Harmonisatie Noordzeebeleid

waterkwaliteitsplan Noordzee

framework for analysis

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PREFACE

In May 1982, the Dutch Government presented an official note to Parliament entitled "Harmonization of North Sea Policies" (nr. 17408 1 and 2). Following consultation and advice procedures on the subject a governmental decision was taken and published (nr. 17408 7 and 8). The Harmonization Note comprises an action program initiating the formulation of a water quality management plan (WQMP) for the Dutch Portion of the North Sea. Action P3 was formulated in the following terms:

> Building on international conventions and actual national policies, the plan will represent the vision of the Dutch government on a coherent and strategic approach to preventing and combatting pollution of the North Sea. The plan will provide directives for international negotiations and in addition will indicate management strategies as far as they can be taken in the Netherlands.

The leading Ministry for drafting the WQMP was the Ministry of Public Works.

By commission of the Directorate North Sea of the Directorate General Rijkswaterstaat of the Ministry of Transportation and Public Works, a study was carried out, the results of which are published in reports underlying said WQMP. The supporting study was performed by specialists of the Directorate North Sea, the Delta Department, (both of the Rijkswaterstaat), and the Delft Hydraulics Laboratory. The present report is the last in a series of four underlying reports or background documents:

1. An inventory of institutional and legislative aspects (in Dutch).
2. The ecology of the North Sea (in Dutch).
   A. Description.
   B. Analysis.
3. Activities and sources of pollution (in Dutch).
4. Framework for analysis.

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1 INTRODUCTION

On the North Sea, as on many other coastal waters around the world, the demand for goods and services, produced from renewable and non-renewable marine resources, strongly increased in the last two decades. This refers not only to the increased outputs of traditional human activities such as fishing, marine transport, and disposal of wastes, but also to products and services previously produced primarily on land, e.g., oil and gas, sand and gravel, and sites for industrial operations. In addition to these specific, mainly sea-based activities, coastal waters often provide a sink for wastes produced by a great diversity of land-based activities, which wastes enter a specified coastal water region through the inflow of rivers, direct discharges of liquids and solids, sea currents, and atmospheric deposition. Such inputs represent the application for one of the services of the marine ecosystem: its assimilative capacity.

The increased level of sea-based human activities and the increased volume of wastes discharged into a specific, geographically defined coastal water region result: in increased competition between activities for limited space; often in undesired effects on the marine ecosystem, with corresponding adverse effects on humans and human activities; and in under or over utilization of valuable resources. In such situations governments should perform a major role in the management of marine resources.

Marine resources management includes making decisions on such resource utilization questions as: the allocation of special zones for exclusive use by one or some activities, e.g., navigation lanes, military zones, offshore mining areas; the location of dumping sites for industrial wastes and the amounts to be dumped; the location of sand and/or gravel exploitation sites and the amounts to be extracted; and the amounts of finfish and/or or shellfish to be caught in specific areas during specific times of the year.

The complexity of the decision problems often stems from some combination of the following characteristics which exist in many marine resources management situations:

- the importance of the contribution to the state of the marine ecosystem of cross boundary flows of wastes, produced outside a specified coastal water management region;
- the international context of the legal and institutional structure;
- the absence of a proper integration of management tasks at a national level;
- the absence of a mechanism for comprehensive planning for marine resources management;
- inadequate knowledge of natural processes in the specified marine ecosystem;
- the fact that adverse effects of ambient water quality on human beings and economic activities often are not direct and instantaneous, but build up gradually and are difficult to reverse because of the long memory of the natural processes involved (as a consequence measures to counteract these adverse effects do not show immediate results); and
- the difficulty to make operational, e.g., through the formulation of specific (quantitative) water quality standards, the general, public concern for so-called ecological values of marine resources.

In situations such as those indicated above, careful and consistent planning of governmental actions is an important management instrument. Such planning has at least three functions:

i. integration, or, as it is called in the Netherlands, harmonization of actions by different governmental agencies, on both national and international levels;
ii. allocation of management resources for any governmental agency involved; and
iii. provision of information to the public of the goals for governmental actions and related management strategies.

Planning should be based on quantitative analysis to the extent possible, to reveal consequences of proposed governmental and private actions and to provide the responsible governmental agencies with useful information for the decisions to be made. As management of marine resources is a continuous activity, planning and the supporting analyses must be virtually continuous, operationally structured in subsequent rounds of planning, providing specific outputs of information at specific points in time. The analysis in any given round of planning for marine resources management for a specified region is normally based on existing data and knowledge, to be updated in subsequent (rounds of) planning. Given this dynamic character of planning, it is useful to develop an operational framework for analysis, which makes explicit the steps of analysis and the computational methods involved.

The Delft Hydraulics Laboratory (DHL) recently has been involved in two programs to support planning for coastal waters management and to develop frameworks for analysis.

- Coordination of case studies in the context of the Analyzing Biospheric Changes (ABC) program of the International Federation of Institutes for Advanced Study (IFIAS).
  The coastal waters problem area of the ABC program includes three case studies which were carried out in the period 1982 to 1985: Tokyo Bay; Strait of Malacca; and North Sea. The coordination includes developing a framework for analysis, the exchange of experience, and the publication of results, including a synthesis report on the case studies. In addition to the three case studies, close cooperation has been maintained with the series of assessments of U.S. coastal waters being undertaken by the Strategic Assessment Branch, Ocean Assessment Division, National Oceanic and Atmospheric Administration (NOAA) of the United States.
- Preparation of a water quality management plan of the Dutch portion of the North Sea.
  This program is sponsored by the Directorate North Sea of the Directorate General Rijkswaterstaat (RWS) of the Dutch Ministry of Transportation and Public Works. The supporting analysis for the plan was carried out in an eighteen month period between 1983 and 1984 by a combined project team from RWS and DHL. The study resulted in: (i) a draft plan which will be presented in mid-1985 to the public; and (ii) a first step for a framework for analysis within the specific political and administrative setting in the Netherlands. As such it contributes to the ABC program above and to the revision of the general framework presented in

this ABC program in 1982 [5][1].

As mentioned in the preface, this report is one of the so-called background documents of the Dutch North Sea water quality management plan. As such it presents a coherent description of the methodological and computational framework which has been developed during the analysis and which in its individual elements is described in detail in the other background documents [6,7,8,9].

Because the description of the framework is relevant in the context of the ABC program, for the evaluation and further development of the framework for analysis, it was decided to write this volume in the english language. As such it will reach individuals in addition to those involved in further elaborating and implementing the Dutch water quality management plan, including those in scientific institutes and management agencies in other countries. To serve this purpose, the report should include both a description of the framework and of the major results of the analysis carried out for the water quality management plan.

An additional consideration is the following: any operational framework for analysis should be problem specific within existing constraints, e.g., the management problem at hand, the planning objectives, the institutional setting for planning and analysis, and the available resources. Consequently, in order to understand the framework developed for the Dutch water quality plan, it is required to describe the management and planning context of the development of the plan.

The above considerations lead to the following organization up of this report.

Chapter 2 gives a general introduction to marine resources (and coastal waters) management and discusses the basic concepts of the marine resources management system, planning, and framework for analysis.

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1) Numbers between brackets [ ] refer to the bibliography at the end of the main text.

Chapter 3 describes the general nature of the North Sea management problem through an introduction on the main characteristics of the natural system, the utilization of the marine resources, and the legal and institutional context.

Chapter 4 focusses on the water quality management of the Dutch portion of the North Sea. It describes the goal of the planning for water quality management, the perceptions of ambient water quality problems, the analysis conditions, and the framework for analysis adopted.

Chapter 5 describes the methods of analysis used, including a description of the method used to evaluate the effect of ambient water quality on the marine ecosystem and Chapter 6 presents the results of the analyses.

Annex A describes a coastal water data management system (COWADAT), which was developed during the preparation of the water quality management plan for the North Sea, but is set up for a more general application for other coastal water management regions.

This report has been composed by Rob Koudstaal, based on contributions from Paul Baan, Peter de Bruyn, Peter Glas and Hans van Pagee, all belonging to the Water Resources and Environment Section of the Delft Hydraulics Laboratory. A major input, in particular with respect to the descriptions involved in the chapters 2, 3 and 4, has been received from Blair T. Bower, advisor to DHL and coordinator of the coastal waters problem area of the ABC program. Typing, drawing and final editing was taken care of by Nel Woldhuis and Engelbert Vennix of DHL.

1.1 DEFINITION OF TERMS

It is essential to define the following terms used throughout this report: marine resources; coastal waters; natural system; ecosystem; and water quality.

<u>Marine resources</u> refer to both renewable and non-renewable resources of marine origin. Thus, the objective of marine resources management is to

produce an optimal (socially defined) mix of goods and services from a specific marine resources area (region).

Coastal waters refer in general to offshore regions, up to a 200 mile limit. Such waters include bays and estuaries where relevant.

Natural system and ecosystem are terms which are considered to be synonymous. These systems include all physical, chemical, and biological components and their corresponding processes and interactions. Natural system management aims at the maintenance of renewable resources and biologic productivity.

Water quality refers to the state, as measured by specified indicators, of both the water column and the sediments. The management concern is with the effect of changes in the state of water and sediments on receptors, including humans, plants and animals.

2 NATURE OF MARINE RESOURCES MANAGEMENT[1)]

Characteristics, mentioned in chapter 1, of what has been called the marine resources or coastal waters management problem, and which often hamper adequate management decisions being made, may not be critical individually, but, due to their scale and combined occurrence, they create a more or less typical category of coastal waters management problems with the corresponding need for information and analysis. This chapter describes the basic (typical) concepts of marine resources management and the analysis and planning which are integral parts of such management. Section 2.1 presents a description of possible goods and services to be produced from a marine resources region and pays specific attention to the "services" disposal of wastes and sink for residuals. Section 2.2 defines the functions of which marine resources management is comprised, indicating that analysis for planning is just one of the management functions. Section 2.3 describes the marine resources management system providing the basic concepts for any systems approach to marine resources management. In sections 2.4 and 2.5, specific attention is paid to the development of management strategies and to the utilization of criteria for evaluation of strategies. Section 2.6 presents a short summary of a generalised framework for analysis for coastal waters or marine resources management.

2.1 PRODUCTION OF GOODS, SERVICES AND WASTES

Within any given marine resources management region, a set of activities operates over space and time. Moreover, such a region often functions as a sink for wastes produced by human activities outside the area, crossing its geographic boundaries through natural transport mechanisms such as river flows, air currents, sea currents, and morphological processes, as well as by direct discharges. These activities within the region and its sink function reflect both the domestic and international demands for the products and services which can be produced in and obtained from the region. Table 2.1 lists typical products and services produced in marine

1) This section draws on material in [5].

PRODUCTS

Derived from renewable resources	Derived from non-renewable resources
Finfish	Oil
Shellfish	Gas
Kelp and other seaweeds	Minerals, e.g., manganese, nickel, sulfur, copper
Seashells	Sand and gravel
Freshwater (desalinated seawater)	
Energy from waves, tides and thermal or salinity gradients	

SERVICES

Derived from renewable resources	Derived from non-renewable resources
Transport, national and international	Disposal of wastes consisting of conservative materials, e.g., radioactive and non-degradable compounds in sludges and waste-waters, dredging spoil, obsolete products
Defence	Sink for conservative residuals, e.g., radioactive and non-degradable compounds in river water and atmospheric deposition
Facility siting: on-shore/off-shore fixed or mobile industrial operations, e.g., materials processing, marine terminals, ports, seabed pipelines and cables, power plants	
Recreation: e.g., bathing, boating, fishing, skindiving, observing birds/mammals/fish	
Disposal of non-conservative wastes, e.g., degradable compounds in sludges, waste waters, and solid wastes	
Sink for non-conservative residuals, e.g., heat in relation to thermal discharges from power plants and other industrial operations, carbon dioxide in atmosphere from antropogenic sources	

Table 2.1 Typical products and services produced in a marine resources region

resources regions. In this table, distinction is made between products and services which are produced from renewable (flow) resources and those which are produced from non-renewable (stock) resources. "Renewable" means that within some specified time period the natural system will, itself, regenerate the resources required to produce a specified product or service, e.g., fish populations will be replenished, decomposition of organic wastes allows continuous discharge of such wastes up to some amount. "Non-renewable" means that once the resources are extracted or removed from the area, they will not be regenerated by the natural system, at least not within a time period which is practicable in relation to resource management, e.g., formation of manganese modules on the seabed, elimination of seabed ecosystem by covering with dredging spoil, rubble, and similar non-degradable materials.

Disposal of wastes refers to direct discharges into the specified marine regions, e.g., emission of liquid residuals from sea-based activities within the region such as shipping and offshore operations, dumping of industrial wastes and sludges from ships; dumping of dredging spoil; and coastal outfalls from industrial activities and municipalities.

Wastes enter the marine resources region as a consequence of both land and sea based human activities. After discharge to the natural environment, the wastes are affected by, and in turn may affect, various physical, chemical and biological processes. These processes transform the time and spatial patterns of entering waste materials into time and spatial patterns of ambient water quality. Utilization of marine resources as a receptor of wastes from land and sea based human activities counts on its assimilative capacity (or supposed capacity) to receive such wastes without resulting in changes in ambient water quality which are considered as undesired or unacceptable from whatever motivation.

Ambient water quality, which relates to the quality of water and organisms in a broad sense, is measured by such indicators as: concentration of oil (hydrocarbons); concentration of total dissolved solids; biomass of fish per unit volume of water; concentrations of heavy metals in water, bottom sediments, and indicator species such as mussels; and number of fecal coliform organisms per unit volume.

