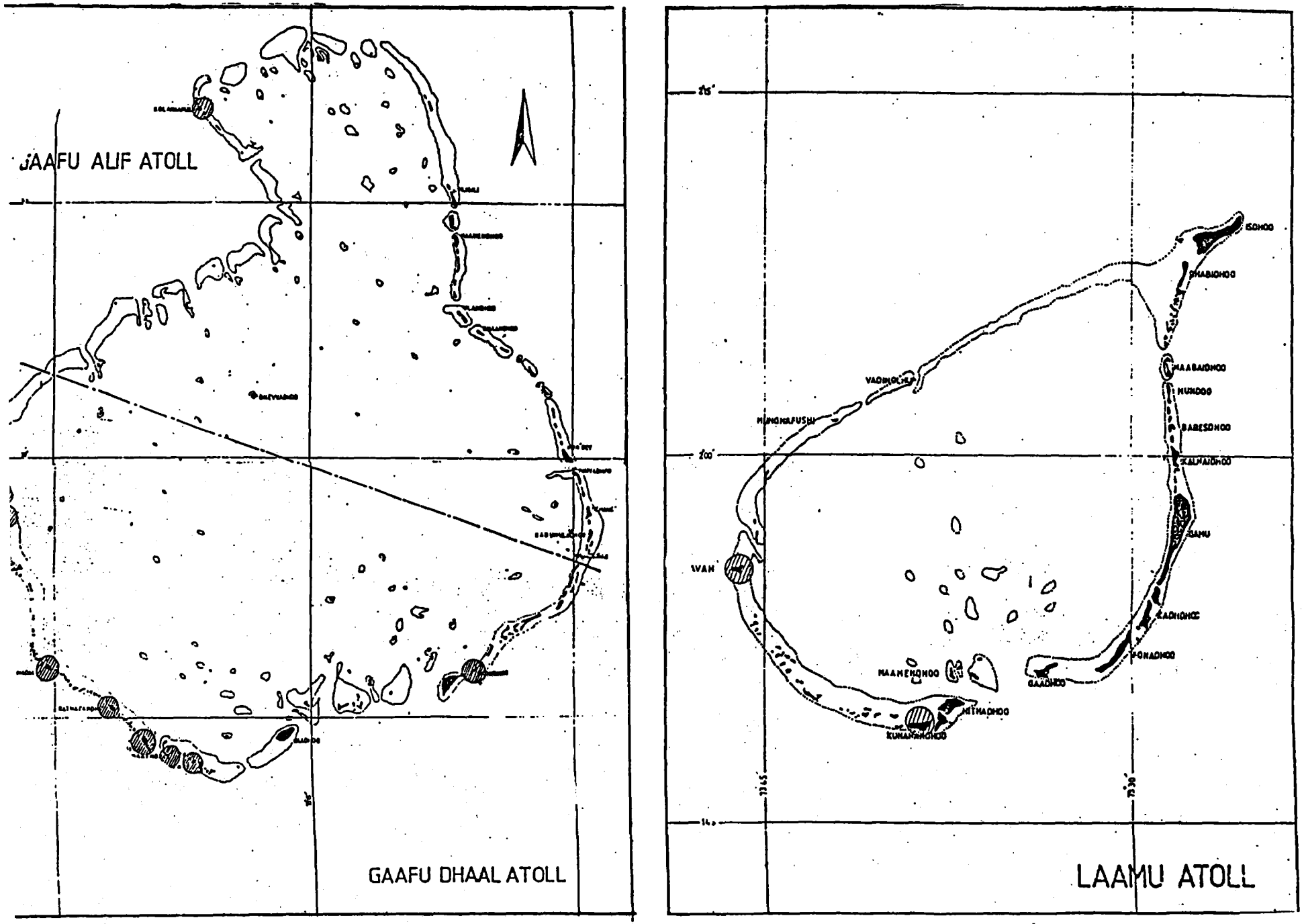


Figure 6. Examples of Maldive atoll configurations indicating sites of flooding.

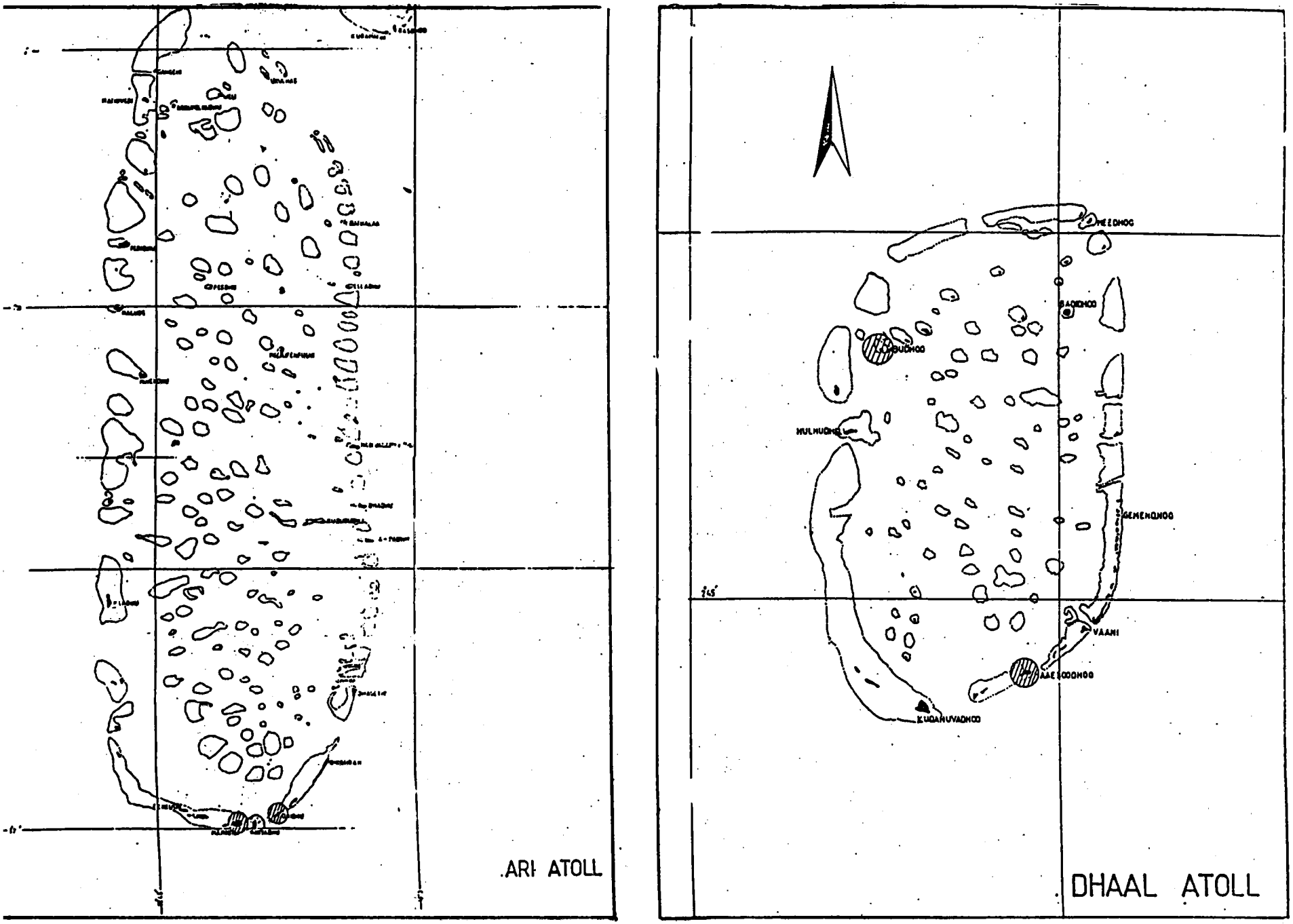


Figure 7. Examples of reef orientation in Maldive atolls, shaded areas are previous sites of flooding.

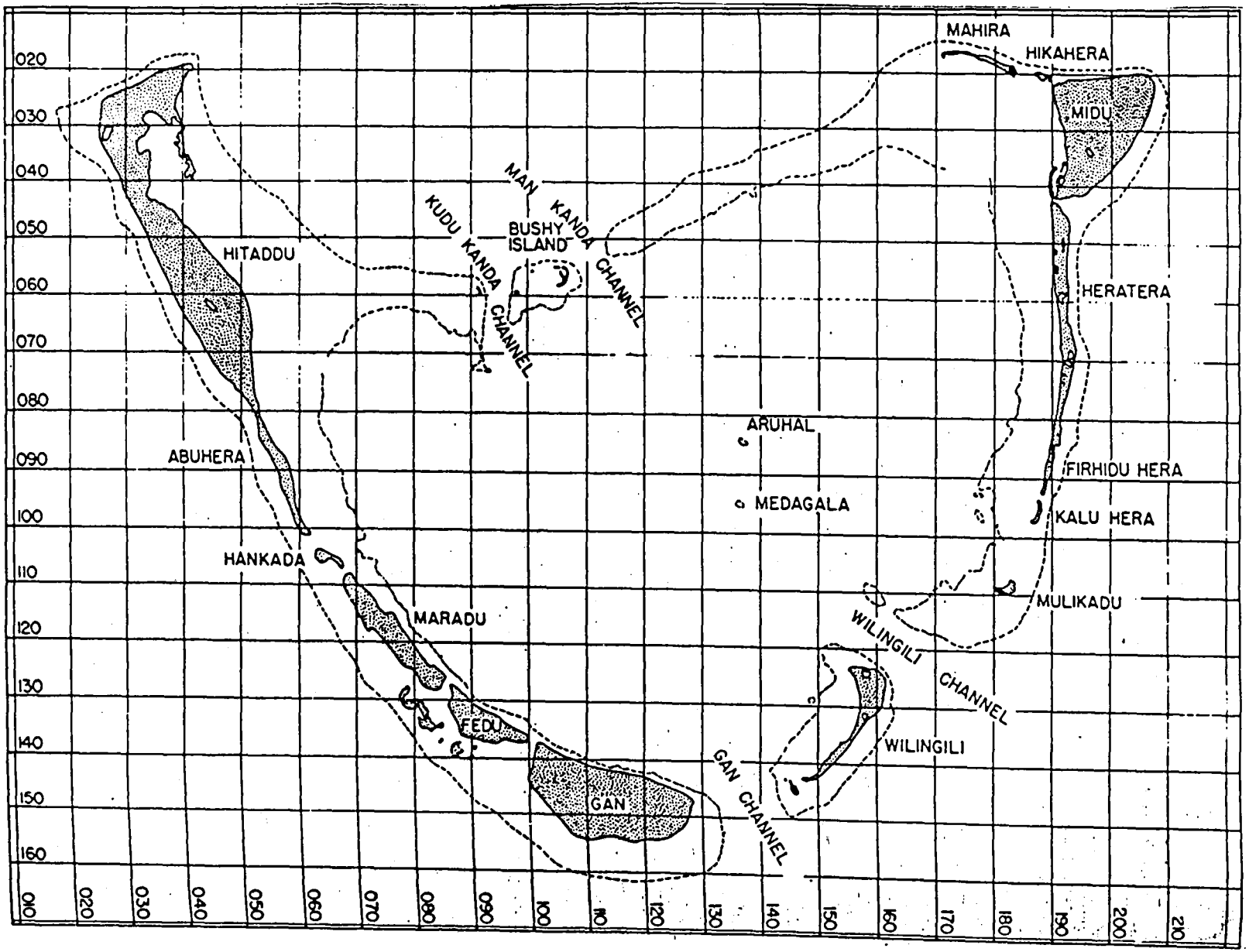


Figure 8. Addu Atoll, southern Maldives. The islands of the southwestern sector are now connected by a solid causeway causing extensive erosion.