Changes in ambient water quality affect various human activities, such as beach-related recreation and commercial fishing. These impacts, as perceived by humans, and the responses of individuals and groups to the perceived effects, may provide the stimulus for activating the institutional system. This, in turn, may stimulate some form of management action.

The above is presented schematically in figures 2.1 and 2.2. In addition to effects from changes in ambient water quality, two other stimuli for management actions can be identified. One refers to situations where activities compete for limited space, e.g., when navigation lanes cross gas and oil exploitation areas, or military zones coincide with fishing grounds. Such interactions may reduce some outputs or may increase their production costs. Another trigger is provided when management actions are required to stimulate or reduce production activities from the point of view of resource utilization. For example, a national energy strategy may result in slowing down gas and oil extraction from a certain area of the continental shelf; sand and gravel mining may have to be stimulated in order to save land based natural resources; coastal navigation has to be stimulated to replace road transport. Obviously these three major stimuli for governmental actions may be interrelated, e.g., when due to limited space or poor water quality demand is not met by the produced outputs.

2.2 FUNCTIONS COMPRISING MARINE RESOURCES MANAGEMENT

Marine resources management is a continuing activity. To produce a set of products and services from any given marine resources region involves multiple functions (tasks). Because it is important to illustrate the complexity of management, table 2.2 lists relevant management functions. (The list is not meant to be exhaustive.) These functions can be grouped in several ways. One grouping could have the following categories: (1) resource assessment; (2) analysis/planning ; (3) research; (4) direct production of goods and services, including design and construction of facilities; (5) operations, including provision of navigational aids, setting of standards; and (6) application of incentives, monitoring of performance, and imposition of sanctions.

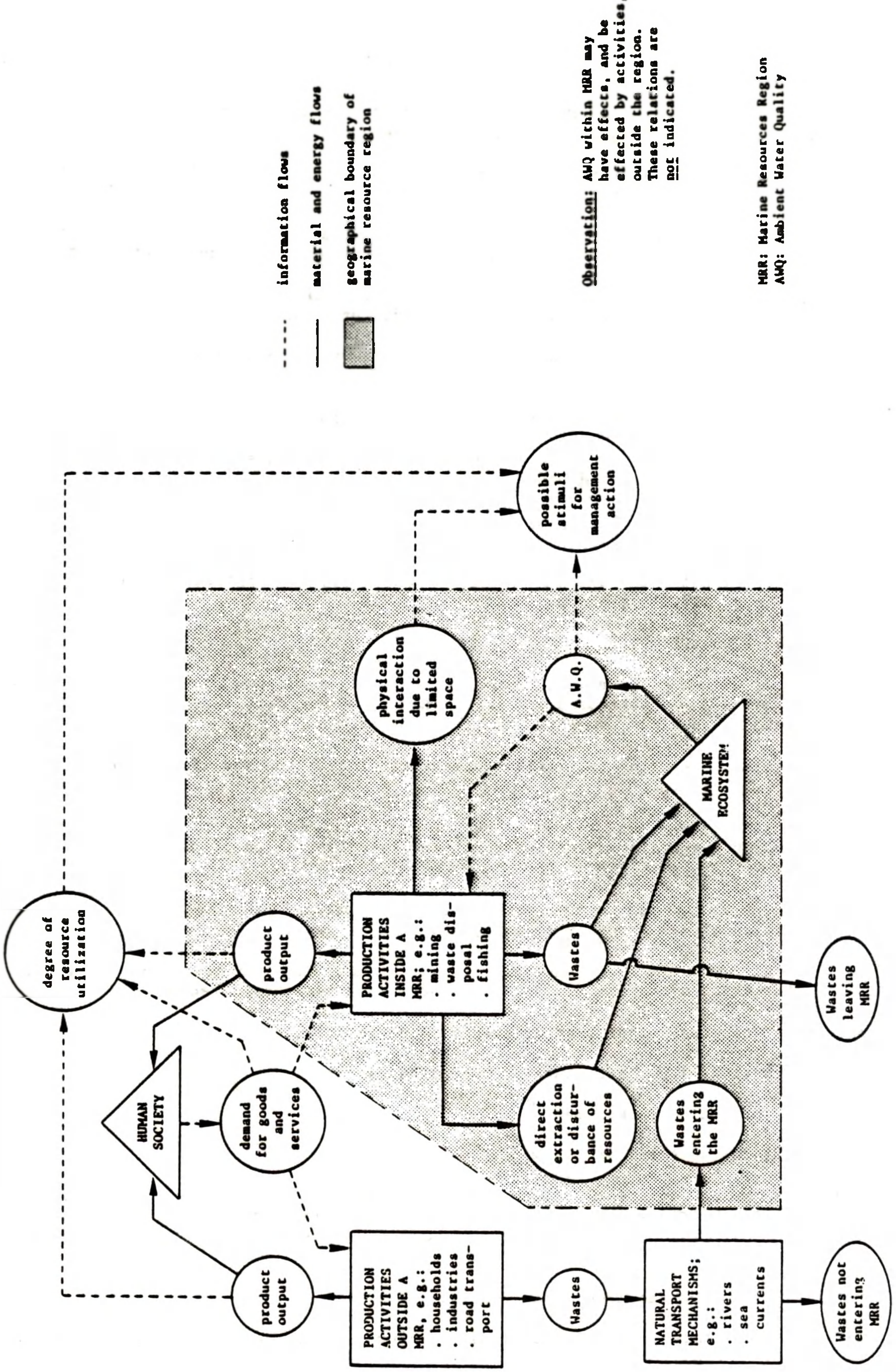

Figure 2.1 General scheme for production of goods, services and wastes in a marine resources region

Analysis and planning, i.e., the determination of the mix of products and services to be produced where and when in any given management region.

Direct production of products and services, e.g., minerals, oil and gas, fish, recreational boating and fishing.

Resource assessment and associated data collection, e.g., productivity of a given region for a particular fish species under different levels of management inputs.

Exploration to determine available quantities and qualities of fuel and non-fuel resources and costs of their exploitation by different technologies.

Research on the impacts of residuals discharges on water quality and hence on biota and on various fish species.

Leasing of offshore oil, gas, mineral exploitation rights.

Monitoring of offshore exploration activities, including imposition of sanctions for failure to adhere to specified procedures.

Monitoring of offshore drilling and production activities, including imposition of sanctions for failure to adhere to specified procedures.

Monitoring of impacts of offshore structures on biota, fish marine mammals, aquatic ecosystems, e.g., drilling and production platforms.

Cleaning up oil spills.

Monitoring of dumping of wastes, including imposition of sanctions for failure to adhere to specified procedures, e.g., dumping in non-designated areas, dumping during prohibited periods, dumping prohibited materials.

Construction and operating facilities to enhance finfish and shellfish productivity, e.g., artificial reefs.

Monitoring fishing vessels, domestic and foreign, for adherence to specified procedures including the use of specified equipment, and imposition of sanctions for non-compliance.

Monitoring of marine transport activities - commercial and recreational - for adherence to specified procedures, e.g., disposal of wastes.

Installation, operation, maintenance of navigational aids and operation of navigational information system, e.g., provision of charts, weather forecasts.

Monitoring (tracking) major weather events, such as hurricanes.

Geologic research, e.g., structure of submarine canyons.

Patrolling for national defense.

Provision of rescue services.

Research on marine ecosystem processes, oceanic-atmospheric interaction processes, technology of monitoring, technology of production of goods and services, technology of aids to navigation, technology of resource assessment, e.g., remote sensing techniques.

Monitoring of ambient environmental quality.

Application of incentives to constrain and/or induce behavior, e.g., permits, charges, performance standards.

Table 2.2 Examples of functions comprising marine resources management

Another way of grouping management actions is with respect to the location in the system to which the action is directed, i.e., demands for goods and services, production activities, handling and modification and disposal of wastes from activities, effects on the marine ecosystem.

Two further points with respect to functions should be emphasized. One, no distinction is made in table 2.2 between public and private entities with respect to responsibility for carrying out these functions. However, some functions will always - of necessity - be carried out by governmental agencies, e.g., monitoring of activities of private enterprises and of lower level governmental agencies to ascertain adherence to standards and procedures.

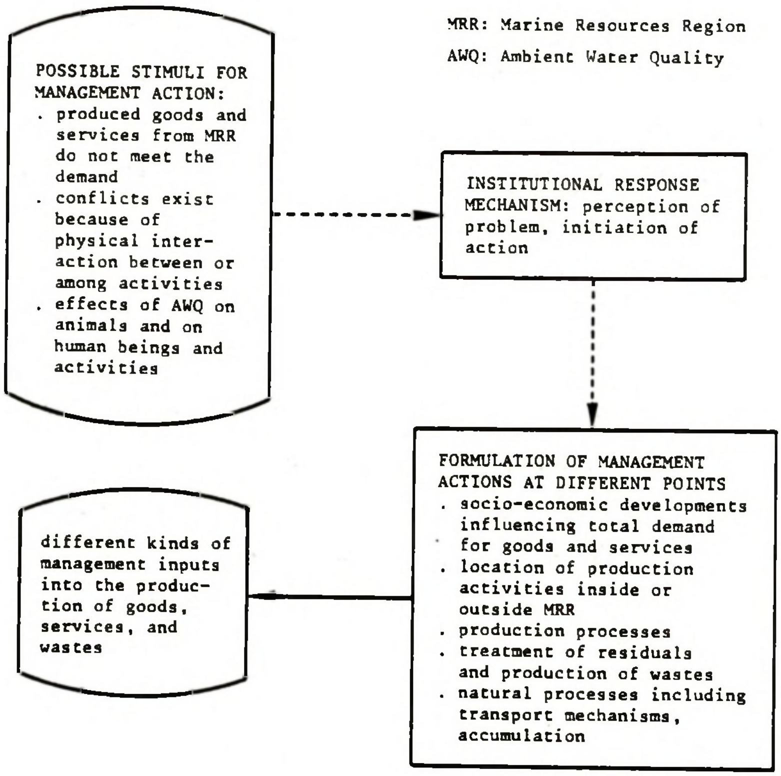

Figure 2.2 Marine resources management in relation to the production of goods, services and wastes

Two, many of the functions can be subdivided, and diffferent agencies and enterprises can carry out the subfunctions. For example, a governmental agency might perform the activities to improve fisheries habitat, while the private sector harvests the increased output made available by the improved habitat.

2.3 MARINE RESOURCES MANAGEMENT SYSTEM

Figure 2.3 combines figures 2.1 and 2.2 and depicts the overall marine resources management system. The figure shows only the major elements of the system and the major flows of materials, energy and information into, through, and out of the system. The following provides a short summary of the major elements.

The system is driven by the demands for products and services which can be produced on and from a marine resources management region. These demands originate both from within the region and from outside the region. To produce these desired products and services, various alternative physical measures (technological options) are possible. These activities affect marine ecosystems both directly, e.g., in the harvesting of fish or seaweed, in the removal of minerals, and indirectly, i.e., through the generation of wastes such as drilling muds and waste heat in production and the subsequent discharge of those wastes into the marine environment. Both the direct and indirect paths of effects - in conjunction with inputs from nature and from wastes entering and/or leaving across the boundaries of the marine resources region - yield changes in the time and spatial patterns of ambient water quality as a result of the various processes occurring in the marine environment, e.g., transport, transformation, accumulation.

The effects of the changes in ambient water quality on marine ecosystems, on humans and on the activities of humans, and on exposed materials, stimulate - if they are perceived to be sufficiently adverse - the institutional mechanism of a society. Other stimuli are provided by physical interactions between activities due to limited space and by the degree of resource utilization itself. The institutional mechanism includes

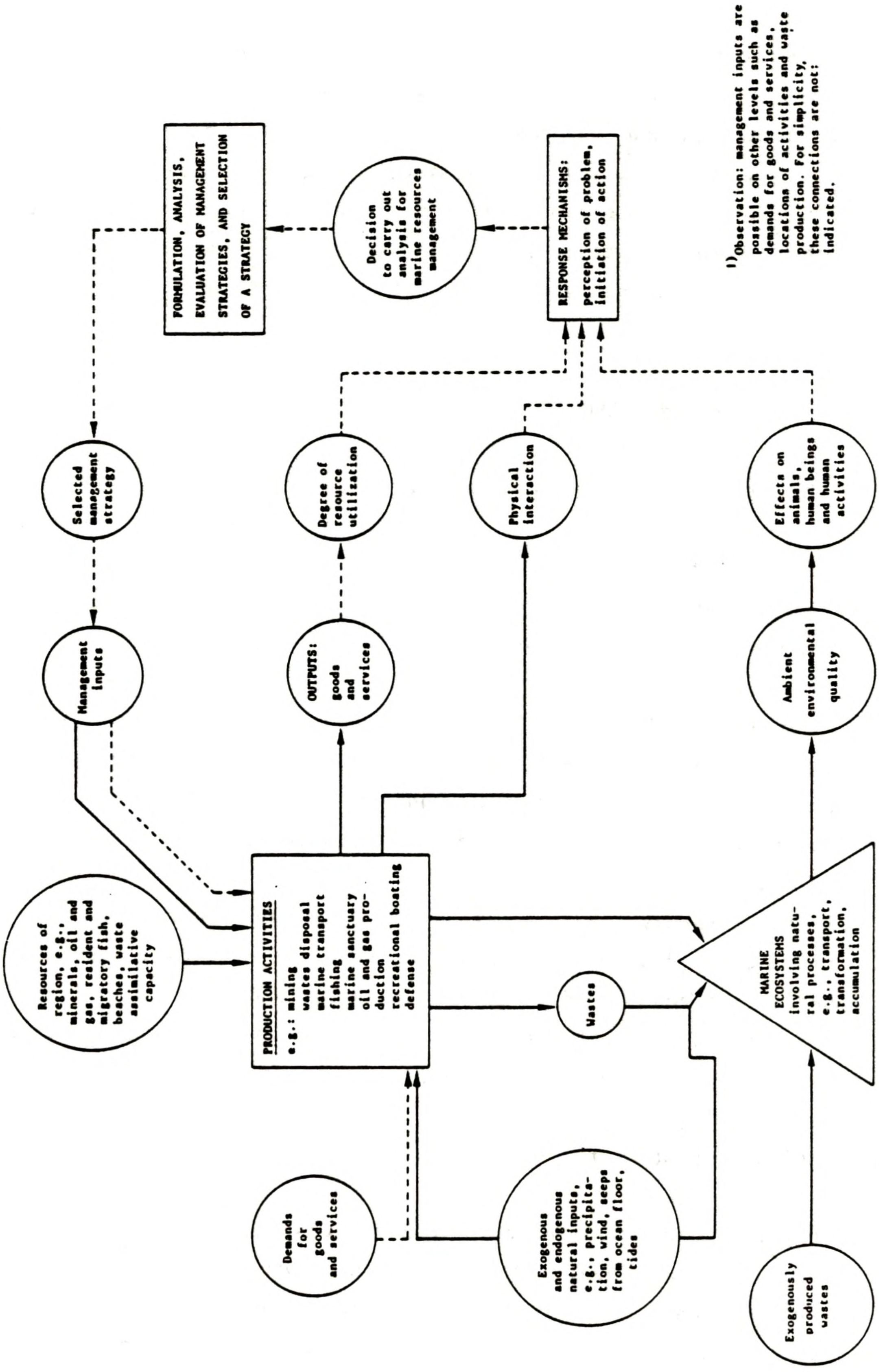

Figure 2.3 Generalized scheme of a marine resources management system

the governmental structure, the formal political processes, and the informal power structure. The flows of information to the parts of the institutional mechanism and the reactions of that mechanism to the information, result in a selected marine resources management strategy. The strategy may affect one or more elements of the system, e.g., demands for goods and services, characteristics and levels of products and services to be produced, locations of activities, methods of production, methods for modification and disposal of wastes after generation.

2.4 PLANNING FOR MARINE RESOURCES MANAGEMENT

Planning is a major task of marine resources management. Planning refers to the development and selection of a concrete (specific) set of actions to be taken to produce the desired mix of goods and services from a marine resources management region over time. A planning document should contain the following elements:

- description of the physical and institutional settings;
- specification of the goals of the plan and the objective function(s);
- estimation of demands for goods and services over time;
- assessment of the marine resources available for producing the goods and services;
- selected strategy, where strategy is as defined below;
- estimation of benefits and costs of selected strategy, distributions of benefits and costs, and financial analysis; and
- estimation of the effects of the strategy other than those in monetary terms, e.g., administrative, physical, net energy use.[1)]

Strategies consist of three components:

i. Physical measures (technological options) for: (a) producing the products and services; (b) handling, modifying and disposing of wastes; and (c) monitoring performances by activities.
ii. Implementation incentive systems to induce socially desired behaviour by resident and transient activities in the marine resources manage-

1) For example, in relation to the criteria presented in table 2.3.

ment region. Such incentive systems include, for example: a set of rules, procedures or standards an activity must follow or meet, usually specified in an operating permit; a basis and a procedure for measuring performance or adherence to the rules, procedures or standards, e.g., sampling fish catch on board a fishing vessel according to a specified procedure; a set of sanctions for failure to comply with the rules, procedures and standards; and a schedule and procedure for monitoring or inspection to determine such compliance.

iii. Institutional arrangements which specify: (a) which governmental agencies have responsibilities for which functions and subfunctions of marine resources management; and (b) the modes of interaction between the public and private sectors involved in a marine resources management region.

Relation with other management tasks. Management includes a set of continuous activities such as monitoring of ambient water quality, geologic research, research on marine ecosystem processes, which activities are related to plan implementation and the preparation for the next round of planning. Figure 2.4 schematically depicts the relation between planning for marine resources management which provides specific information at specific moments in time (plans) and these continuous activities.

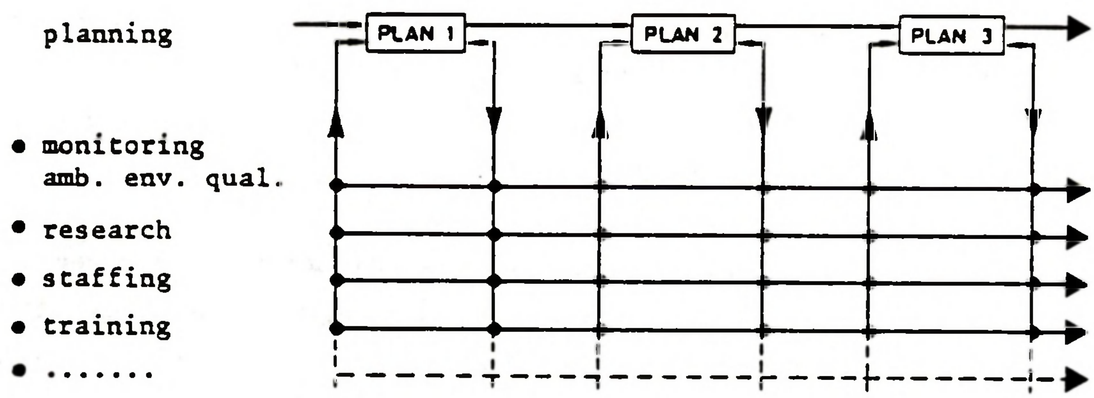

Figure 2.4 Schematized relation between planning and selected continuous management tasks

2.5 CRITERIA FOR EVALUATING MANAGEMENT STRATEGIES

In marine resources management, as in all decision-making contexts, criteria must be established by which to choose a strategy from among candidate strategies. These criteria represent factors which decision makers and other interested groups consider relevant in evaluating and subsequently selecting strategies. Not only must the criteria be specified, but relative weights must be attached to them, and some method for combining the weights, e.g. additive or multiplicative, must be selected.

Although real resource costs and values of outputs of products and services represent major factors in choosing a strategy, they are not the only relevant criteria. Decision makers use multiple criteria in making decisions, with the criteria and their relative importance being made more or less explicit. Table 2.3 represents one list of criteria for evaluating strategies. Any or all of these criteria may be of interest to the decision makers having jurisdiction over a given marine resources management region. Discussion of the criteria shown in table 2.3 follows.

1. A marine resources management strategy results in changes in the physical, chemical, and biological indicators of ambient environmental quality; these changes in turn have impacts on various species in the different subsections of the region and on certain processes of the marine ecosystem, such as oxygen interchange at the air ocean surface interface, redissolving of materials from sediments. In some cases there may be effects on marine ecosystems <u>outside</u> the given region. There also may be an interest in the extent to which the strategy is a net producer or user of energy.

2. The values of the various products and services produced in a region represent the direct benefits of a management strategy. The costs to produce the outputs plus any damages from such production represent the direct costs of the strategy. Indirect benefits are the monetary values resulting from changes in activities on-shore which are associated <u>indirectly</u> with activities in the management region. An example would

1. PHYSICAL, CHEMICAL, BIOLOGICAL EFFECTS OVER TIME
   a. Changes in ambient environmental quality in the various subregions and subsections of the region
   b. Effects of changes in ambient environmental quality on receptors, users of the region
   c. Extra-regional ecosystem effects
   d. Net energy used or produced

2. ECONOMIC EFFECTS AND THEIR DISTRIBUTIONS OVER TIME
   a. Direct benefits, e.g., values of products and services produced
   b. Direct costs of products and services produced
   c. Administrative costs
   d. Indirect benefits associated with products and services produced
   e. Indirect costs associated with products and services produced

3. ADMINISTRATIVE CONSIDERATIONS
   a. Simplicity
   b. Effects on staffs of existing agencies
   c. Retention of effectiveness under changing conditions
   d. Ease of modification under changing conditions

4. TIMING CONSIDERATIONS
   a. Years before production of products/services begins
   b. Years before adverse impacts on ambient environmental quality begin to be measured
   c. Time required to establish implementation incentive/institutional arrangement systems

5. POLITICAL CONSIDERATIONS
   a. Priority in relation to execution of strategies in other marine resources management regions
   b. Degree to which strategy can be executed by a single agency rather than by multiple agencies
   c. Impact on intergovernmental relations, i.e., relations between and among various governmental levels
   d. Acceptability to public
   e. Legal difficulties

6. ACCURACY OF ESTIMATES
   a. Physical, chemical, biological effects
   b. Benefits, direct and indirect
   c. Costs, direct and indirect.

Table 2.3 Examples of criteria for evaluating strategies be a facility producing equipment for a factory for processing fish caught in the region. Indirect costs are analogous to indirect benefits on the cost side.

Although administrative costs of a marine resources management strategy may be small in relation to overall costs, the costs of such activities do comprise part of direct costs. They are separately identified because they are too often neglected, with consequent unexpected demands on budgets of management agencies and of individual activities. The administrative costs include public and private administrative costs for monitoring of activities, e.g., equipment for measuring specified indicators in inputs and discharges, analysis of samples, reporting, supervision of operating personnel, processing and granting of permits, inspection of operations.

A very important consideration with respect to economic effects is their distribution. Who benefits from the products and services produced in the region and who pays in what form and over what periods of time for their production? Distribution effects should be determined in relation to division of costs among local, provincial, and national levels and between public and private entities. It often is important also to determine explicitly the distribution of benefits and costs over time, i.e., who receives and/or incurs them when in the project period.

3. Critical to the execution of any management strategy are its admninistrative facets. Four of these have been identified. Simplicity of administration refers to the desirability of strategies being easily understood by the activities involved, management agency inspectors, elected officials, and other interest groups. Another important criterion with respect to administration is how a strategy affects the responsibilities and staffs of existing agencies. A strategy which involves significant shifts in bureaucratic empires requires careful and substantial effort to obtain acceptance.

One of the most critical aspects of a management strategy involves responding to changing conditions. Thus, the strategy must be administratively flexible. Flexibility in administration refers to the degree to which a strategy remains effective under changing conditions and the ease with which the strategy can be modified over time, if necessary, to respond to changed conditions.

4. Physical measures to produce products and services vary with respect to the time required to install and place them in operation to produce goods and services. Similarly, there may be varying amounts of time after they are in operation before measurable effects on ambient environmental quality occur. Likewise, different implementation incentive system-institutional arrangement combinations require different amounts of time to be established. Thus, where there is an interest in obtaining outputs as soon as possible and/or where there are adverse ambient environmental quality conditions which need to be ameliorated as soon as possible, timing is likely to be an important consideration in the selection of a marine resources management strategy.

5. The political considerations criterion reflects the complex set of intergovernmental relations in a federal society. The political criterion is differentiated from the administrative criterion in that the latter relates to the administrative considerations delineated above for a <u>given</u> institutional structure.

6. Accuracy of the estimates of the costs of the strategy, of the estimates of impacts on ambient environmental quality which the strategy is predicted to have, and of the estimates of benefits, may affect the choice of a strategy. A strategy which has large estimated positive benefits and/or low costs, but for which there is large uncertainty in the estimates of costs, effects, and/or benefits, may not be preferred to one which has substantially fewer benefits and the same or somewhat higher costs, but for which the probability of achieving those benefits is high. Aversion to risk and uncertainty varies among decision makers and other groups interested in management strategies.

Two final comments with respect to criteria merit mention. One, it is difficult to quantify, rigorously, all of the above criteria. With respect to some, only qualitative scales such as low, medium and high, will be possible. For others, only descriptive commentary will be possible. Nevertheless, it is considered useful and essential to attempt to identify explicitly, in any given context, the criteria of relevance for marine resources management decisions. Two, not only do the criteria affect the decision with respect to selection of a strategy, they also affect the selection of the analytical approaches and computational procedures used in the analysis. In order to apply the criteria to the proposed strategies, information on those criteria must be generated in the analysis, e.g., distribution of costs. Thus the analytical approaches and the computational procedure or procedures must enable the production of the data needed to apply the criteria to proposed strategies.

2.6 FRAMEWORK FOR ANALYSIS

Analysis is one of the basic functions of marine resources management and is an essential task in planning, i.e., the process of selecting a management strategy for any given marine resources management region. Because marine resources management is a continuous activity, the decision regarding the mix of products and services to produce on and from the region must be made from time to time (this is referred to as the planning decision). Hence, analysis for management must be virtually continuous, with specific outputs of information required at specific points in time. Analysis is that activity which produces information for the planning decision. Thus, analysis is a part of planning. The actual planning decision is normally part of the political process, undertaken after relevant information is generated in the analysis.

Analysis for planning should be clearly distinguished from research and data collection the objective of which is to increase basic knowledge, e.g., of physical, chemical and biological processes. Such research and data collection are essential for further developing the capacity to predict consequences of management actions, and therefore should be tuned to this prediction need. The delination of both short-run and long-run data collection and research efforts should be an integral part of the planning process. The outputs should be programmed to become available to the planning process at specified points in time in the future.

Figure 2.5 shows the seven segments comprising analysis for marine resources management. These segments are: (1) setting up the analysis; (2) estimating demands for products and services which could be produced in the region; (3) analyzing the potential activities and the so-called "combined" sources of discharges (rivers, groundwater, atmosphere); (4) analyzing natural systems including cross-boundary flows; (5) formulating and analyzing management strategies; (6) evaluating strategies; and (7) presenting results. Discussion of each of these follows.