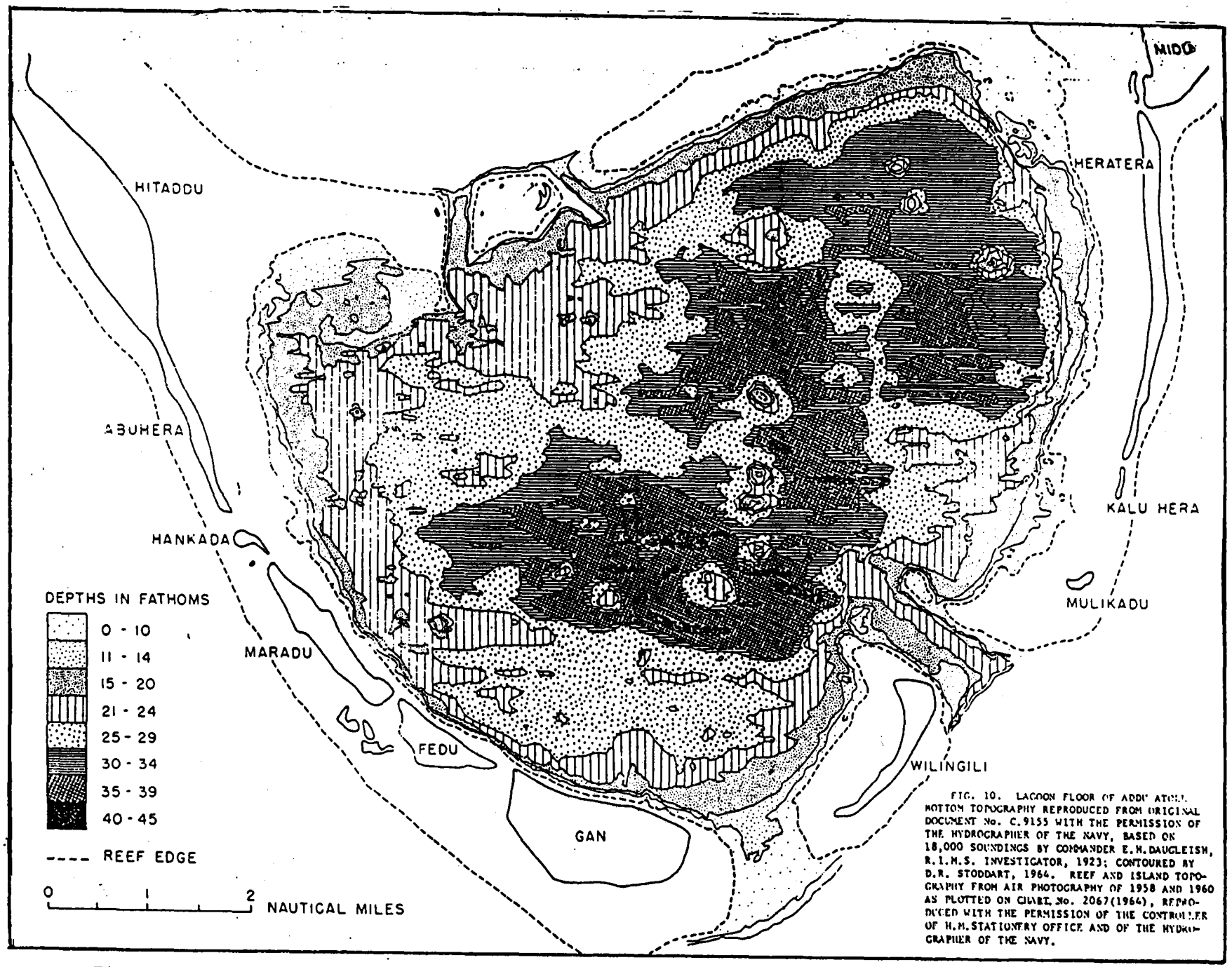
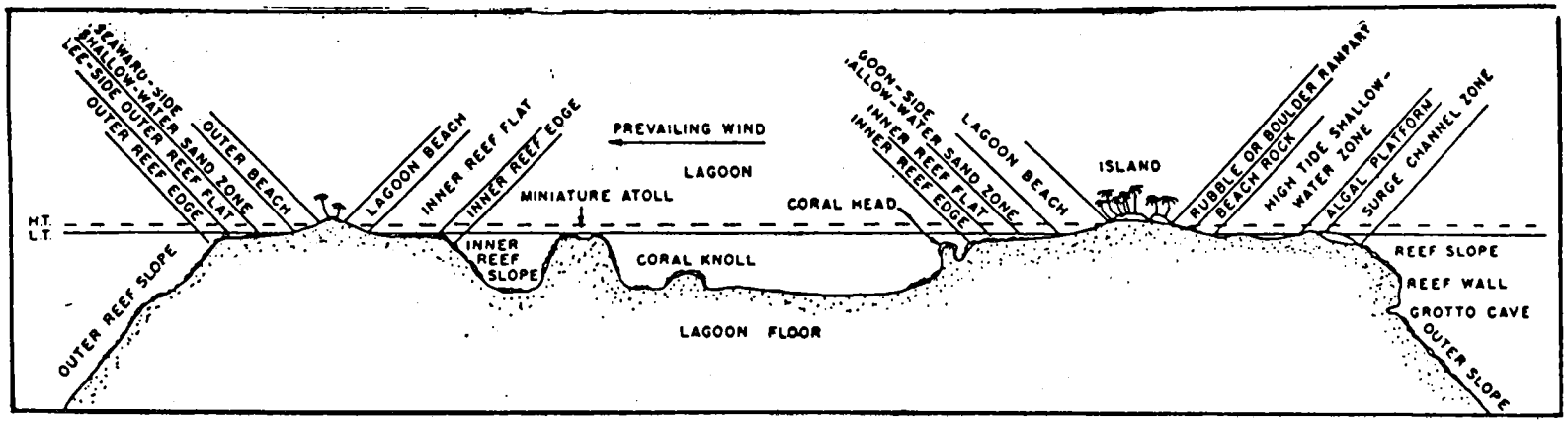


FIG. 10. LAGOON FLOOR OF ADDU ATOLL. BOTTOM TOPOGRAPHY REPRODUCED FROM ORIGINAL DOCUMENT No. C.9155 WITH THE PERMISSION OF THE HYDROGRAPHER OF THE NAVY, BASED ON 18,000 SOUNDINGS BY COMMANDER E.H. DAUGLEISH, R.I.M.S. INVESTIGATOR, 1923; CONTOURED BY D.R. STODDART, 1964. REEF AND ISLAND TOPOGRAPHY FROM AIR PHOTOGRAPHY OF 1958 AND 1960 AS PLOTTED ON CHART No. 2067(1964), REPRODUCED WITH THE PERMISSION OF THE CONTROLLER OF H.M. STATIONERY OFFICE AND OF THE HYDROGRAPHER OF THE NAVY.

Figure 9. Addu Atoll lagoon bathymetry, after Stoddart et al., 1966.



Zonation of Maldivian reefs, after Eibl-Eibesfeldt (1964).

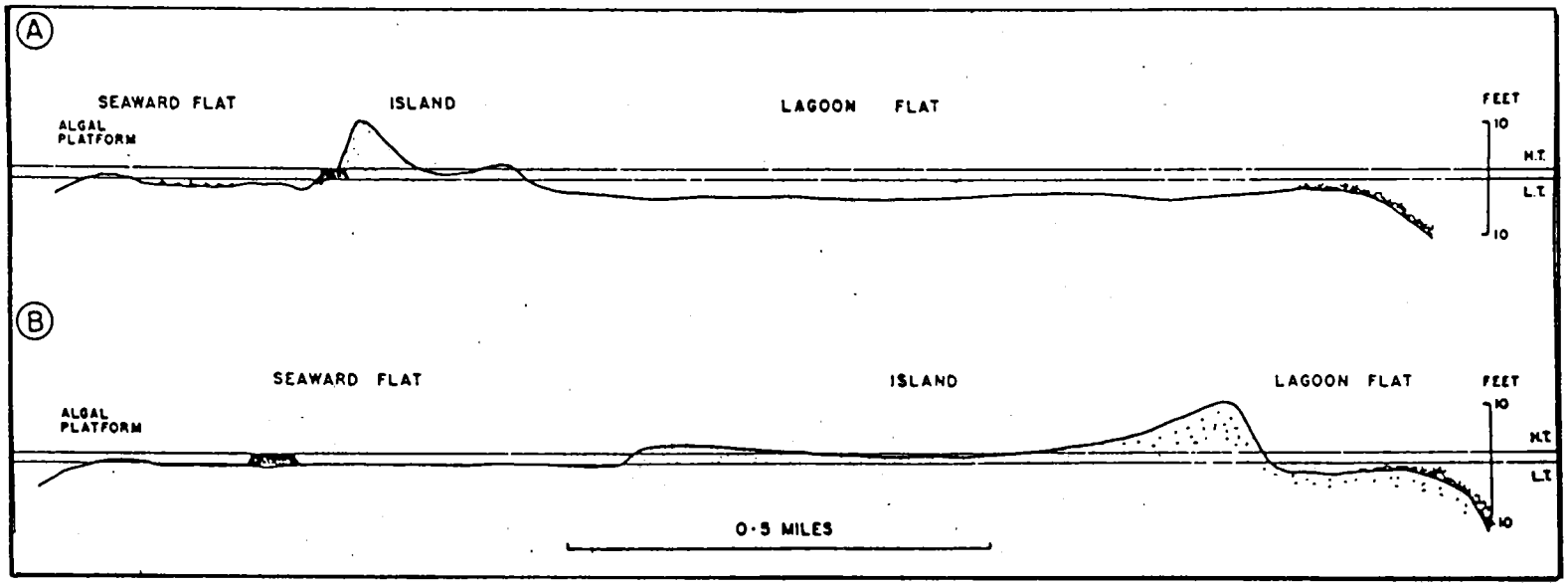


Figure 10. Diagrammatic cross-section of peripheral atoll reefs at (A) Hitaddu and (B) Gan Islands, Addu Atoll.

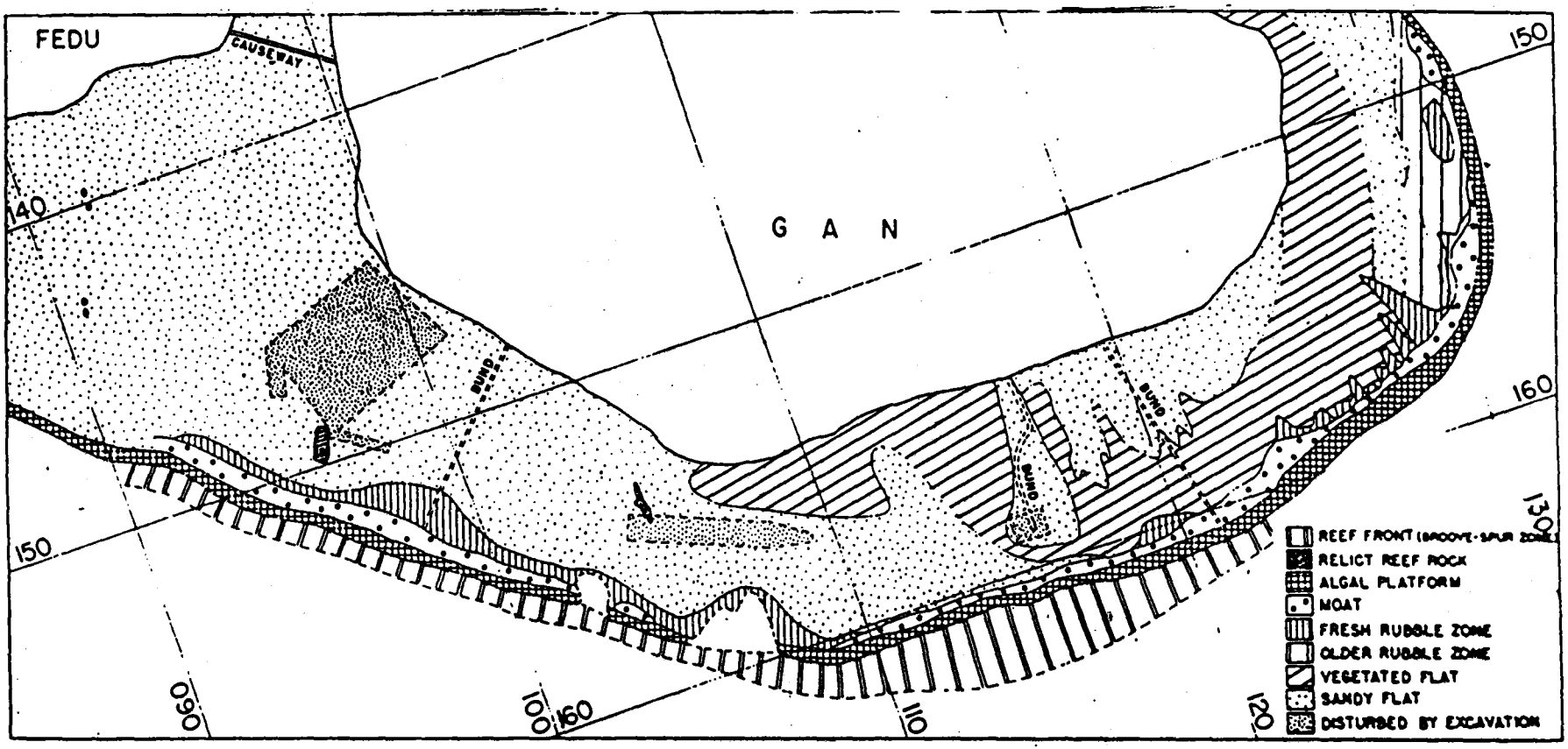


Figure 11. Ecological zonation on the seaward reef flat at Gan Island (Stoddart et al., 1966)

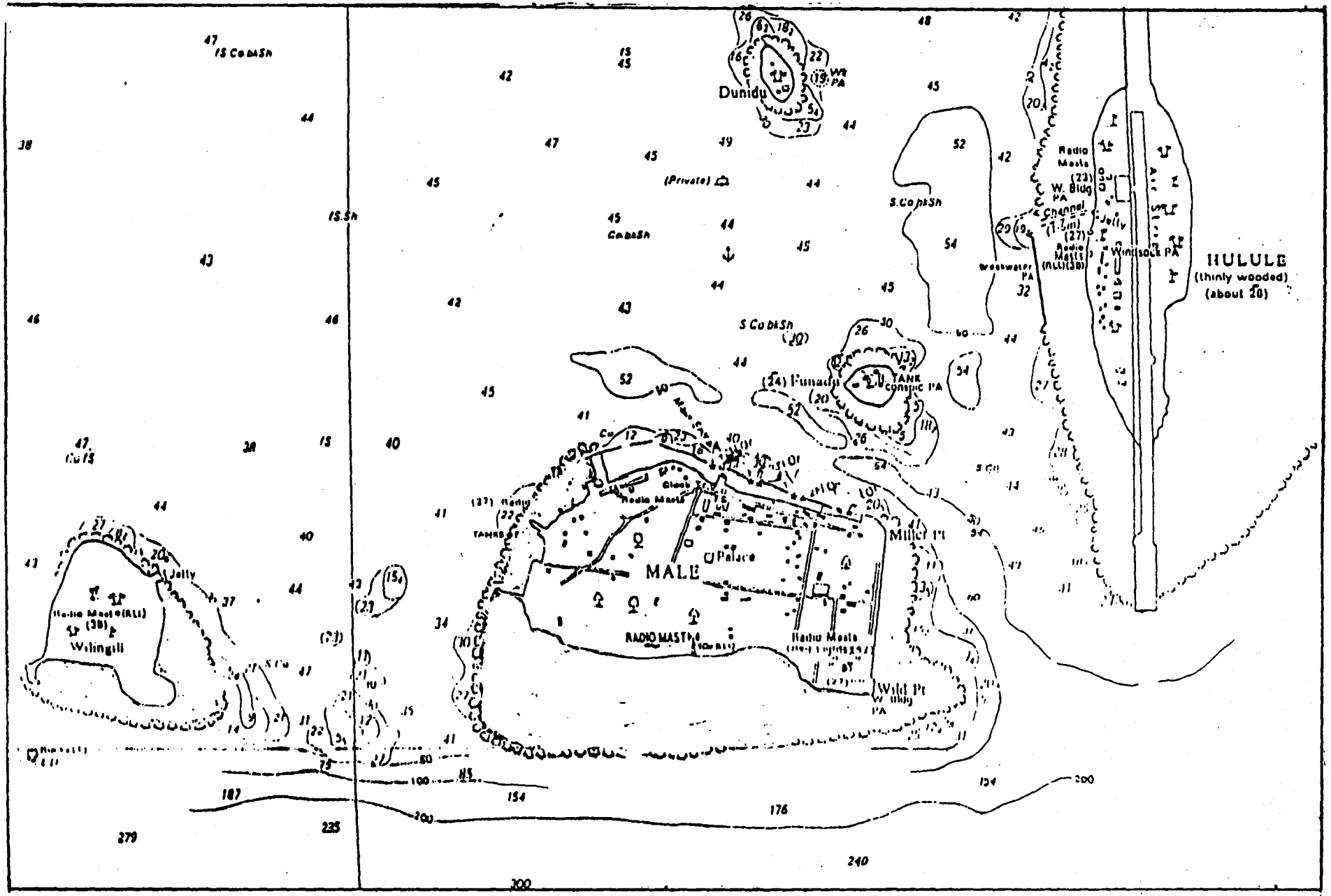


Figure 12. Malé Island, capital of the Maldives prior to land reclamation.

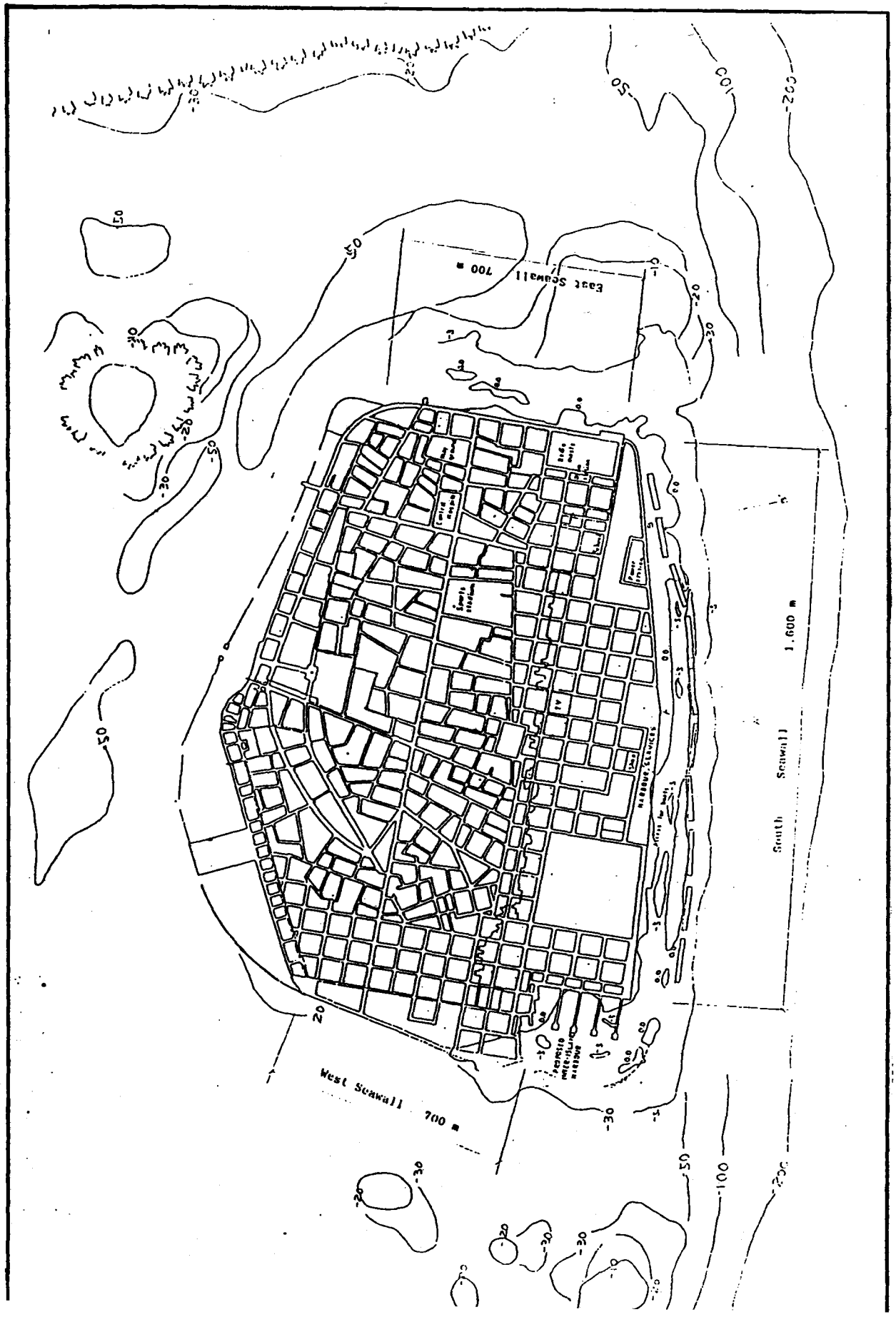


Figure 13. Malé Island after reclamation (1988)

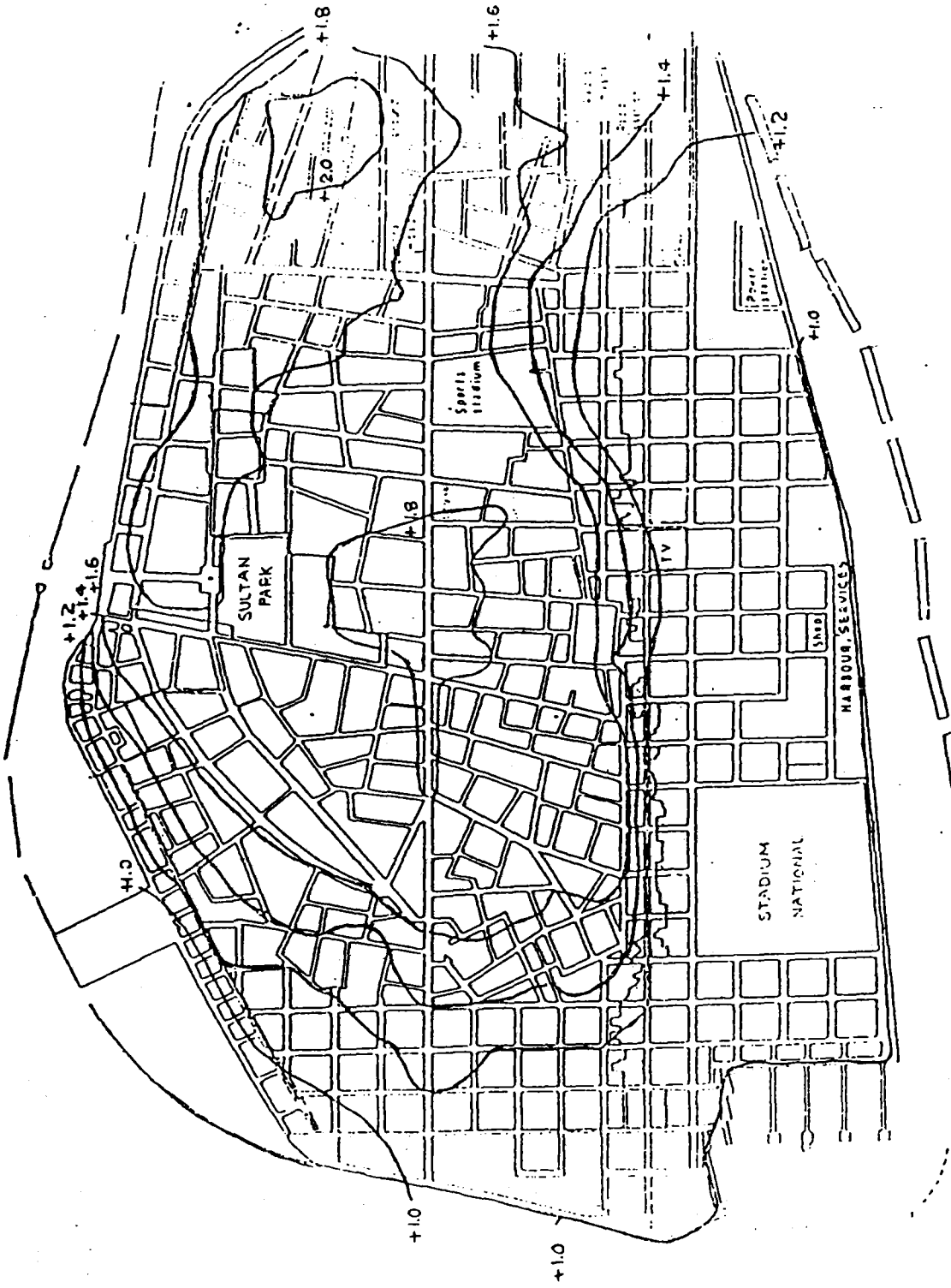


Figure 14. Land elevation and coastal defenses, Malé Island, Maldives.