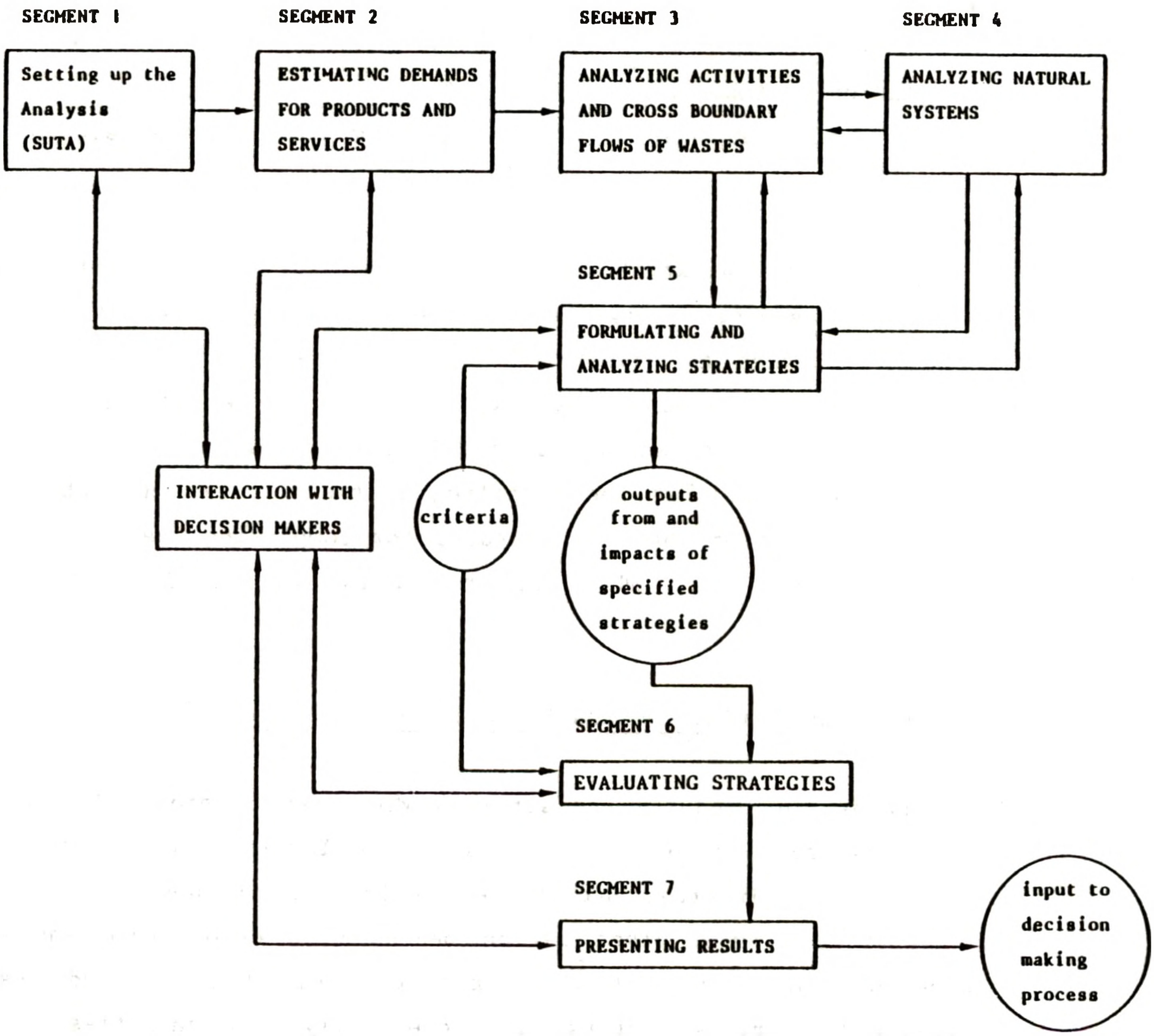

Figure 2.5 Segments of analysis for marine resources management

Segment 1: Setting up the analysis (SUTA)

SUTA refers to the sequence of steps - and related criteria, considerations, and assumptions - which must be performed to "set up" an analysis for marine resources management. Included are, for example, the delineation or preliminary selection of:

- the boundaries of the region and subregions to be analyzed;
- the time horizons or the time period to be analyzed;
- environmental conditions to be used, e.g., streamflow conditions, precipitation and temperature inputs, tidal fluctuations;
- the specific objectives for the analysis and the priority of questions to be answered;
- the number of scenarios to be analyzed, i.e., combinations of values of exogeneous variables; and
- the criteria for evaluating strategies and the relative weights of those criteria.

Whatever the context, SUTA is a necessary and critical part of analysis for marine resources management. It is the process which determines what types of analyses to undertake, in what order, to produce the desired information in relation to the questions to be answered, in the time available, for any given context in which the analysis is being made. The output of SUTA includes the detailing of the specific characteristics of the analysis and of the work schedule for completing the analysis in the time prescribed, i.e., when the information is needed for the decision process.

Segment 2: Estimating demands for products and services

The demands for products and services which can be produced from a given marine resources region are related to the levels of economic activities onshore and to international trade. Estimating the demands for products and services from a given region begins with demographic and economic projections over time at the national level, final demand associated therewith by various sectors, and "eventually" the qualities of various raw materials, e.g., manganese ore, sand and gravel, crude petroleum, needed to meet the input requirements of the activities producing the products and services. Demands at the national level plus relevant international demands must then be translated into projections of demands on the given marine resources region.

Segment 3: Analyzing activities and extra regional sources of wastes

Segment 3 is comprised of two aspects (parts). One involves the analysis of the activities producing the goods and services in the region in terms of the factors which influence both the choice of technology and the quantities of wastes generated and discharges. The other involves the analysis of extra regional "combined" sources of inputs of wastes to the region, namely, atmosphere, ocean currents, and rivers. To the extent possible, the types of activities and/or the specific geographic region associated with these combined sources should be identified.

Segment 4: Analyzing natural systems

Analyzing natural systems involves the estimation of the time and spatial pattern of ambient water quality and of effects on ecosystem components, e.g., various trophic levels, of the time and spatial pattern of discharges of wastes estimated in segment 3. The natural systems models used may be simple or complex.

Segment 5: Formulating and analyzing strategies

In section 2.4 the components of management strategies were defined. Typically many strategies can be formulated to reach any given objective formulated in the SUTA segment. To select among the possible strategies, consequences should be estimated in relation to the multiple criteria selected by the decision makers, examples of which were shown in table 2.3.

Segment 6: Evaluating strategies

Decision-makers use multiple criteria in making decisions. These criteria are specified in SUTA and the consequences of management strategies in terms of these criteria are estimated in segment 5. In addition, relative weights are attached to the criteria in the decision-making process. Assigning such relative weights to the individual criteria comprises an activity which is the responsibility of the decision-makers, not of the analysts. The analyst, however, plays an important role in providing the motivation and the framework for making explicit and using these weights.

The explicit application of relative weights yields a rating of proposed strategies. This process is called evaluation. Analytical methods exist to contribute to the evaluation of strategies, such as cost benefit analysis and multi-criteria evaluation methods.

Segment 7: Presenting results

The types and amounts of data and the formats used to present the data will vary in relation to the questions being asked, the level of detail of the analysis, the structure of decision-making in the region, and the characteristics of the region.

Not only the results of the analysis must be presented, but also information on: (1) selection and definition of the characteristics of the system considered; (2) selection and definition of goals and objectives; (3) selection and definition of mixes of activities; (4) selection and description of analytical methods and computational procedures, paying special attention to the underlying assumptions and the accuracy of the results; (5) selection and description of criteria used for evaluation; and (6) discussion of the data presented. Such information is helpful to the decision-makers in making their decisions. In general it can be said that it should be considered a major task of the framework for analysis outlined in this document, that the selection procedure which leads to the finally presented promising strategies should be made explicit in a clear and understandable way.

3 NATURE OF THE NORTH SEA MANAGEMENT PROBLEM

Management of the marine resources of the North Sea is both a multi-product and multinational problem. The latter aspect is discussed in section 3.3.

With respect to the former, management actions relating to the determination of resource utilization mainly refer to defining the timing and/or locations of harvesting finfish and shellfish and extracting sand and gravel, and oil and gas. Management actions relating to regulation of activities mainly relate to the interactions between and among economic activities such as shipping, fishing, and oil and gas extraction. Management actions directed toward pollution reduction or water quality improvement may interfere with the above mentioned actions. Generally actions to reduce pollution are triggered by public concern about the extent to which the North Sea has become a sink for the disposal of residuals from many human activities in a densely population and heavily industrialized zone of Europe. Hoewever, no direct danger to public health or adverse economic consequences occur at present (1985). The concern with respect to ambient water quality is mainly related to the continuing buildup of contaminants in the North Sea ecosystem.

Formulation, evaluation, adoption, and implementation of strategies for managing the marine resources of the North Sea are seriously hampered by:

- inadequate knowledge of the effects of water and sediment pollution on the biological components of the ecosystem, in particular effects in the long-run;
- lack of evidence of adverse socio-economic consequences of the ecological effects;
- inadequate knowledge of the sources of discharges, possible measures to reduce discharges, and the costs and distribution of costs of the measures;
- cross-boundary nature of the movement of substances, i.e., wastes are transported across the North Sea boundaries both into and out of the system;

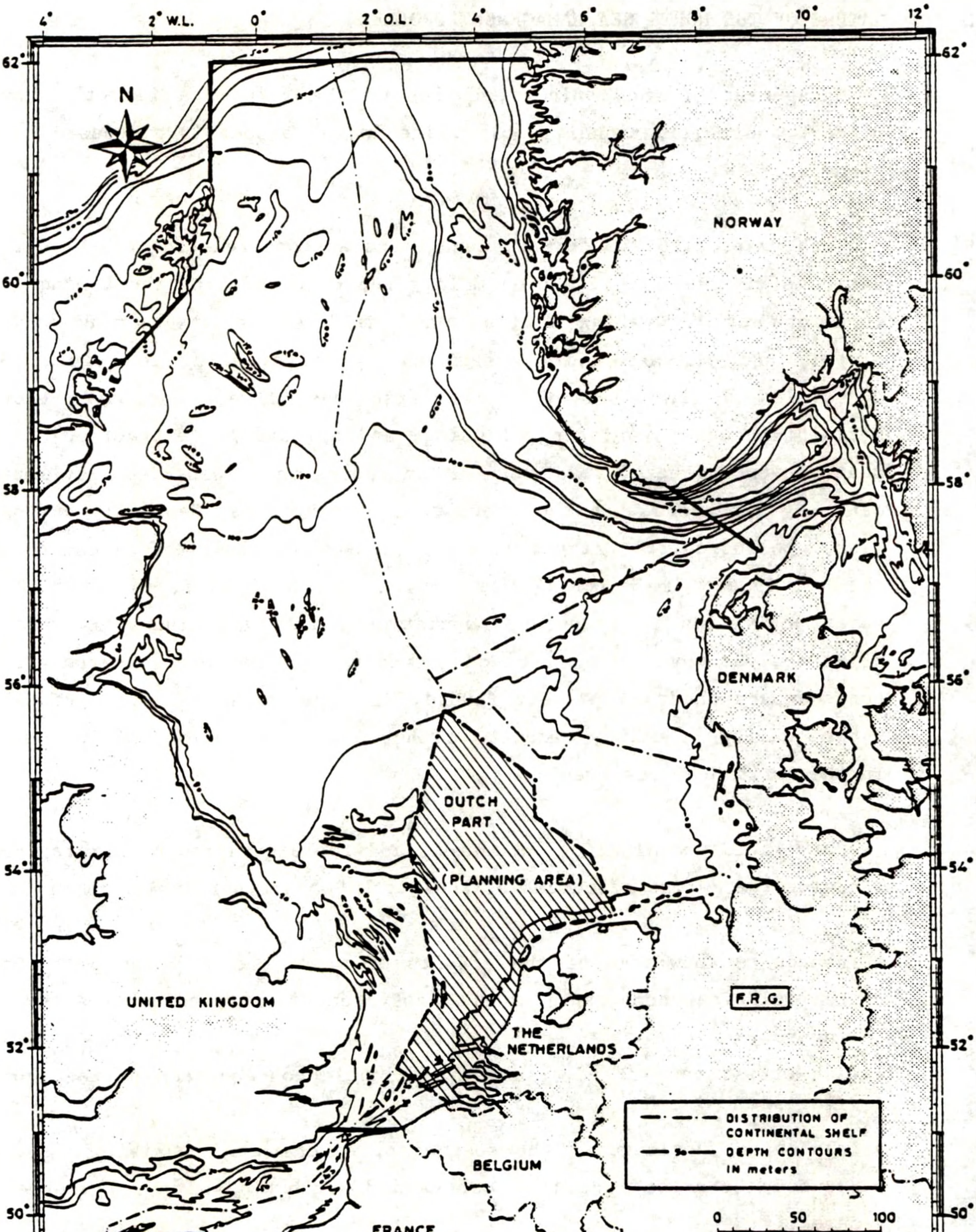

Figure 3.1 North Sea geography and planning area

- major sources of discharges are land-based and are located in various countries bordering the North Sea;
- some of the activities involved in utilization of the marine resources of the North Sea are subject to existing international agreement and regulations;
- the different countries involved have different legal and institutional approaches to marine resources management; and
- difficulties in intranational coordination because of multiple agencies having jurisdictions over activities and different types of sources of discharges, i.e., land-based and offshore.