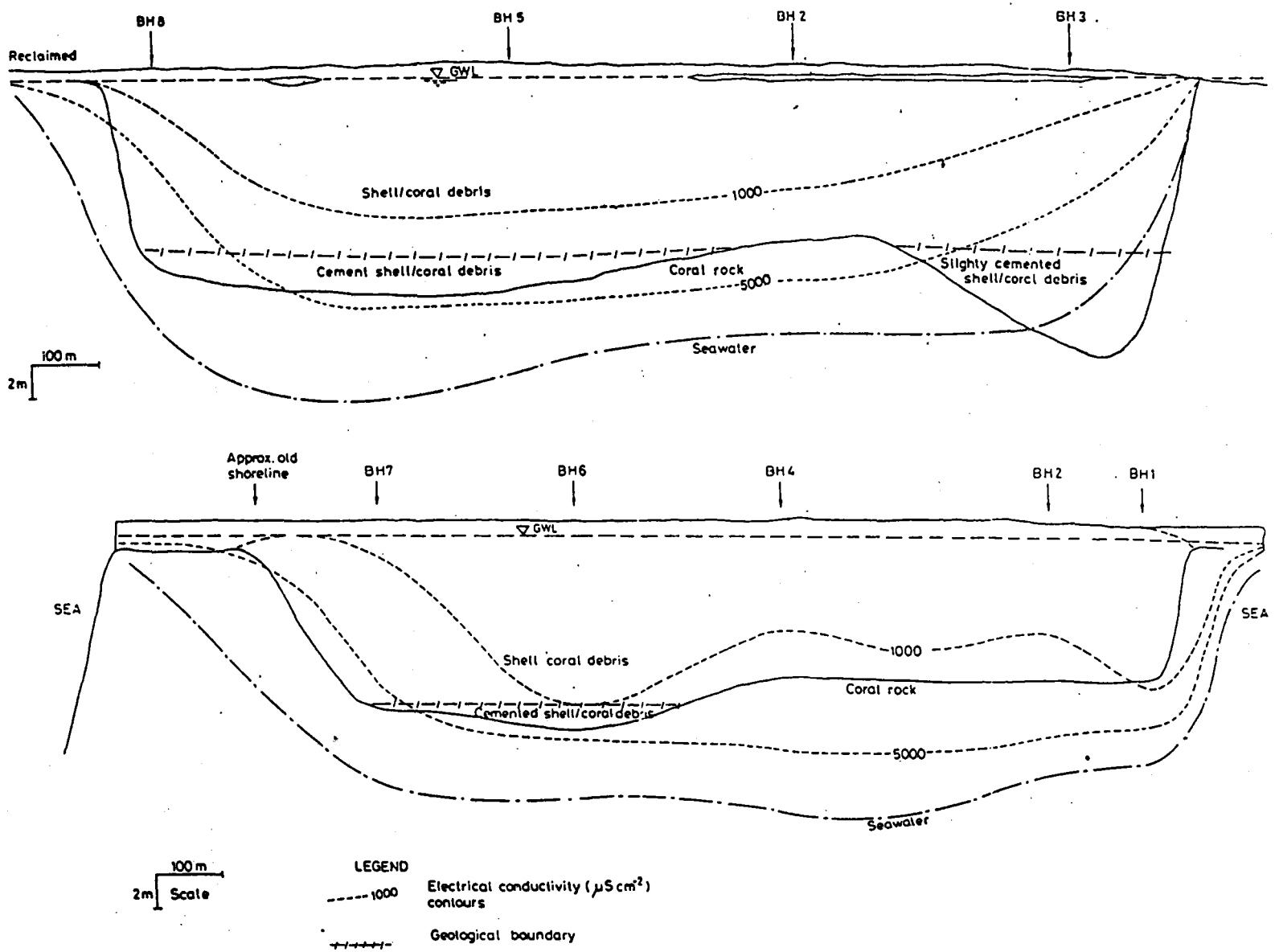
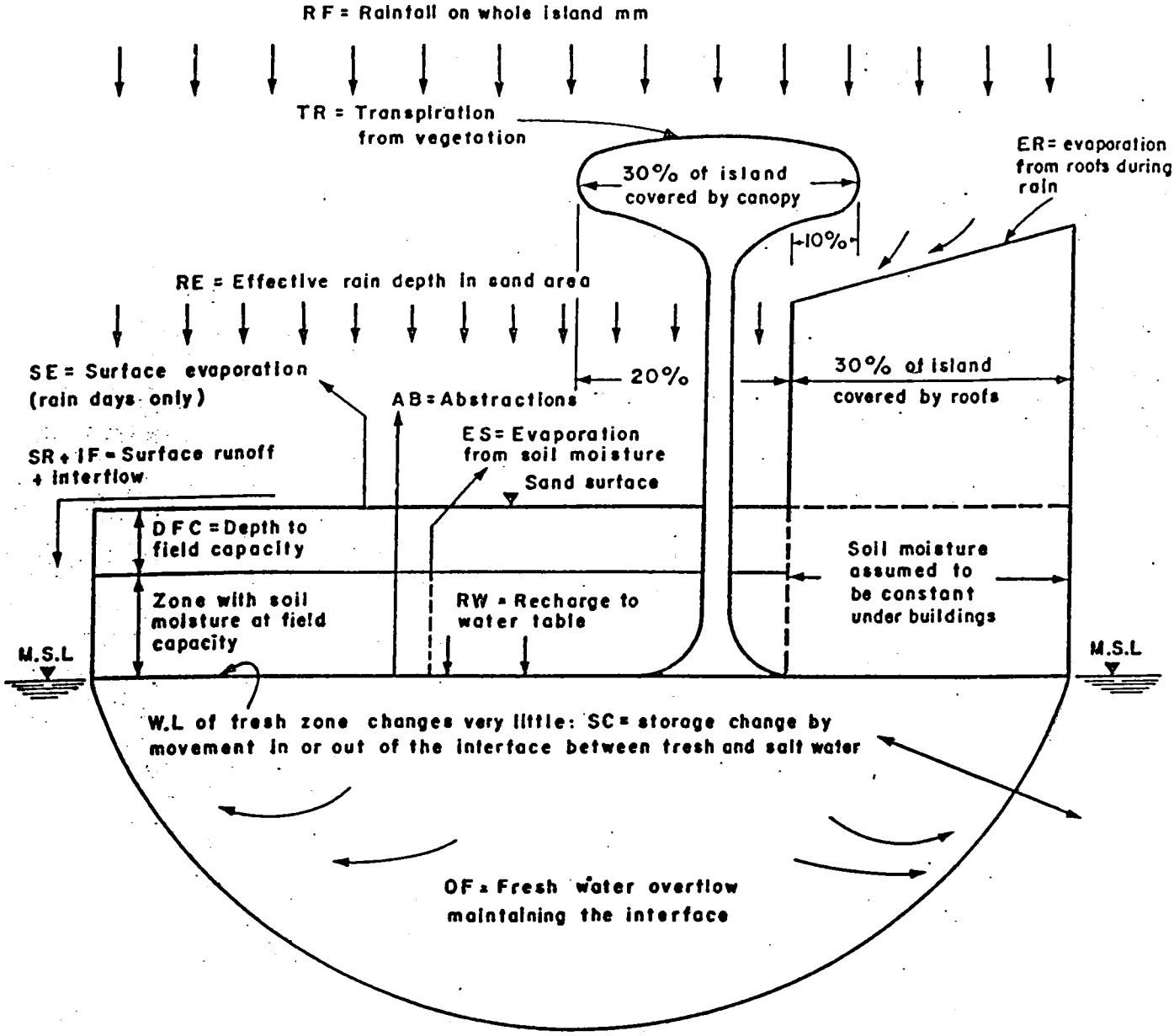


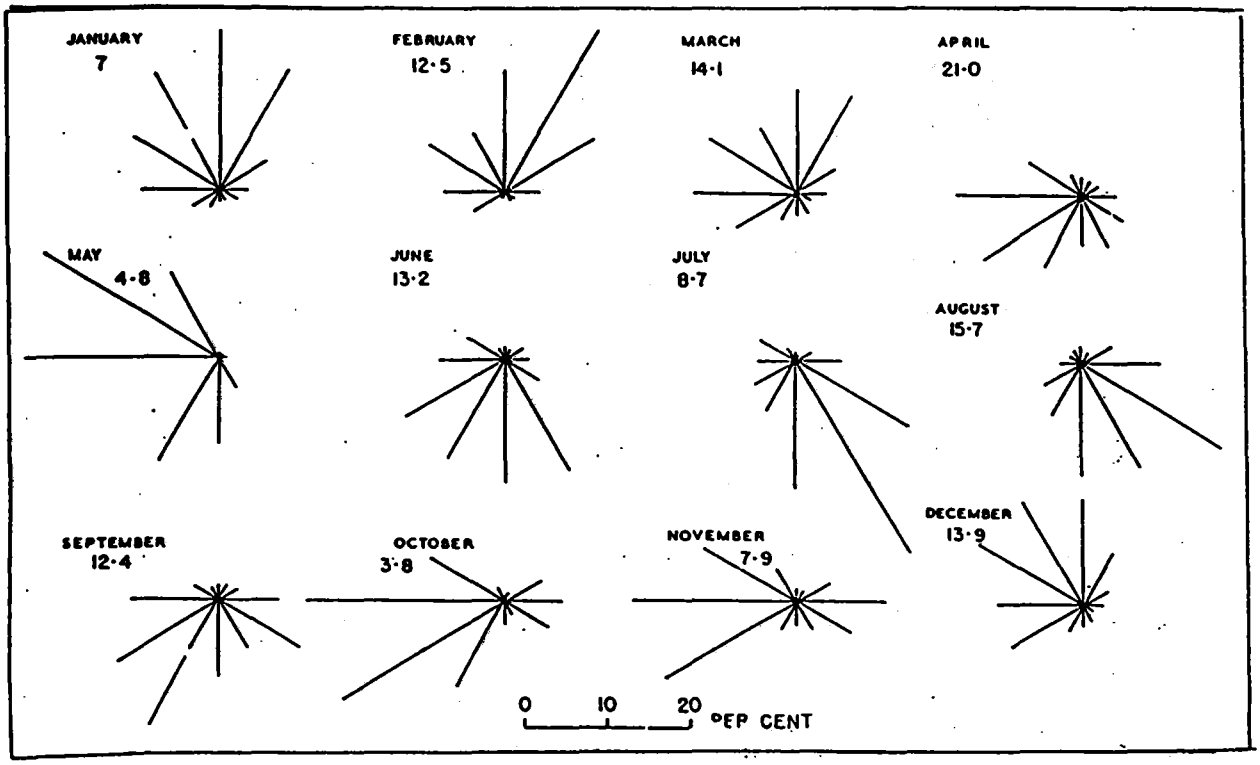
Figure 15. The subsurface lithology and extent of the freshwater lens in Malé island



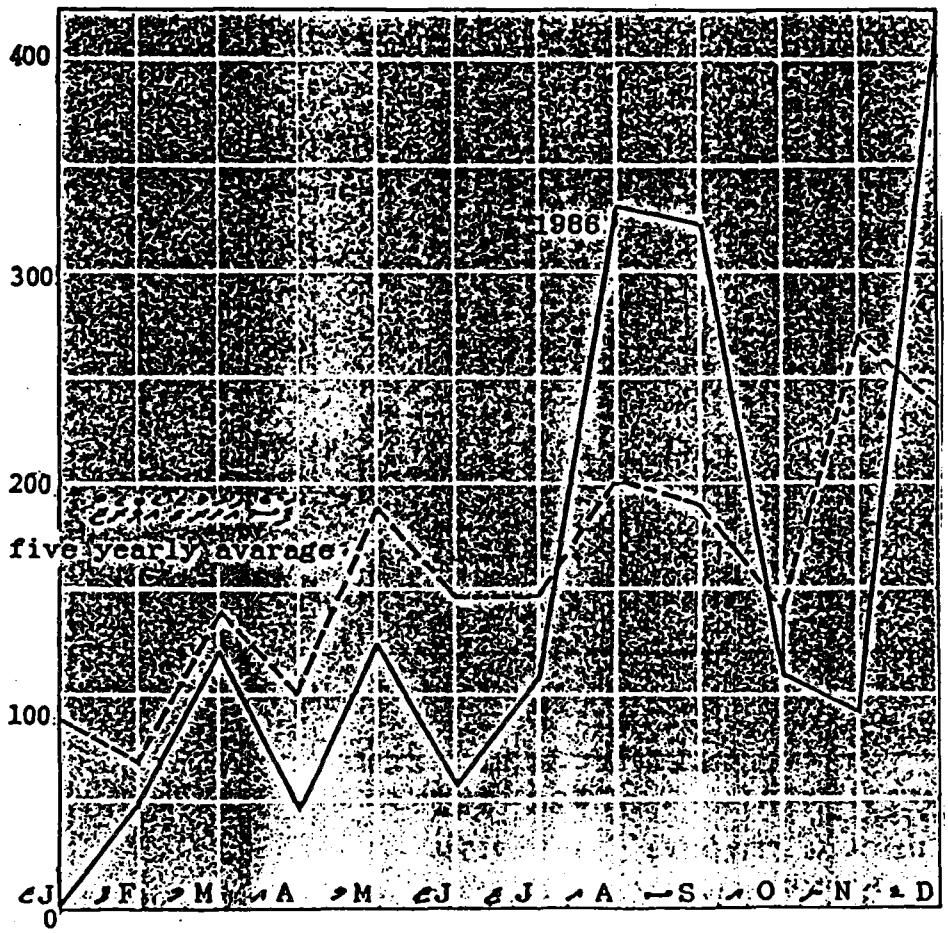
RE = RW + SE + ES + SR + IF _____ equation (1)
units : mm. over sand area

RW = TR + AB + OF + SC _____ equation (2)
units: mm. over whole island

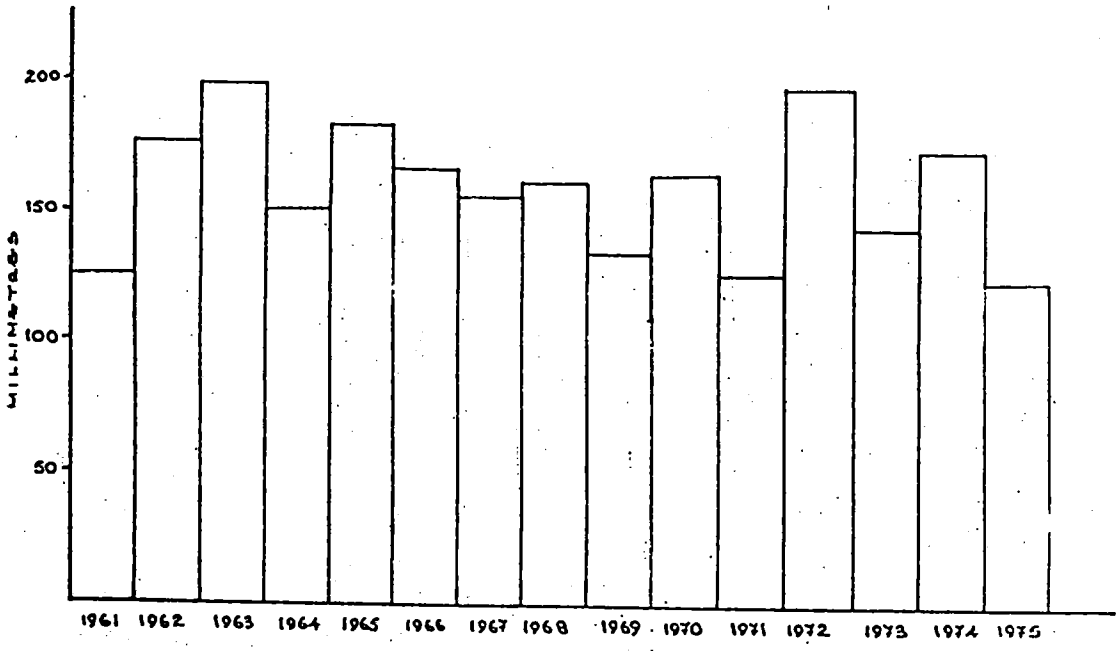
Figure 16. Malé hydrological cycle (Binnie & Partners, 1983)



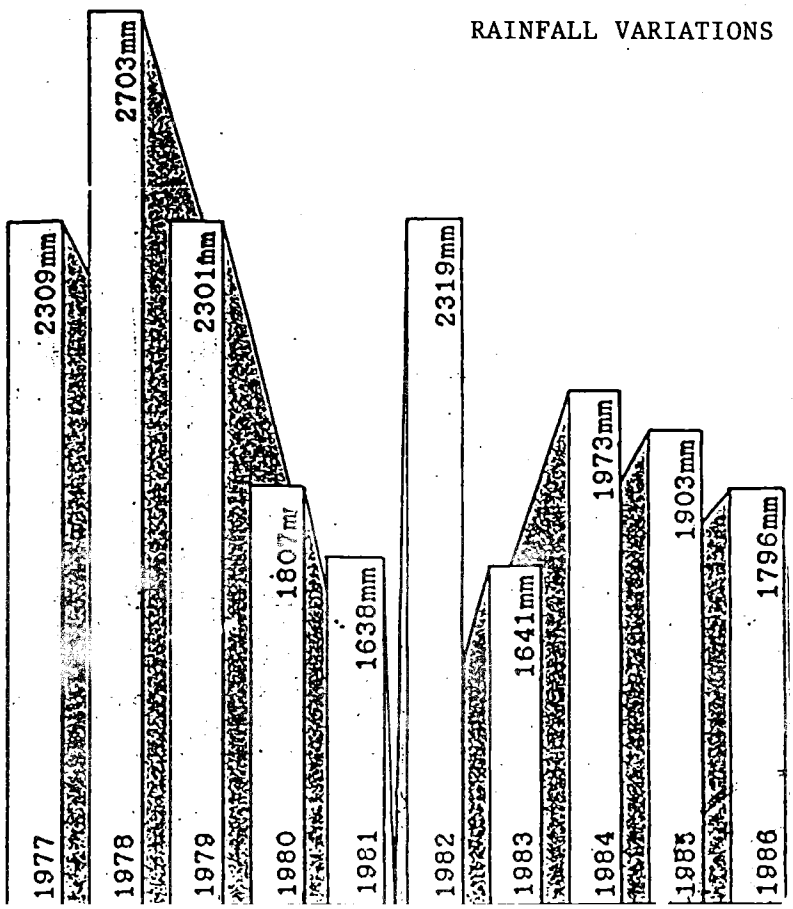
Mean monthly wind directions at Gan island, 1960-64

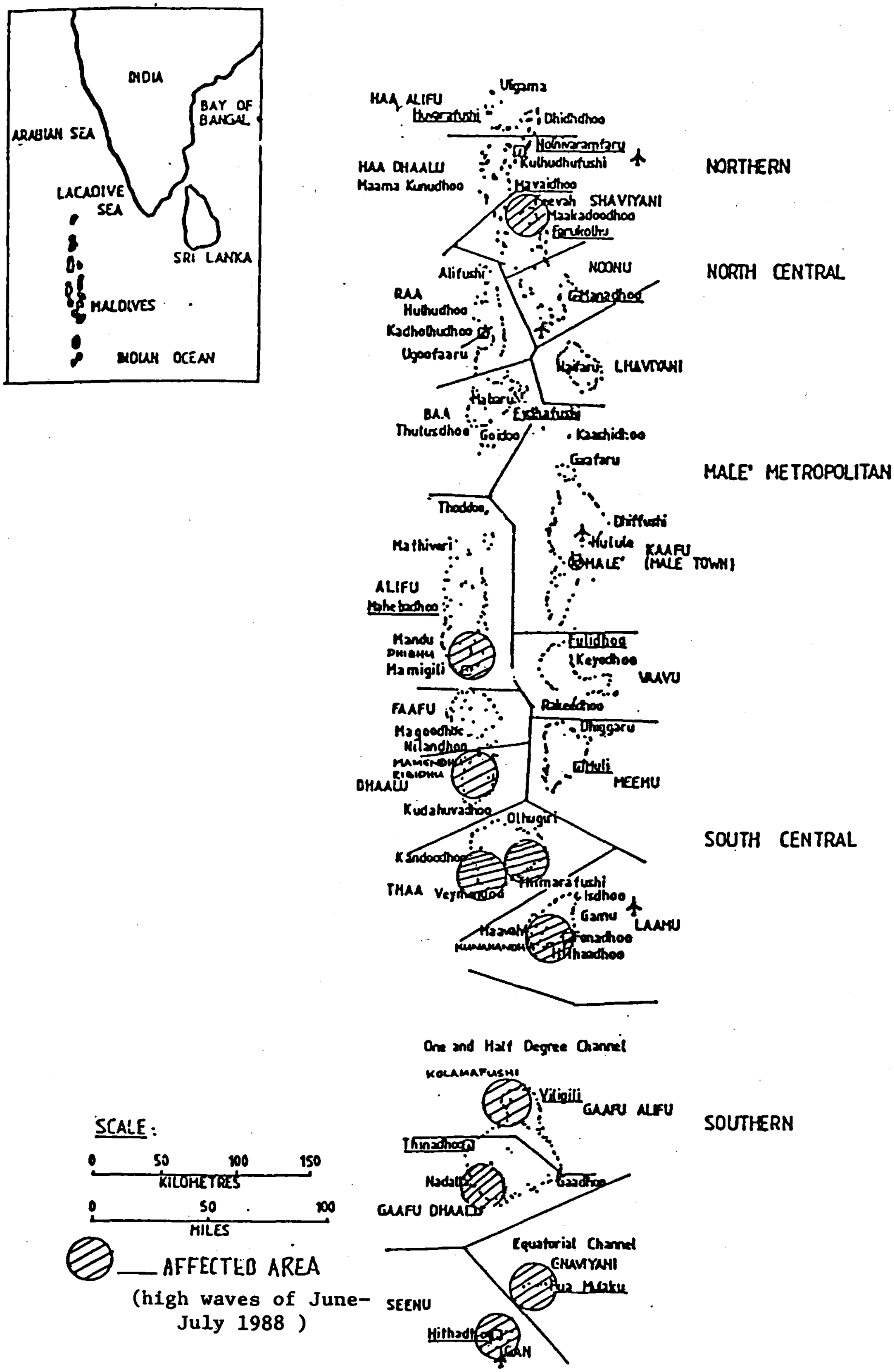


MONTHLY DISTRIBUTION OF RAINFALL

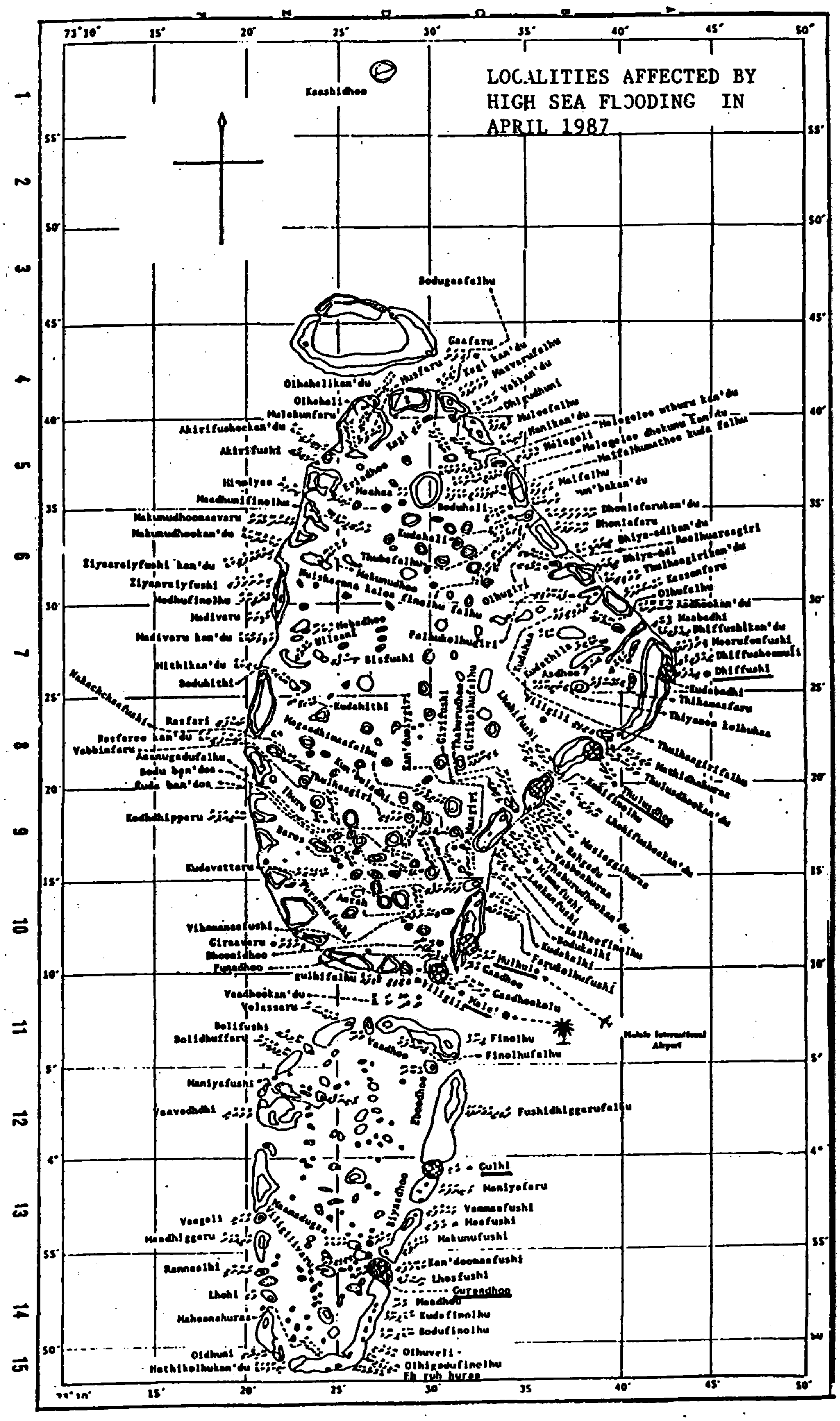


RAINFALL VARIATIONS





(high waves of June-July 1988)