Chapter 3 relates to the entire North Sea. Section 3.1 is a description of the natural system (ecosystem) of the North Sea and of the apparent water quality problems of the North Sea. Section 3.2 describes the human activities which involve utilization of the marine resources of the North Sea. Section 3.3 describes the institutional and legal context (setting) of marine resources management of the North Sea.

3.1 NATURAL SYSTEM OF THE NORTH SEA

The North Sea is a rather shallow shelf sea with an average depth of less than 100 meters. The boundaries of the North Sea are indicated in figure 3.1. A distinction can be made between a southern and a northern part, the boundary being the 56° parallel. The southern part has an average depth of only 37 meters and only in the northern part in front of the Norwegian coast are depths greater than 200 meters found. Wind and tides induce a more or less regular water circulation.

The water movement in the southern part is mainly directed towards the northeast while in the central part an anti-clockwise circular movement occurs (figure 3.2). Areas with thermal or salinity stratification are limited and are mainly found in the deeper parts in front of the Norwegian coast. Retention times are large. Water entering the southern North Sea boundary through the English Channel leaves the northern boundary in front of the Norwegian coast after 150-250 days. Under winter conditions retention times are smaller because of stronger, prevailing southwesternly winds.

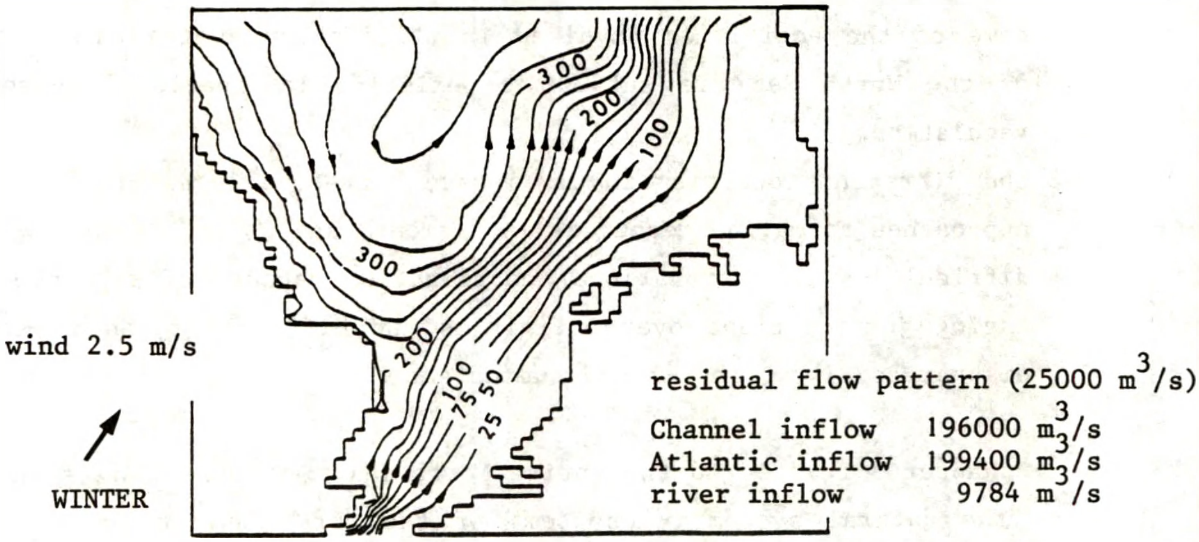

Figure 3.2 Water movement in the North Sea

Substances entering the North Sea are transported according to the streampattern of figure 3.2, either in solution or adsorbed on suspended sediments. The sediments accumulate mainly in estuaries in the south-western part of the Netherlands and along the English coast, and in an extensive intertidal sedimentation area starting north of the Netherlands with the famous Waddensea area and continuing eastward through the German Bight to the Danish West coast. Another sedimentation area is found in the deep northern parts of the North Sea.

Based on currently (1985) available data, there appears to be no significant increase in substances entering the North Sea ecosystem. Nevertheless, given the constant magnitudes of inputs of substances, the result will be a continuing build up of the concentrations of certain substances in the sediments of the North Sea. Depending on the extent to which the adsorption process is reversible, the quality in the water column will be affected to a greater or lesser extent by accumulation in the sediments. Time scales for such processes are very long.

The North Sea constitutes a highly productive ecosystem. Substances are taken up by algae and benthic organisms and are transferred to and accumulated in higher levels of the food chain. The following effects have been noted at the top of the food chain, and have been attributed to -but not yet proven to be caused by- the presence of toxic substances in North Sea water and sediments.

- Skin diseases, found on flat fish in the German Bight and the Dutch Wadden Sea.
- Some local and temporal massive fish kills.
- Very large reductions between 1940 and 1965 of the populations of the sandwich tern (sterna sandvicensis) and the eider (Somateria mollissima). The former species having been found to have egg shells that had become 5% thinner over this period.
- Significant reduction in the resident seal population.
- Significant reduction of the delphine population.

In addition to these effects, substantial loads of phosphorus and nitrogen have increased algal growth, resulting in oxygen depletion in bottom sediments in some areas and changes in abundancy and diversity of species throughout the food chain, in some area. These effects are not yet fully understood; therefore they are not yet amenable to prediction.

Changes in both abundancy and diversity of species are affected by: changes in quality of water and sediments; loss of habitat; and direct disturbances because of human activities. For example, commercial fishing resulted in a significant reduction of the herring population, subsequently restorted because of catch limitations imposed at the European Community level. Other major disturbances result from sand and gravel extraction, land reclamation activity in estuaries and in the Waddensea area, and military activities.

Compared with the physical processes in the North Sea, relatively little is known about the chemical and biological processes, and of the socio-economic effects of changes in such processes, and in the outputs of those processes. Such lack of knowledge presents a serious limitation for a proper evaluation of environmental and economic consequences of actual developments and of proposed management strategies.

3.2 HUMAN ACTIVITIES: USES, CONFLICTS, EFFECTS ON ECOSYSTEM

The geographic location of the North Sea, surrounded by densely populated and highly industrialized areas in Europe (figure 3.3), explains the intensive use of the natural renewable and non-renewable resources of the Sea. Developments resulting in rapidly increasing use of these resources started in the 1960s with the rapid economic growth in this decade. On top of this development a gradual shift from land-based to sea-based activities took place as a consequence of the gradual depletion of land resources. This last-mentioned shift in location of activities seems to be continuing, independent from economic growth, thus resulting in a continuously increasing demand for goods and services from the marine resources of the North Sea.

For the Dutch partion of the North Sea an inventory was made of the major conflicts [1]. Figure 3.4 presents a summary, which is illustrative for the management problems of the whole North Sea, which can be subsumed under the three following categories.

i. Overfishing

The total capacity of fishing boats of EC countries exceeds the capacity required to catch (harvest) the quota established by the EC. Employment is an important criterion in establishing the quota. However, enforcement of the quota is difficult because the fishing industry is comprised primarily of private interests.

ii. Economic consequences due to direct, day-to-day interaction between or among activities which compete for limited space

The activities involved are shipping, pipelines and cables, commercial fishing, oil and gas extraction, and military activities. A special kind of problem is encountered in front of parts of the Dutch coast where sand extraction may affect the stability of flood protection works, both natural and artificial.

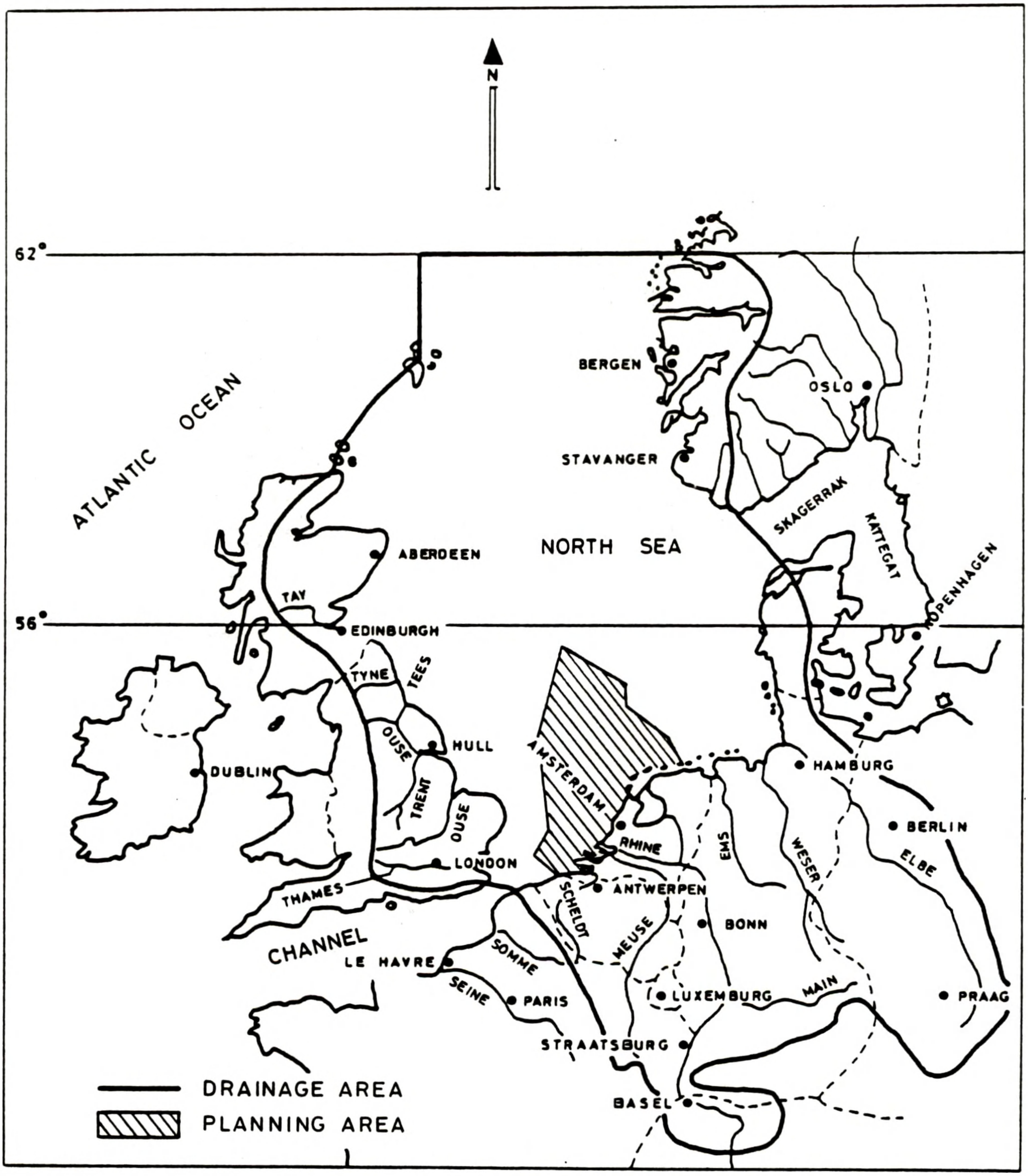

Figure 3.3 Drainage basins

	CONFLICTS BETWEEN ACTIVITIES								MAJOR PROBLEMS RELATED TO INDIVIDUAL ACTIVITIES	MAJOR LAND-SEA INTERACTIONS
shipping	damages due to anchoring	. wrecks damage nets . safety fishing activities	. allocations of reserved areas						. locally high risk of accidents . waste discharges . regulations hampered by international nature	. waste receiving harbour facilities replacing sea disscharge
pipelines and cables		. damage to nets and pipes and cables						. damage to pipes and cables	. high investments and control costs	. landing facilities (land use planning)
commercial fishing					. damage to ecosystems . concentration of toxics in tissues			. no fishing during exercises	. overfishing . insufficient knowledge of fish pollution and behaviour . control fish catch is difficult . increase of full costs	
gas and oil extraction								. allocation of reserved areas	. high risk of accidents . juridical position of employees on platforms insufficient . insufficient regulations for governmental control between exploration and exploitation phase	
sand and gravel mining							. mining in coastal zone endangers coastal protection works		. disturbance of benthic live; limited knowledge . high transportation costs . insufficient regulation permits	. sea mining replaces land based activities
disposal of wastes						. water quality does not meet swimming standards mainly along South-Holland coast			. damage to all biotic components of ecosystem; knowledge limited . international nature hampers cooridinated approach . no standards for water and sediment quality . control is difficult	. major sorces are land based activities . sea dumping alleviata land environmental problems
recreation									. safety yachting insufficient	
onshore facility siting and land reclamation									. damage to habitat . high costs - difficult financing . limited knowledge coastal morphology	. land use planning
military activities									. disturbance of living organisms	

Observation:
- only major aspects related to actual conflicts are indicated
- adapted from [1]
- disposal of wasted includes the discharge through rivers, atmosphere and discharge channels

Table 3.4 Major conflicts among human uses of the Dutch portion of the North Sea

The management task refers mainly to the allocation of activities in space, i.e., to specific areas of the North Sea, and to the determination of the levels of the activities, e.g., how much sand extraction per year. In the analyses to determination spatial allocation and levels of activities, three factors should be explicitly considered.

- Some activities are subject to to international rather than to national demands and regulations, e.g., some aspect of commercial fishing and some aspects of shipping.
- Alternative methods of producing some of the goods and services, e.g., oil and gas, sand and gravel, are possible on land. Therefore, the analyses should consider and weight land-based alternatives against North Sea alternatives.
- The ambient water quality effect of the activities within the North Sea area may extend beyond the boundaries of the North Sea. Conversely, some activities outside of the North Sea area affect ambient water quality within the North Sea.

iii. Water quality consequences due to discharges of wastes

Ecosystem processes, including physical, chemical and biological processes transform a time and spatial pattern of impacts of human activities into short run and long run time and spatial pattern of changes in ecosystem characteristics which in turn affect human activities. Such ecosystem characteristics mainly relate to ambient water quality which in a broad sense is comprised of chemical composition of water, sediment and organisms, as well as diversity and abundance of species. Ecosystem characteristics also include physical conditions for navigation and recreation and to the area of intertidal wetlands. Further specification of the interaction between human activities and the ecosystem is given in figure 3.5.

Impacts of human activities on the ecosystem processes are manifold. Figure 3.5 differentiates between the following categories.

- Physical boundary conditions, which affect physical processes such as water circulation and coastal morphology. These processes are affected by dredging operations for shipping, large amounts of dredging spoil being dumped in front of the coast, and by land reclamation and other infrastructural works, such as harbours and the Delta Works in the southwestern part of the Netherlands.
- Chemical composition of water and sediments indirectly changed by inputs of waste materials into the North Sea.
- Disturbance or destruction of habitat for finfish, shellish and mammals, e.g., by dredging operations for shipping, intensive commercial fishing using groundnets, sand and gravel mining, disposal of large amounts of dredging spoil, and land reclamation.

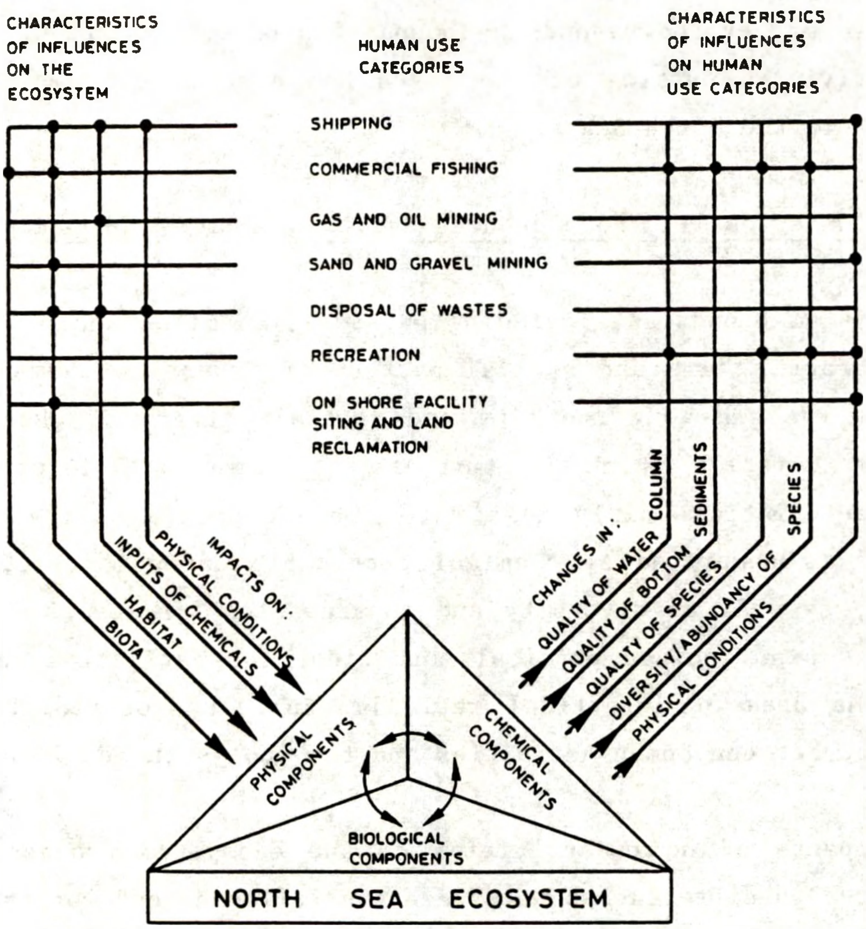

Figure 3.5 Interaction between human activities and North Sea ecosystem

- Fish catch (fin and shellfish) by commercial fishing, changing the composition of fish species and affecting the biologic processes of the ecosystem.

Figure 3.5 groups the changes in the ecosystem, due to the above mentioned impacts, into five categories. Physical conditions refer for instance to water velocities, sedimentation or erosion rates, area of intertidal wetlands, or in more general terms to water and sediment circulation patterns and morphological processes.

The category dumping of wastes needs some further explanation. This category refers to human activities whose primary use of the North Sea ecosystem is related to the capacity (or supposed capacity) of the ecosystem to receive wastes without "singificant" changes in ambient water quality and corresponding adverse effects on human beings and activities. Such wastes are generated on land and enter the North Sea through specially designed equipment such as ships or discharge pipes. In addition to dumping, disposal of wastes includes residuals discharged by sea-based activities such as shipping and offshore mining. The word sink is used to indicate that wastes enter the planning area through the natural transport mechanisms of river inflows, sea currents, and atmospheric deposition. The atmosphere, rivers, and sea currents are considered as combined sources of inputs.

3.3 LEGAL AND INSTITUTIONAL CONTEXT

Marine resources management in the North Sea must distinguish between two legal and institutional contexts, the territorial zone and the full Sea. Different legislation applies in the two contexts. In territorial waters the coastal states execute full sovereign power (Geneva 1958), with the exception that free passage is to be given to "innocent" ships. In full sea the utilization of marine resources is regulated through international conventions. Many conventions exist within different contexts, e.g., global, regional, European Community, and are related to different uses of the marine resources. Countries are free to join such conventions. The most important ones are related to the exploration and exploitation of sea bed resources (Geneva 1958); the pollution by dumping of wastes from ships (Oslo 1972: regional, part of the Atlantic Ocean and the North Sea; London 1972: global); the pollution from land (Paris 1974); and the pollution from navigation (MARPOL, London 1973/78). Some of these conventions include zoning of the full North Sea, of which the main one is included in Geneva 1958, dividing the continental shelf in different parts in terms of governmental jurisdictions (the Dutch part coinciding with the planning area, the focus of the study). Other zonifications refer, e.g., to fisheries, monitoring obligations with respect to oil contamination, and combatting oil pollution.

The conventions often lead to more regular cooperation among countries and frequent meetings provide operational means at a non political level to implement the corresponding conventions. Activities within such cooperation include, for example: developing additional regulations; following implementation of international agreements on national levels; and monitoring of the effectiveness of the corresponding regulations. Important cooperative frameworks are provided by the International Maritime Organization (IMO) and the secretariats of the Oslo 1972 and Paris 1974 conventions.

In addition to the above, the European Community (EC), which does not include Norway, plays an important role in the management of the North Sea, in particular regarding the integration of national environmental policies. The main instrument of the Community consists of directives, which generally result from previous coordination between and among the countries involved. In the case of Norway, negotiations with respect to policies are conducted between the EC and Norway.

It should be emphasized that all above mentioned conventions and EC directives have no operational authority in the sense of control and sanctioning. To achieve enforcement, agreed upon "guide lines" in such international arrangements must be translated into national legislation and implemented through national agencies.

In addition to the fragmentation due to the multinational context of the North Sea, management interests are further divided within each nation among many governmental authorities. No country involved gives responsibility to one authority for integrated management of marine resources; different ministries represent as many interests. For example. in the Dutch context the main ministries involved are: transportation and public works; housing, land use, planning and environment; economic affairs; and agriculture and fisheries. In 1977 an Interdepartemental Commission for coordination of North Sea Affairs (ICONA) was established, with the Secretariat provided by the Ministry of transportation and public works. ICONA has no operational authority but is considered an important institution to harmonize actions taken by different ministries. In addition to this coordination effort among ministries, coordination sometimes proves to be difficult within ministries and among national, provincial, and local levels. The last kind of coordination stems, among other things, from the situation that areas under provincial and local jurisdiction will include, in the near future, a zone of 1 km outside the low water coastal line.

In addition to the above outline of the legal and institutional context the following points merit emphasis.

- Obviously the available legal instruments and the institutional organisation are important components for the implementation of management strategies. In general it can be stated that no limitations, in the sense of missing instruments of institutions, exist in order to enable governmental authorities to regulate both the human activities within the North Sea and the amount of substances entering the North Sea.

  The above statement does not imply that both the legal instruments and the institutional organisation are adequate for an effective and efficient implementation of management strategies; it does emphasize the fact that when the political will to solve perceived problems, is strong enough, the legal instruments and the organizational structure are good enough to implement such strategies.

- As mentioned, the EC directives do not have operational authority in the sense of control and sanctioning. However, they do have legal authority in the sense that EC countries are obliged to implement these directives in their national legislation. This has two consequences. On the one hand the directives can be characterized as effective, because they have induced national legislation, but on the other hand the process of issuing these directives generally takes many years and often only will be concluded when the different countries have already taken preventive measures to preclude the necessity for issuing of the directive itself.

Little or no knowledge exists of how the directives are implemented in the different national legislation. An example of the problems encountered in this respect in the process of formulating directives is the noticeable difference between the UK and the rest of the EC. The former favours controls based on ambient environmental quality objectives and the others desire limit values or uniform emission standards [4].

- No water quality standards for North Sea water exist, except in relation to utilization for swimming and shellfish cultivation. Standards prove to be difficult to formulate for the North Sea where public health and/or economic interests are not directly at stake. Signals of adverse impacts of poor water and sediment quality on marine ecosystem components raise public awareness. However, they are insufficient to provide a basis for specifying desired water quality levels, especially when doing so might result in measures to be taken which have substantial economic consequences.

- Measures to improve water and sediment quality in the North Sea mainly have to be taken outside the boundaries of the North Sea as such. They refer to emissions to surface waters which discharge into the North Sea and emissions to the atmosphere which are subsequently deposited in the North Sea. In such situations local impacts in the direct vicinity of such emissions often provide a much stronger incentive for reduction than the water quality situation of the North Sea. This implies that, for water quality management of the North Sea, use has to be made of legal instruments and institutional organisations which are already existing but are created with different objectives. As an example, reference is made to an expected reduction of Pb (lead) between 1980 and 1990, basically due to measures to abate air pollution from cars in urban areas.

4 ANALYSIS FOR WATER QUALITY MANAGEMENT FOR THE DUTCH PORTION OF THE NORTH SEA

The focus of Chapter 3 was on marine resources management for the entire North Sea, where such management involves the production of a mix of products and services from the marine resources of the area (region). The focus of this chapter is the analysis for the water quality plan for the Dutch portion of the North Sea (see Chapter 1). This involves analyzing the demands for uses of the North Sea, within the Dutch portion itself, from land-based activities in the Netherlands, and from activities within non-Dutch portions of the North Sea and from land-based activities in other countries. Given that water quality in the Dutch portion of the North Sea is affected by, or can be affected by, all of the foregoing categories of activities, a critical question for water quality management of the given area is the extent to which, if at all, measures which can be undertaken by the Dutch (in relation to Dutch activities only), will have positive effects on water quality in the Dutch portion of the North Sea.

The focus of the analysis to support the water quality plan is on water quality management, in terms of analyzing the effects on water quality - in the water column and in sediments - of a given mix of products and services, or activities, for present conditions and for some future set of conditions. Alternative mixes of products and services are not analyzed as possible measures of improving ambient water quality (AWQ); the first task is to ascertain how present activities, and future activities as projected, will affect AWQ which includes the marine ecosystem.

This chapter is organized as follows. Section 4.1 presents the overall goal of Dutch water quality management for the Dutch portion of the North Sea and the analytical objectives defined for the study, in terms of the specific questions to be answered. Section 4.2 presents the framework for analysis and Section 4.3 the analysis conditions defined for the study.

4.1 GOAL FOR WATER QUALITY MANAGEMENT

The nature of the water quality management plan[1)] for the Dutch portion of the North Sea is set for in the ICONA action program (action P3) [1,2] as follows:

> "Building on international conventions and actual national policies, the plan will represent the vision of the Dutch government on a coherent and strategic approach to preventing and combatting pollution of the North Sea. The plan will provide directives for international negotiations and in addition will indicate management strategies as far as they can be taken in The Netherlands." [1, p.33]

The general goal of Dutch North Sea water quality management was stated as follows:

> "To maintain or to obtain a water quality in the North Sea, which enables preservation of the ecological values, thereby taking into account societal demands for the production of goods and services from the North Sea." [3, p.1.3]

The "preservation of ecological values" is specified as being comprised of:

> "Maintaining or recuperating a diversity of organisms and of aquatic ecosystems as close as possible to an undisturbed situation"; and
>
> "Preventing that, due to human activities, changes of the North Sea ecosystem will occur which are irreversible and have adverse effects on the functions[2)] of the North Sea." [2, p.10]

Given this general goal, and given the evidence presented in chapter 3 with respect to observed effects on various species in the North Sea in recent decades, it was concluded that the analysis should mainly consider the problems of: (1) heavy metals in relation to concentrations in both

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1) As noted below, the contents of the water quality management plan as produced in the study is not consistent with the definition of a plan given in section 2.4.

2) In Dutch terminology this includes the production of goods and services in response to societal demand plus a so-called ecologic functioning as an intrinsic value of the North Sea ecosystem.

water column and in sediments, and the resulting possible effects on species; and (2) eutrophication as a result of nutrient inputs, and the resulting possible effects on species.

4.2 FRAMEWORK FOR ANALYSIS

In relation to the framework for analysis delineated in section 2.6, the segments of analysis included in the Dutch study were: setting up the analysis; estimating discharges from various sources; and analyzing natural systems, including the effects or potential effects on species. These corresponds to segments 1, 3, and 4 in figure 2.5.