LOCALITIES AFFECTED BY
HIGH SEA FLOODING IN
APRIL 1987

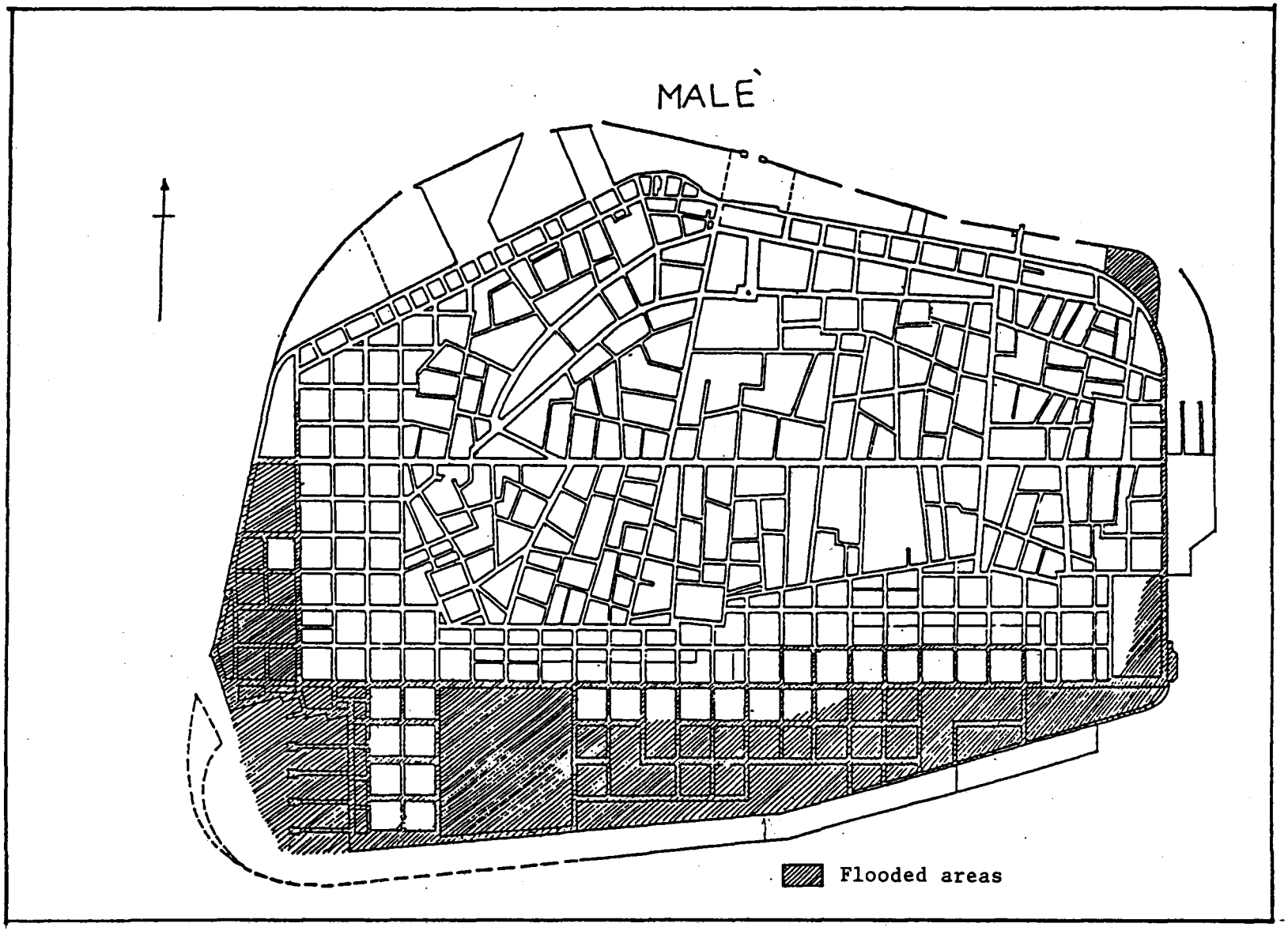


Figure 21. Extent of flooding of Malé island, April 1987

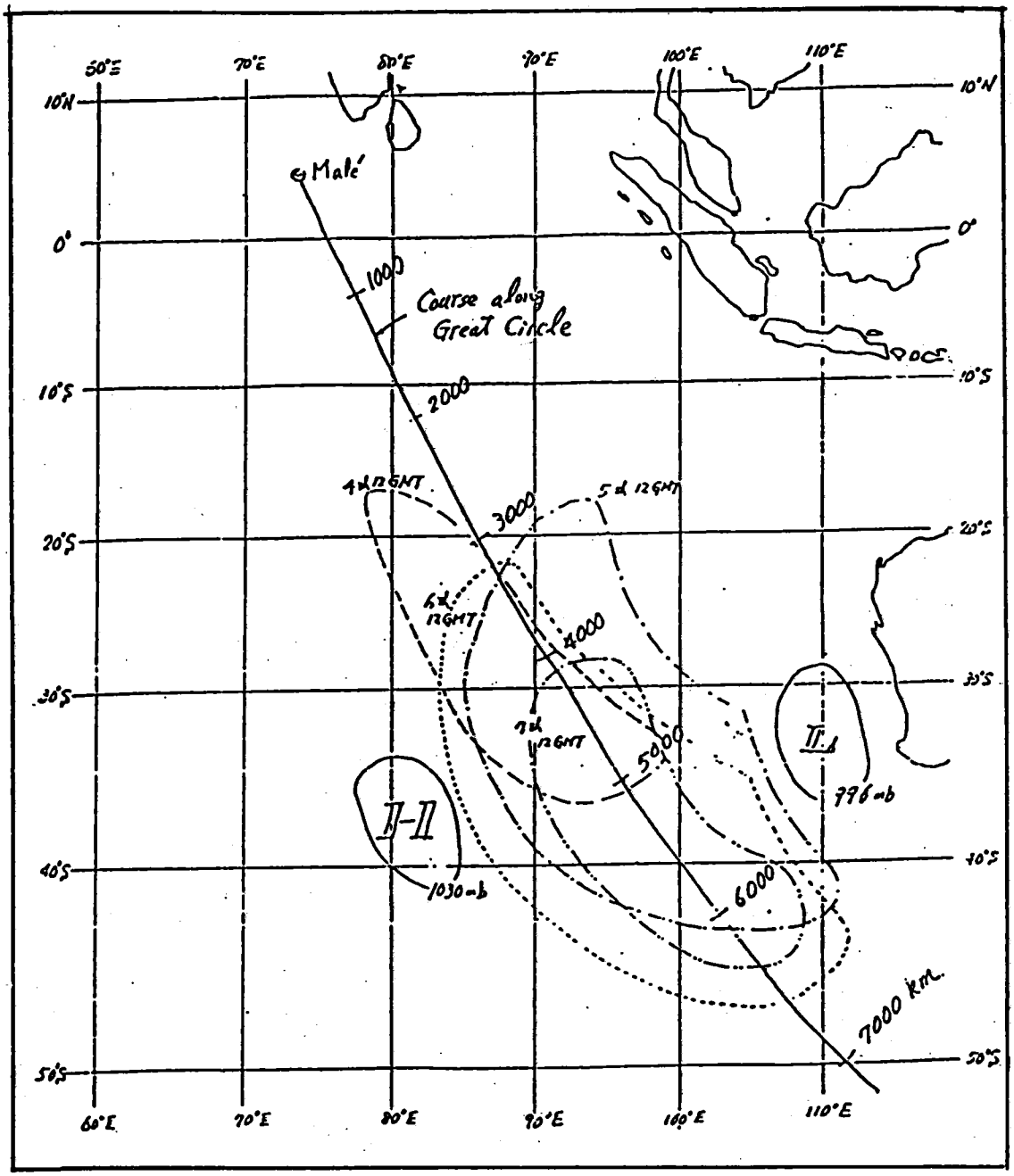
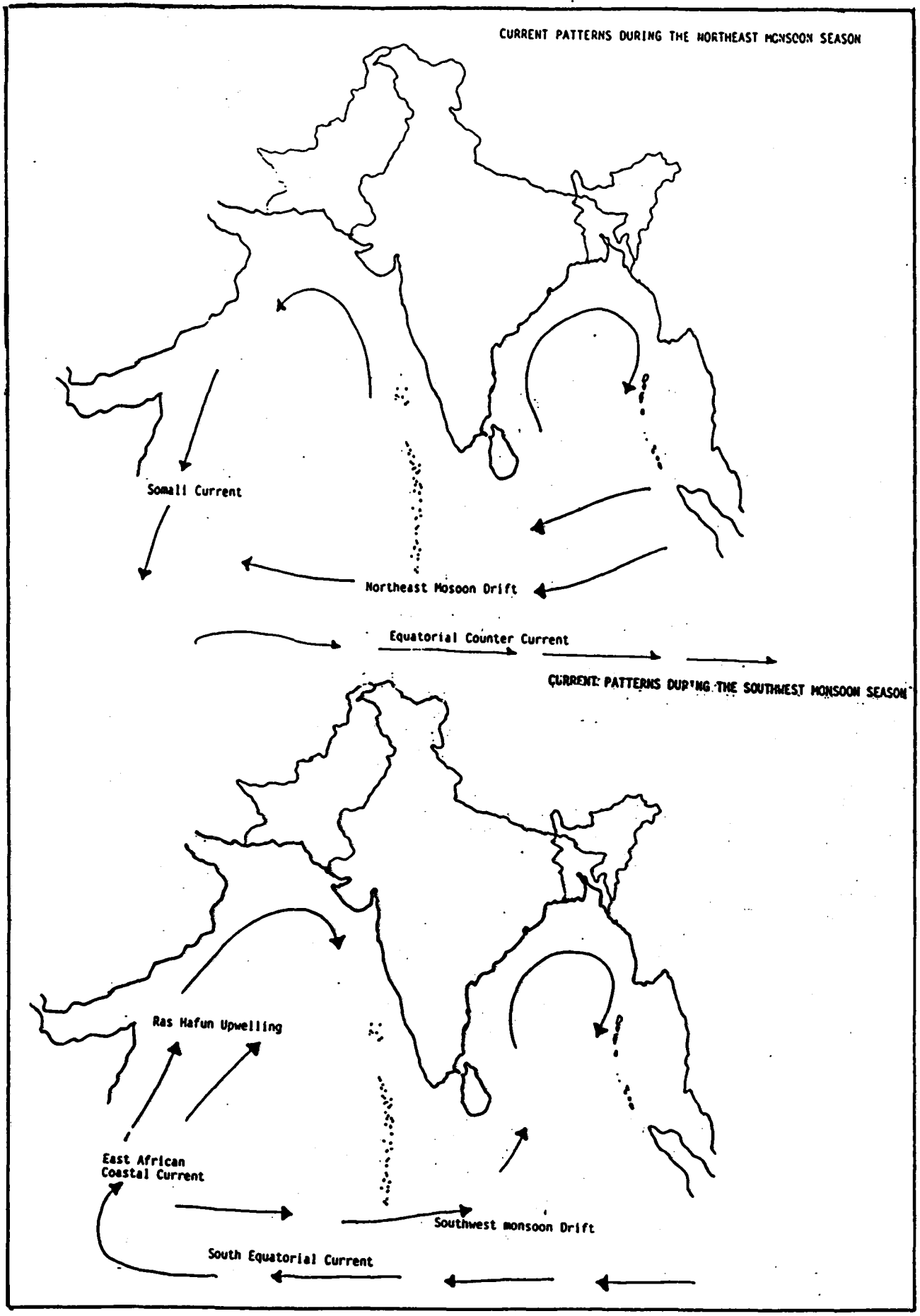
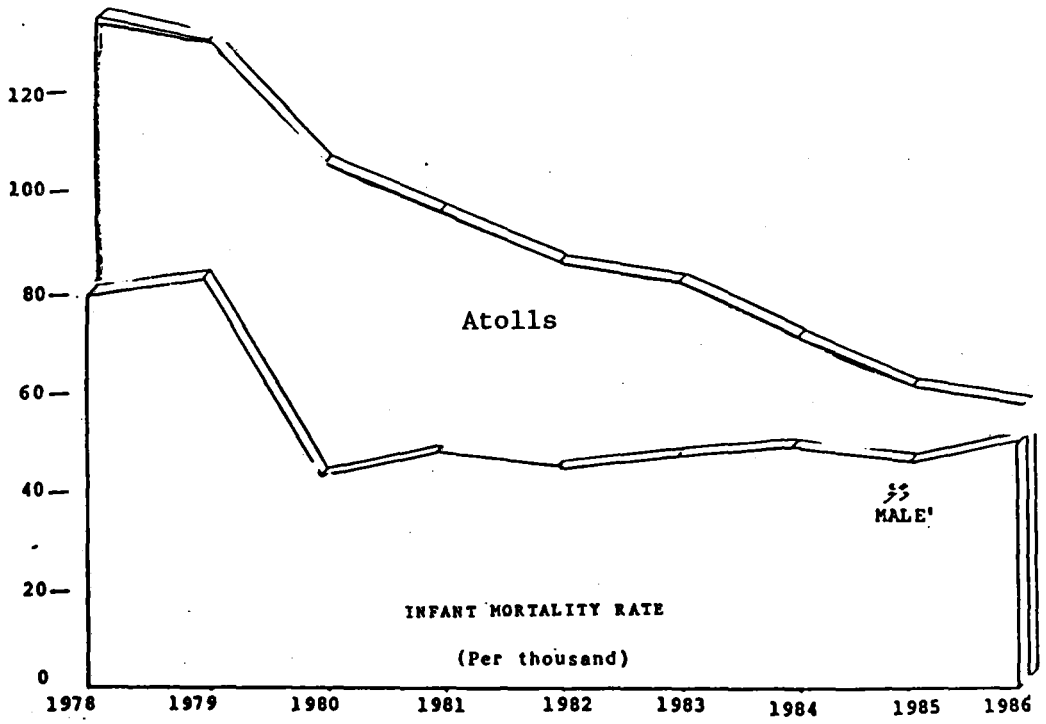


Figure 22. Presumed direction of propagation swells generated by a storm in the SW Indian Ocean, April 1987 (Goda 1988)