In addition, an investigation was made of international agreements, national regulations, and policy guidelines reflecting the legal and institutional structure for water quality management in the Dutch portion of the North Sea. The objective of this investigation was twofold. In the first place bottlenecks were looked for, in the sense that the legal and institutional structure could not provide the proper instruments to stop deterioration or to obtain an improvement of the actual water quality. Secondly, information has been collected to be used in the formulation and evaluation of management strategies (segments 5 and 6 respectively in figure 2.5) in the sense as defined in chapter 2. Such management strategies have not been developped during the study. The collected information has been used to evaluate the formal policy guidelines of the different sectors using the North Sea marine resources, on consistency, in particular in relation with the water quality aspects of the activities involved.

4.3 ANALYSIS CONDITIONS

The analysis conditions established for the study reflect: (1) the specified questions to be answered (related to: how do present and future activities affect AWQ, including the marine ecosystem?); and (2) the available analytical resources, i.e., existing data, manpower, and time. With respect to the second, the study was to be based on existing data and was to be completed within 18 months, at a total of 12 man-years of input.

Details with respect to the various analysis conditions follow.

- Nature of study output

  The characteristics of the output of the study were implicity defined to include: (1) estimates of discharges from various sources; (2) estimates of concentrations of various substances in water; (3) estimates of effects of those concentrations on species; (4) description of the ecology of the North Sea; which in coming years should lead to an indication of ecologically more vulnerable and less vulnerable areas; and (5) delination of the legal and institutional context of water quality management for the Dutch portion of the North Sea. Only the first three outputs are summarized in this report. A detailed description of the different outputs is presented in four background documents [6, 7, 8 and 9; all in Dutch]. Not included in the study output were specific measures to reduce discharges from various sources, the costs of these measures and how the adoption of those measures might be induced.

- Interactions

  Figure 4.1 presents an overview of the interactions between human activities and the North Sea ecosystem considered in the study, displaying the limitation of the analysis to water quality aspects only.

- Study area boundaries

  The study area or planning area coincides with the Dutch portion of the North Sea shown in figure 3.1. In vertical direction the water column was involved from surface down to the bottom (sea bed). Thus, the bottom sediments represent one of the sources of inputs (discharges) of substances into the study area.

  For the purpose of water circulation and water quality modelling the horizontal boundaries coincide with the boundaries of the so called southern North Sea, including in the North the parallel of 56° latitude, and in the South, the line in the English Channel shown in figure 3.1

  The corresponding areas were 57,000 km^2 for the Dutch portion of the North Sea (study area) and 220,000 km^2 for the southern North Sea.

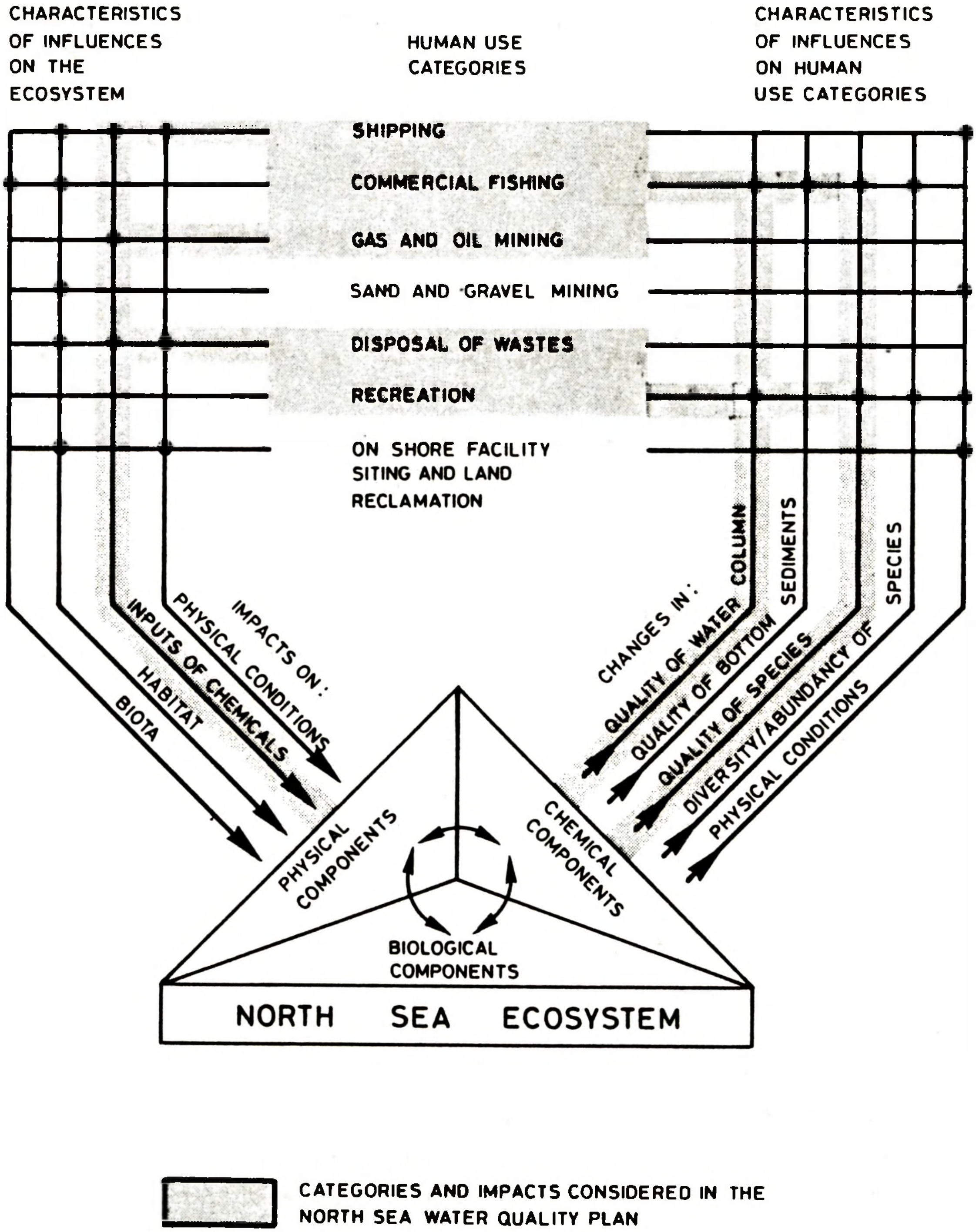


Figure 4.1 Interaction between human activities and North Sea ecosystem, considered in the water quality plan

- Time horizons

Estimates of discharges and of effects of discharges were made for 1930, for nutrients only, and for 1980 and 1990 for the substances given below.

The 1980 conditions do not represent the specific hydrological and economic situation for that year. Further specification is given in section 5.1.

Water circulation modelling differentiated between winter and summer conditions as far as residual currents in the North Sea were concerned. No seasonal differentiation has been applied for river flows. The spatial distributions of considered substances were mainly determined for winter conditions. This was done to limit the computational burden for the comparitive analysis for 1980 and 1990 situations, given the fact that initial calculations showed only small differences in model results for summer and winter conditions. In making the selection, it has been taken into account that the influence on ambient water quality of sedimentation processes, which are not simulated in the water quality model, are stronger in the summer than in the winter season, due to lower wind-velocities.

The eutrophication analysis covered a whole year, using quarterly averages for residual flows.

- Substances

The substances were: cadmium (Cd); mercury (Hg); lead (Pb); copper (Cu); chromium (Cr); zinc (Zn); phosphorus (P); and nitrogen (N). Although these substances do occur in both dissolved and particulate forms, only total (dissolved + particulate) concentrations were considered. In this way the complex interaction between dissolved and particulate forms due to physical, chemical and biological processes did not need consideration. Particulate forms however can settle to the bottom, a process which was neglected in this first analysis. Discharges of organic material were not considered relevant for the analysis of eutrophication in the North Sea.

As part of the description of the ecology of the North Sea the toxic effects of organic micro pollutants (organo chlorines) have been investigated. An inventory was made of discharges of petroleum hydrocarbons (oil) into the North Sea. Based on this inventory oil was not considered to represent a major problem at the present time (1984).

- <u>Sources</u>

The sources of discharges into the study area considered are listed in table 4.1. Sources considered to represent negligible inputs and sources not considered are also listed in the table. The cross-boundary sources are characterized as "combined" sources, in that the estimated discharges from these sources represent the discharges from multiple sources, each of which is not individually identified. Coastal outfalls and rivers refer to all the related English, Belgian, Dutch, German and Danish coasts. Figure 4.2 presents the locations of incineration of industrial wastes, dumping of industrial wastes and sewerage sludges from ships and dumping of dredging spoil.

For the substances mentioned above the discharges by offshore, shipping, and incineration proved to be negligible.

Incidental discharges, e.g., due to shipping accidents or blow outs from oil exploitation operations, have not been taken into account. They are subject to separate planning by the Dutch government.

Inputs of wastes into the North Sea were estimated for 1980 for the southern North Sea and for the study area. Estimates for inputs in 1990 were made for the study area only. River inflows are schematized in figure 5.6 and tabel 5.7.

- <u>Major assumptions and simplifications made in the analyses</u>

Due to lack of knowledge and data as well as due to lack of time available for the study, some assumptions and simplifications had to be made with respect to the functioning of the natural systems. Assessments of the influence of such assumptions on the final results should be subject of a sensitivity analysis. Such an analysis has not been carried out during the 18 month study, but will be carried out in the near future. The major assumptions with respect to the water circulation and water quality analyses are listed below.

- Mass transport calculations are based on tidal averaged residual flows.
- Atmospheric deposition rates are based on a limited amount of observations in the Dutch coastal zone (land area) in the years 1979-1982. These rates were supposed to be the same for the whole North Sea area. 1990 deposition rates were taken equal to 1980 estimates.
- Channel and North Atlantic Ocean water were supposed to have a so-called reference concentration, representing estimates of concentrations at a time that "no or very limited" influences of humans and human activities existed on ambient water quality. In particular for water flowing into the southern North Sea through the Channel, concen-

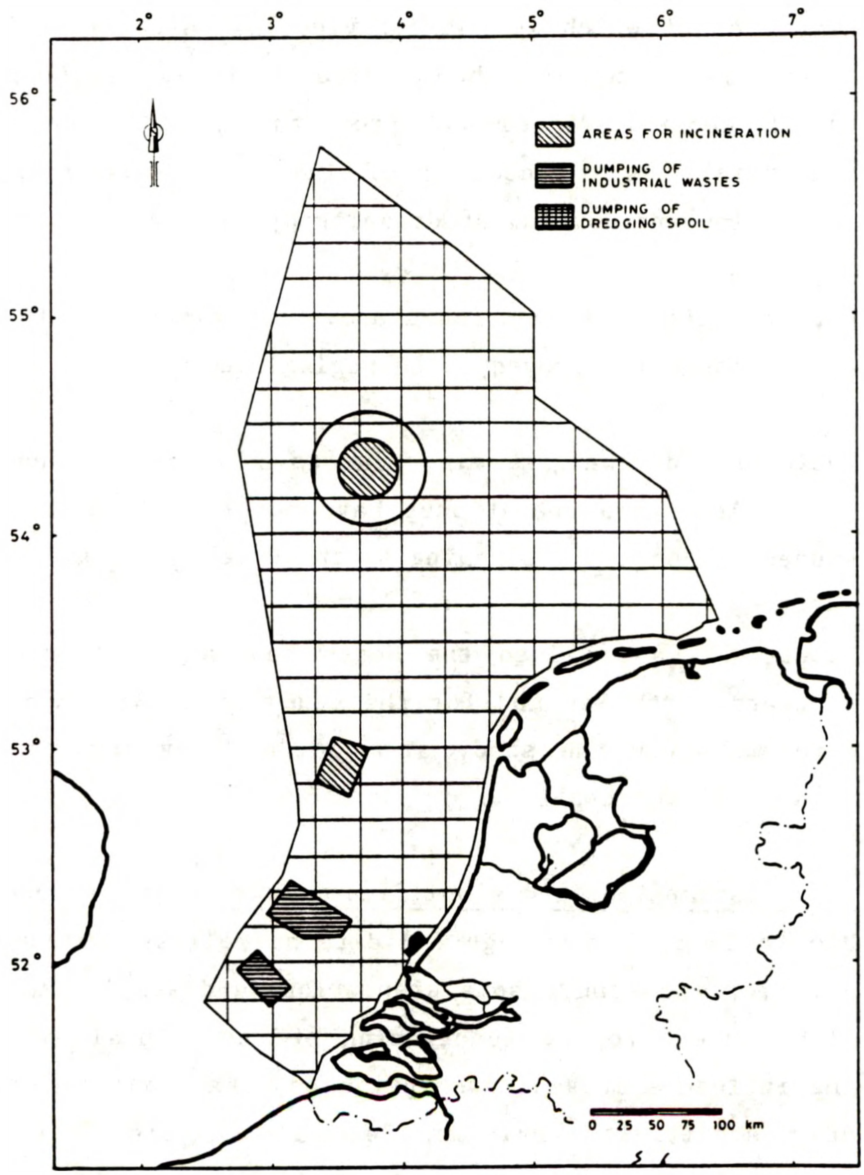


Figure 4.2 Locations in the Dutch portion of the North Sea for incineration and dumping

trations of considered substances along the French coast probably will be higher than these reference concentrations, which will have a major influence on concentrations in front of the Dutch coast.

- River flows and loads discharged into the planning area were supposed to be constant during the year.
- Only total concentrations of considered substances have been taken into account.
- Stratification (temperature, salinity) has not been considered in the quantitative analyses.