CURRENT PATTERNS DURING THE NORTHEAST MONSOON SEASON
Somali Current
Northeast Mosoon Drift
Equatorial Counter Current
CURRENT PATTERNS DURING THE SOUTHWEST MONSOON SEASON
Ras Hafun Upwelling
East African
Coastal Current
Southwest monsoon Drift
South Equatorial Current



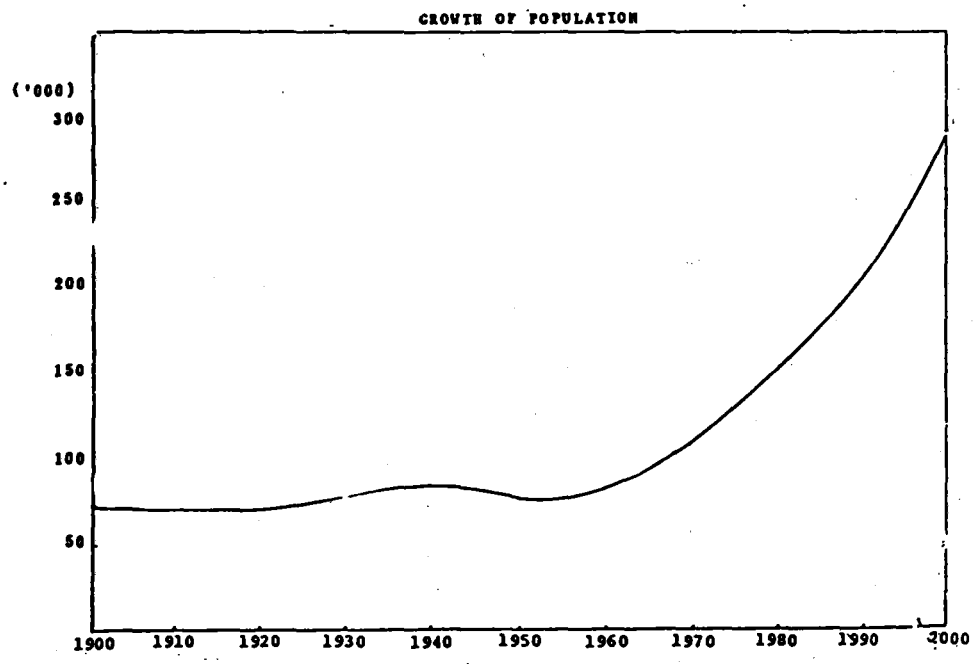


Figure 24. Demographic trends for Malé and the Maldives.

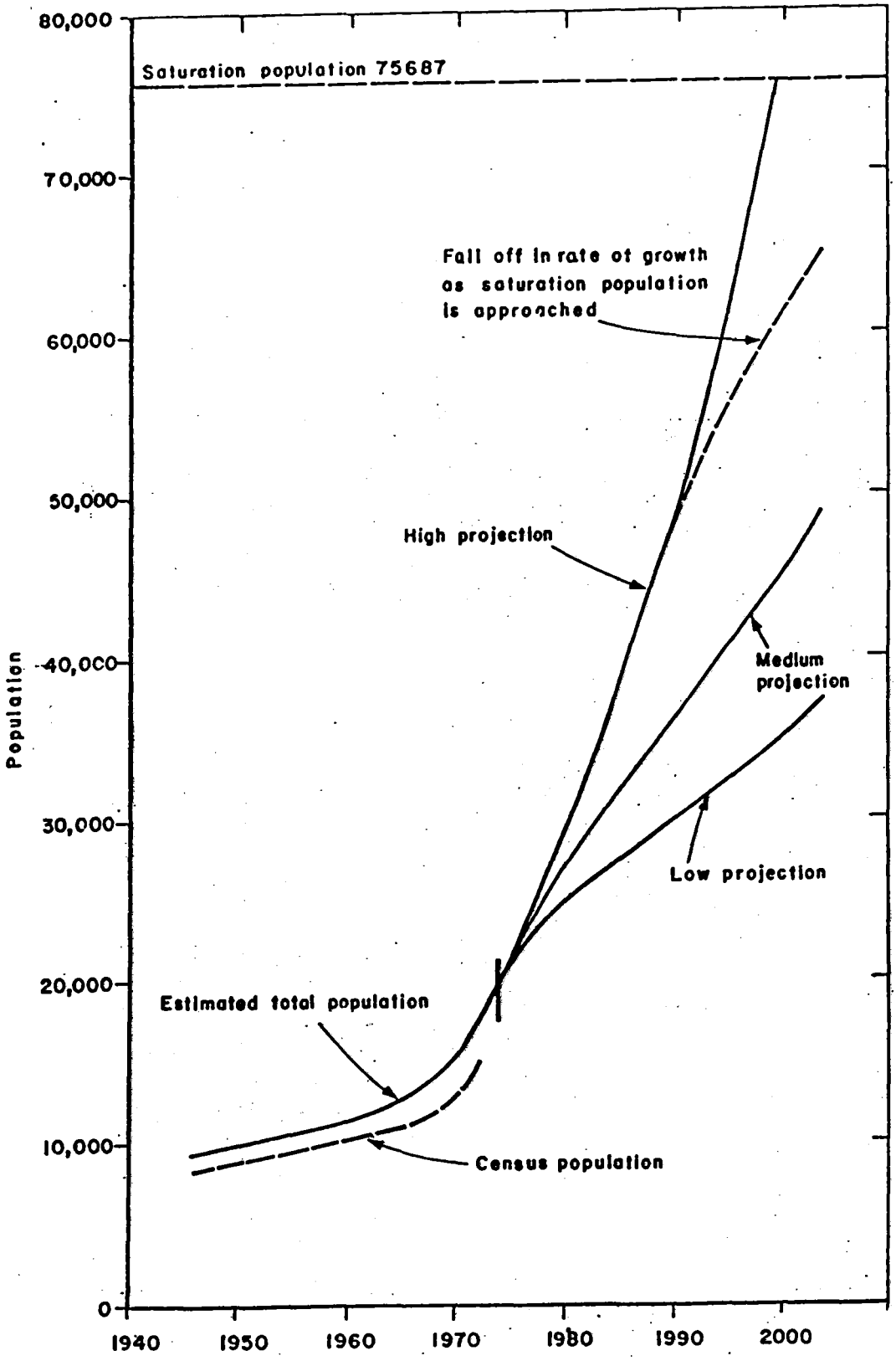
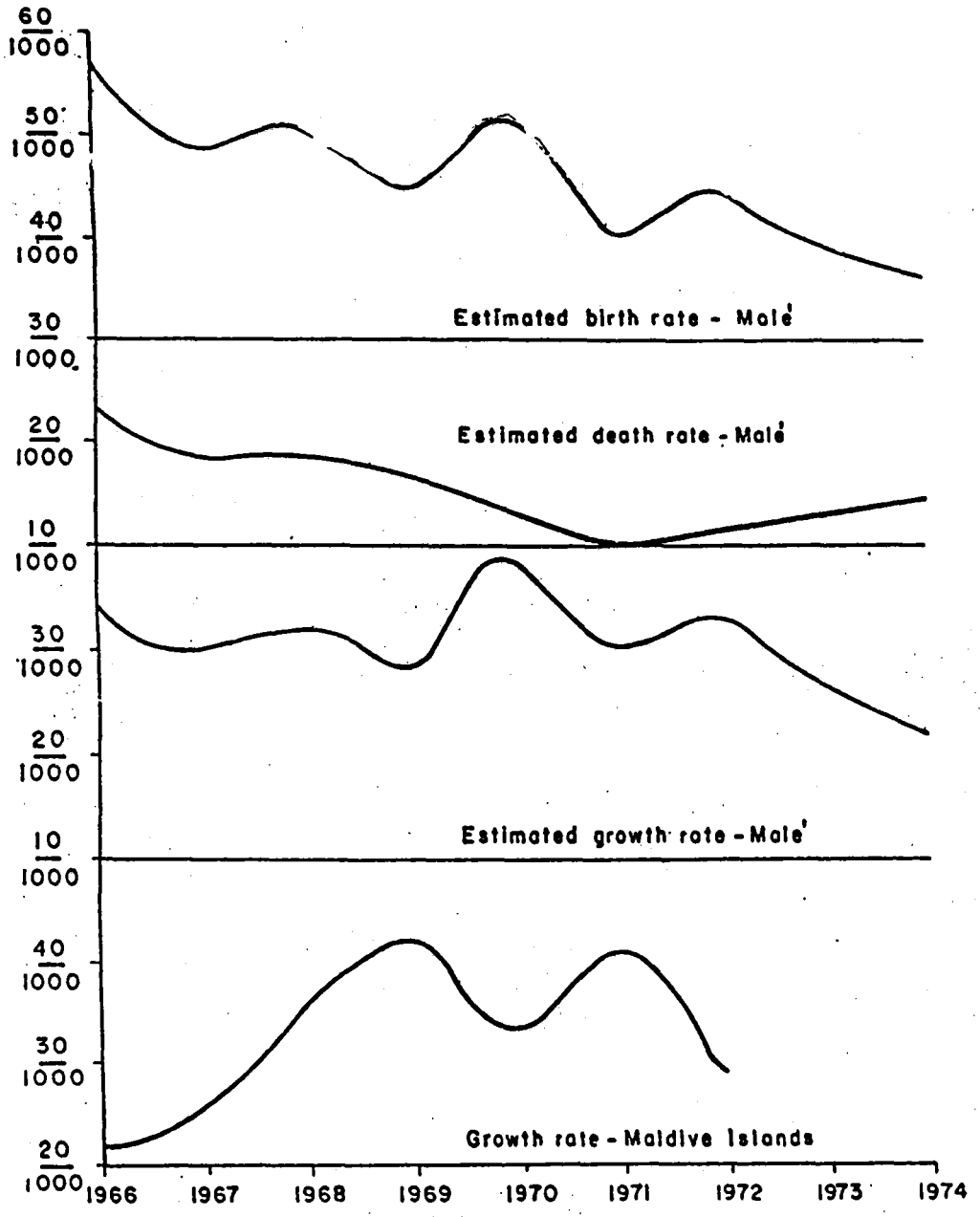
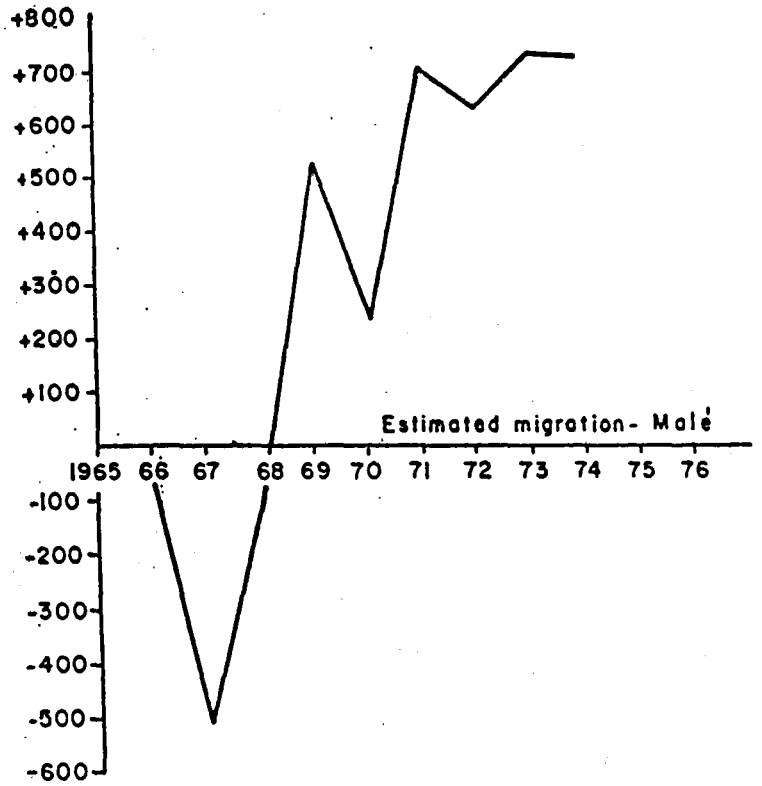


Figure 25. Population projections for Malé, Republic of the Maldives.

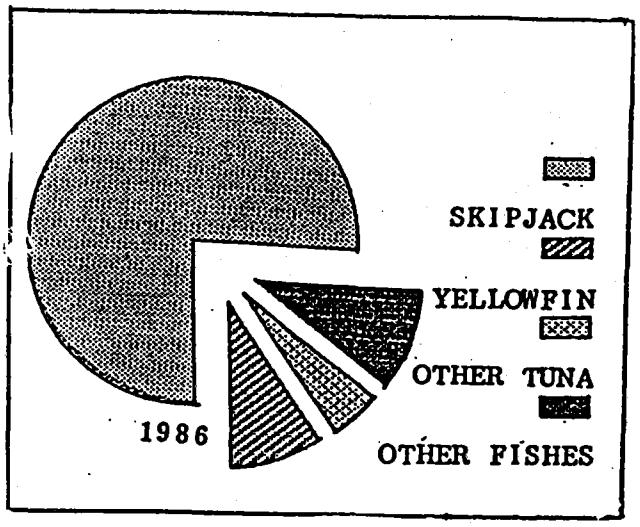




Note.
Rate between June 1973 and June 1974 is shown under 1974 and others similarly

ANNUAL BIRTH, DEATH & MIGRATION RATES

Figure 26. Population parameters for Malé, Republic of the Maldives.



COMPOSITION OF FISH CATCH

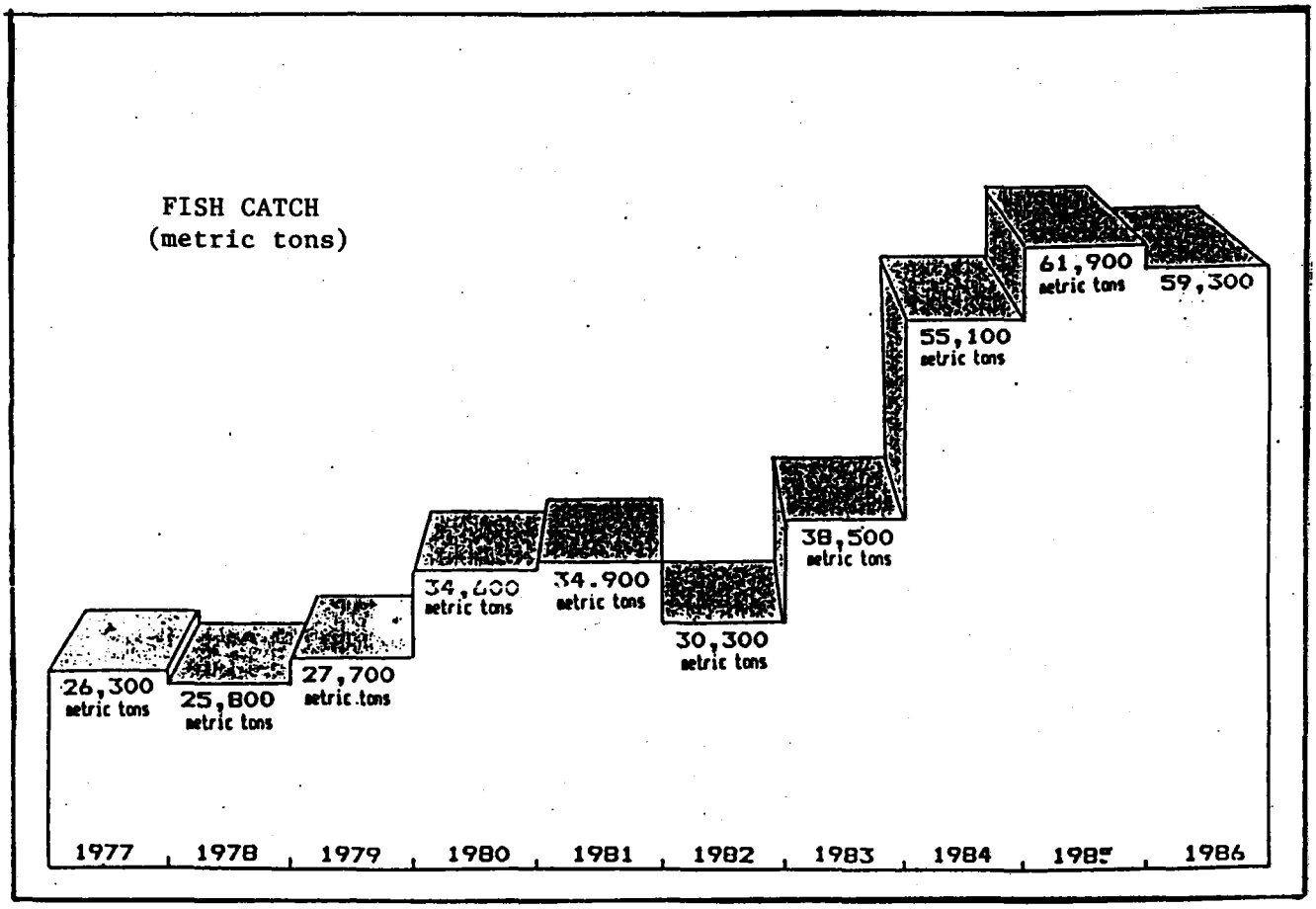
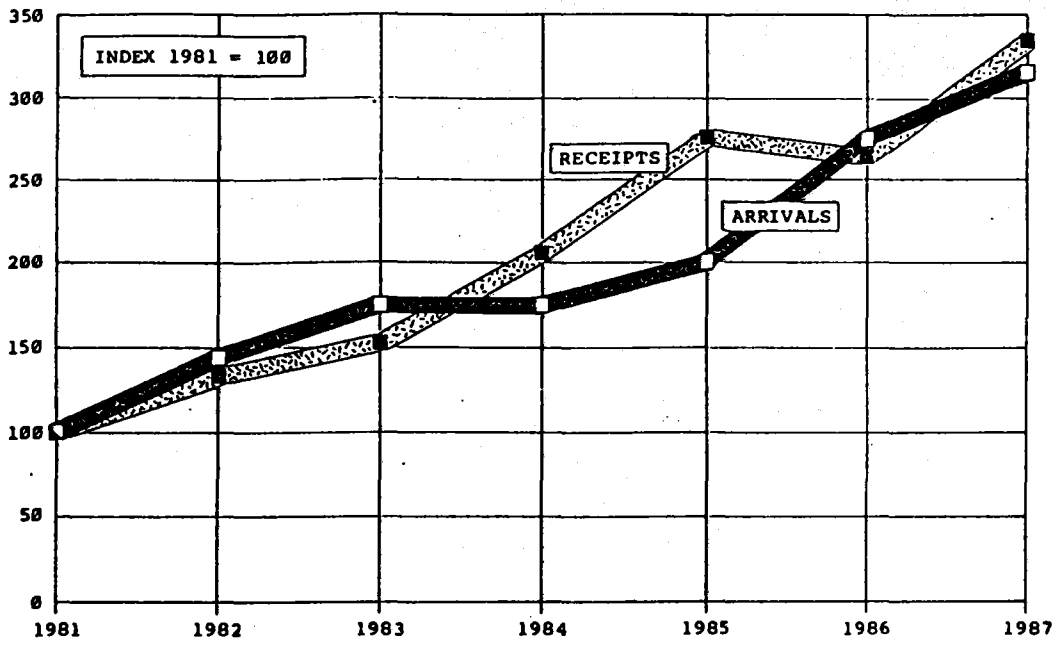


Figure 27. Fish catch and composition for the Republic of the Maldives.

Int'l Tourist Arrivals and Receipts, 1979 - 1987



Seasonal Variation of Tourist Arrivals, 1987

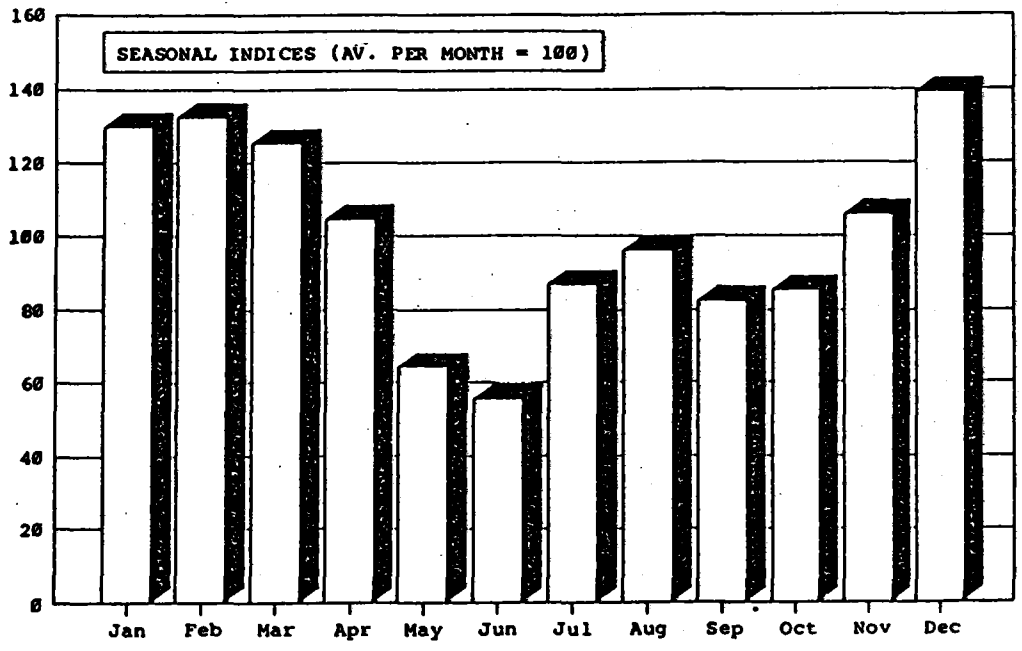


Figure 28 Annual growth and seasonality of tourism in the

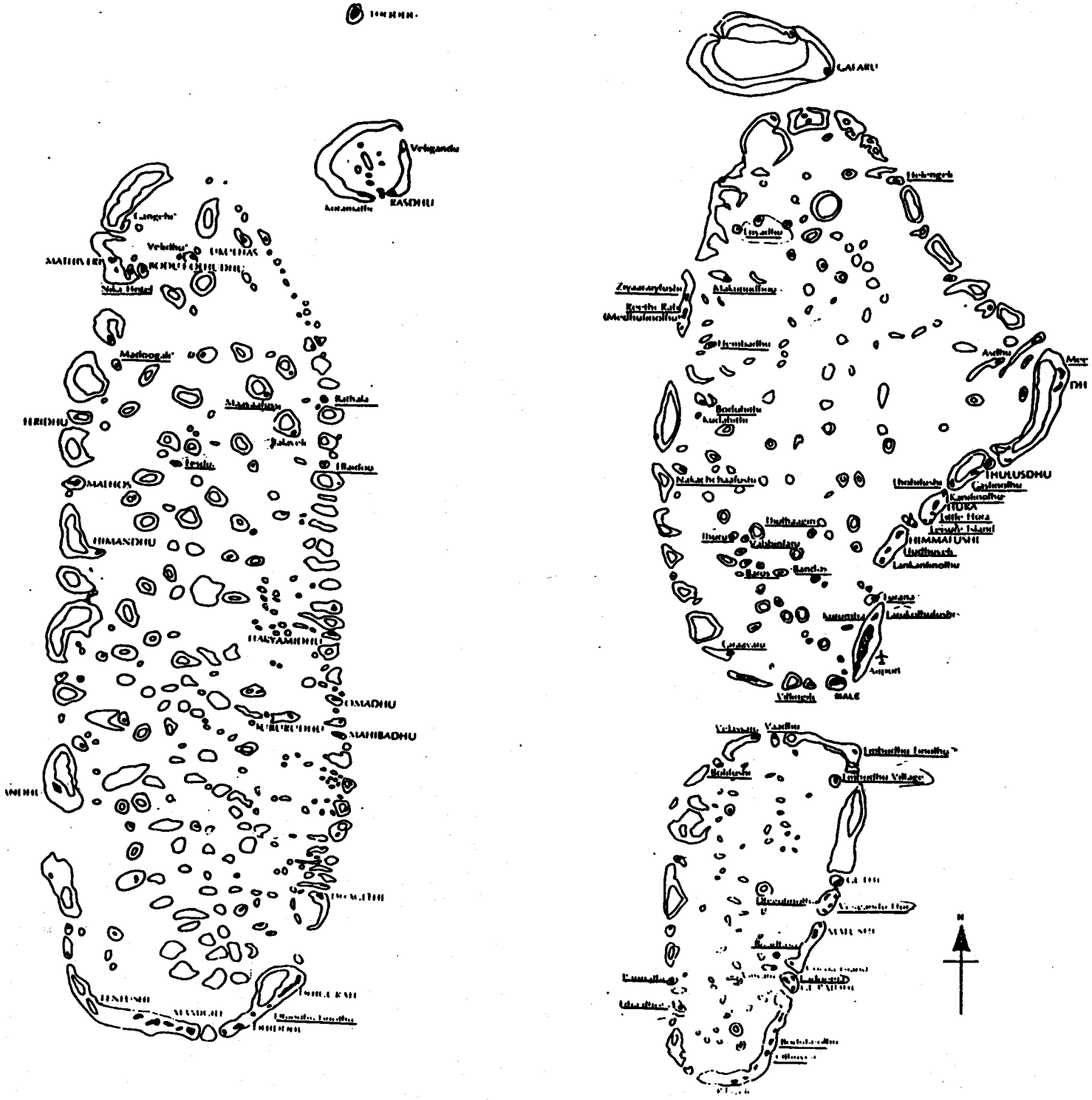


Figure 29. Location of tourist resort islands in the Central Maldives. (Resort island names are underlined).

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