SOURCES CONSIDERED

DIRECT
- coastal outfalls (municipal and industrial)[1]
- offshore oil and gas operations
- dumping of dredging spoil
- dumping of industrial wastes and sewer sludges from ships
- burning of industrial wastes
- marine transport

COMBINED (CROSS-BOUNDARY)
- atmosphere
- rivers
- sea currents (boundaries)

SOURCES NOT CONSIDERED
- pipeline leaks
- accidents
- militairy exercises
- bottom sediments

1) Urban storm runoff directly into the Dutch part of the North Sea is essentially non-existent.

Table 4.1 Sources of discharges into the North Sea planning area

5 METHODS OF ANALYSIS

This chapter describes the methods of analysis used in the study. Section 5.1 presents the methods of estimation of discharges in 1980 and 1990. Section 5.2 gives an overview of the approach followed in the description of the ecosystem, which, among other things is aimed to contribute, in the near future, to the definition of ecologically vulnerable areas. Section 5.3 describes the quantitative analyses of natural systems, including descriptions of: hydrodynamic modelling; water quality modelling; modelling of eutrophication processes; and analysis of sedimentation processes. The methods used in estimating the effects of pollution on organisms are presented in section 5.4; while section 5.5 describes additional methods for the assessment of the ambient water quality situation. Results of the analyses are presented in section 6.

5.1 ESTIMATING DISCHARGES

Yearly discharges of wastes into the North Sea (inputs) are estimated for given mixes of goods and services produced or activities in the present situation and in 1990. Section 5.1.1 deals with the present situation. This situation is characterized by the year 1980, but does not represent specific 1980 conditions. More information is given in the subsequent sections. Section 5.1.2 presents the estimation of inputs for 1990. Results are given in sections 6.1 and 6.2.

Discharges to the Dutch portion of the North Sea were studied in more detail than discharges to the southern North Sea; for the Dutch portion of the North Sea, low and high estimates for the discharges have been made.

Average yearly discharges were used as an input to the water quality models, mainly simulating winter conditions. Due to a lack of data no seasonal differentiation could be applied in the discharges of wastes.

5.1.1 Discharges in 1980

Atmosphere

No observations of deposition rates (kg/km^2/yr) on the North Sea are available. Observations on land sites close to the North Sea and related estimates of yearly deposition rates were available for a period between 1979 and 1982. These estimates showed great variation [10, 11, 12]. Based on this information, average, low and high values could be computed. Deposition rates shown in table 5.1 and used in the study represent the averages of these values.

Substance	kg/km^2/yr
N	1000
P	45
Hg	0.04
Cd	0.3
Pb	11
Cu	6
Cr	0.3
Zn	40

Table 5.1 Estimates of atmospheric deposition rates

In the computation of the total atmospheric deposition the above rates were applied for the whole area under consideration; no differentiation could be made in the deposition rates as a function of the distance to the shores or to specific sources.

Rivers

Discharges of wastes into the North Sea by rivers were taken from reports of governments to the North Sea conference in Hamburg in 1984 [13] mainly representing 1980 conditions.

Discharges by the river Rhine (including the Rotterdam Waterway and the Haringvliet in tabel 5.7), flowing into the Dutch portion of the North Sea were corrected and related to average river flow conditions instead of to specific hydrologic 1980 conditions. Comparison of yearly values of total loads and river flows for a period of about 15 years, shows an increasing load for increasing river flows. This may be due to higher erosion rates upstream or lower retention rates of sediments in estuaries, rivers and harbour basins in years with higher river run-off than average. The reverse may occur for river flows below average values. As the estimates for the year 1990 suppose average hydrologic conditions, a rough correction of about -20% has been applied to the "1980" discharges of the river Rhine, given the fact that average Rhine discharges at the Dutch border in 1979-1980 and 1981 were 2540, 2550 and 3000 m^3/s respectively, compared with an long yearly flow average of 2200 m^3/s.

For discharges by other rivers, which often encompass discharges into estuaries and tidal waters, retention of substances in these waters due to, e.g., sedimentation were not taken into account. In this respect these discharge estimates may represent upper limits.

Part of the discharge by rivers is not related directly to anthropogenic sources. The corresponding, so-called "base" concentration or "natural" concentration is presented in table 5.2. The "natural" concentrations of nutrients (total N and P) in rivers are based on a water quality study of the river Rhine [28]. In this study calculations were made (using a water quality model of the river Rhine) of the quality of Rhine water flowing into the North Sea, based on: (i) estimates of natural concentrations of all considered tributaries to the Rhine; and (ii) eliminations of all point sources of waste water from human activities. Average data on "natural" concentrations (dissolved) of heavy metals are obtained by estimating and studying [14]: current concentrations in natural rivers; erosion rates for the basin of the river Rhine upstream; and current concentrations in lakes with very long residence times. "Natural" concentrations of substances adsorbed on suspended solids correspond to Rhine sediments in 1900 [15]. An average suspended solids content of 20 g/m^3 is used.

Substance	In solution (mg/m^3)	Adsorbed on suspended solids (mg/g)	Total[1)] (mg/m^3)
N	830	35	1500
P	40	3	100
Hg	0.02	0.001	0.04
Cd	0.05	0.001	0.07
Pb	0.35	0.15	3.4
Cu	2.0	0.04	2.8
Cr	1.25	0.09	3.0
Zn	6.0	0.4	14.0

1) For a concentration of suspended sediments of 20 g/m^3

Table 5.2 "Natural" concentrations applied for rivers

Sea currents

Incoming residual flows from the Channel were based on results of model computations, available in literature [22]. These computations resulted in monthly values with an average of 150,000 m^3/s over a period between 1949 and 1972. Such residual flows are induced both by tide and wind effects. In [22] it was estimated that as an average both effects account for 50% of the total residual flow. As wind effects are considerably stronger in winter than in summer, estimates have been made of this wind effect separately, using existing models from the Dutch Meteorological Institute (KNMI) under specific conditions: August 1979 (summer) and January 1979 (winter). These calculations resulted in the following values for average Channel inflow under summer and winter conditions:

summer: 75,000 (tide) + 25,000 (wind) = 100,000 m^3/s

winter: 75,000 (tide) + 125,000 (wind) = 200,000 m^3/s.

Incoming flows through the North Atlantic Ocean boundary "automatically" result from the model calculations (section 5.3.1) once the water-levels and Channel inflow are set.

Dissolved concentrations of substances in inflowing water from the Channel and the North Atlantic Ocean were supposed to have values found in open ocean waters. For the particulate concentration, the natural composition of suspended sediments (adsorbed substances) was used, in combination with measured concentrations of suspended solids at the Channel and North Atlantic Ocean boundaries [14]. Values are presented in table 5.3.

Substance	In solution (mg/m^3)	Adsorbed on suspended solids (mg/g)	Total[1)] Channel (mg/m^3)	Total[2)] North Atlantic Ocean (mg/m^3)
N	110	20	210	130
P	17	1.6	25	19
Hg	0.0025	0.00015	0.0033	0.0027
Cd	0.025	0.0003	0.027	0.025
Pb	0.02	0.030	0.17	0.05
Cu	0.25	0.030	0.40	0.28
Cr	0.3	0.075	0.68	0.38
Zn	0.35	0.075	0.73	0.43

1) For a concentration of suspended solids of 5 g/m^3
2) For a concentration of suspended solids of 1 g/m^3

Table 5.3 "Natural" concentrations applied for Channel and North Atlantic Ocean water

Coastal outfalls

Coastal outfalls comprise discharges by industry and communities (sewer systems) to the North Sea and to estuaries and rivers under tidal influence. As retention in such waters under tidal influence is not accounted for, the discharges in this respect represent upper limits. Data of discharges were taken from reports of governments to the North Sea conference in Hamburg in 1984 [13] and represent 1980 conditions.

Dumping of dredged spoils

Data on amounts of dredged spoils from harbours (mainly Rotterdam) and corresponding waste loads were obtained from reports to the Oslo Commission [17]. For the Dutch situation an average was taken of the yearly load in 1979, 1980 and 1981. For the UK and Belgium 1981-values were taken. The gross discharges had to be reduced because part of the substances is from marine origin and can be characterized as "recirculation". The recirculating marine part of the sediment was estimated for each dumping site. To determine the recirculating loads, average concentrations in sediment along the southern Dutch coast were used (table 5.4).

Substance	mg/kg
N	2,000
P	2,000
Hg	0.5
Cd	1.0
Pb	78
Cu	30
Cr	125
Zn	190

Table 5.4 Average concentrations (adsorbed) in marine sediment along the southern Dutch coast

Dumping of industrial waste and sewer sludges from ships

Data on amounts and waste loads were obtained from reports to the Oslo Commission [17] and to the North Sea conference in Hamburg in 1984 [13], representing 1981 conditions.

Burning of industrial waste

On the Dutch portion of the North Sea industrial wastes (mainly halogenated hydrocarbons) from different countries are burned which may result in local pollution through atmospheric deposition. These amounts however, are so small that they can be neglected in the quantitative analysis calculating water quality distribution in the North Sea.

Marine transport

Marine transport presents an important source for oil discharge. For the considered substances the contribution of this activity can be neglected.

Offshore oil and gas operation

Estimates for discharges by oil and gas operations in the North Sea are based on data on drilling and production activities from the Dutch Ministry of Economic Affairs (1982) and on average concentrations of substances in waste liquids. The following assumptions have been made:

- Average boring depth ranged from 3000 to 3500 m in the southern North Sea to 3500 to 4000 m in the central and nothern part. Multiplication with the total number of drills in the areas considered, yields the total drilling depths.
- An average value of 0.33 m^3 drilling liquid to be discharged for each m drilled was obtained from inventory studies mainly for the Gulf of Mexico [18, 19, 20].
- Product water in oil varies among other things with the age of the fields. An average value of 20% product water in oil was applied for the

North Sea. The total amount of product water in gas produced in the North Sea is small and was neglected.

- Data on concentrations in waste drilling liquids and product water are lacking for the North Sea. Therefore data for the Gulf of Mexico are applied [20]. These data are presented in table 5.5.

Substance	Drilling liquid	Product water
N	150	-
P	280	-
Hg	1.0	0.003
Cd	1.0	0.34
Pb	26	1.0
Cu	6.2	0.46
Cr	320	0.2
Zn	50	0.8

Table 5.5 Average concentrations in drilling liquid and product water observed in the Gulf of Mexico (g/m^3)

5.1.2 Discharges in 1990

Discharges for 1990 were estimated for the planning area only.

Atmosphere

Due to lack of data on sources and their future developments, atmospheric deposition in 1990 was kept equal to the 1980 situation.

Rivers

Discharges from rivers entering the North Sea through the UK, Belgian and German coasts have been taken equal to the 1980 data. For rivers entering through the Dutch coast (nrs. 3 to 12 incl. in figure 5.4 and table 5.7), the following procedure has been followed.

Discharges into the North Sea were assessed, based on estimates of waste loads into the rivers proper and so-called reduction factors. A reduction factor is the ratio of waste load entering the sea and the total waste load discharged into a river, including the foreign part crossing the border. Due to, e.g., sedimentation in river basins, reduction factors are below one. Reduction factors have been determined for 1980 conditions for which year both the total loads discharged into the North Sea and the rivers themselves where known. For the Rhine through Rotterdam these reduction factors vary roughly between 0.1 and 0.6 for different substances. For heavy metals the variation is between 0.4 and 0.6.

Data on waste loads discharged to rivers in 1990 in the Netherlands were obtained from Dutch water quality plans [21]. For the waste loads in rivers crossing Dutch borders, two scenario's were developed (table 5.6). These percentages have been estimated based on observed developments in waste loads in rivers crossing Dutch borders, since 1980.

Substance	Low scenario	High scenario
N	75	100
P	75	100
Hg	25	50
Cd	25	50
Pb	50	75
Cu	50	75
Cr	25	50
Zn	50	75

Table 5.6 Scenario's (1990) for waste loads in rivers crossing Dutch borders as percentage of 1980 loads

Sea currents

Residual currents and concentrations of substances in these flows might change over time. As data on this phenomenon, however, are lacking, the inflow of substances with residual currents in 1990 were kept equal to those of 1980, including reference concentrations for inflowing Channel and North Atlantic Ocean water.

Coastal outfalls

Data for 1990 on industrial and municipal discharges to the sea were obtained from Dutch water quality plans [21].

Dumping of dredged spoils

Two scenario's were applied for the dumping of dredged spoils from Rotterdam harbours into the North Sea:

- a low scenario: in line with an adapted government policy that only the relatively clean part, rich of marine sediments, is dumped; and
- a high scenario: the amount of dredged spoils dumped in 1990 is equal to the amount in 1980.

Concentrations of substances in the dredged spoils for the 1990 situation have been estimated by applying a reduction coefficient to the 1980 concentrations; the reduction coefficient being the ratio of the 1990 and 1980 waste loads to the rivers involved. Reduction factors range from roughly 0.4 for chromium to 0.9 for nitrogen.

A small amount of dumped dredged spoils from Scheveningen harbour was kept equal to the 1980 figures.

Just like for 1980 the gross discharges were reduced to net discharges by correcting them for the recirculating amounts in the marine part of the sediment.

Dumping of industrial wastes and sewer sludges from ships

It is expected that dumping of industrial wastes from ships in Dutch waters will be ended before 1990. Sewer sludges are and will not be dumped in the North Sea by the Netherlands.

Burning of industrial waste

Burning of industrial waste on the Dutch portion of the North Sea most probably will come to an end before 1990. Therefore the discharges in 1990 were set to zero.

Marine transport

Neglectable for the considered parameters as in 1980.

Offshore oil and gas operations

Based on expected developments in exploration and production activities of oil and gas, waste discharges for 1990 were estimated as follows (Dutch Ministry of Economic Affairs):

- Trends in concessions issued, as well as in number of exploration drills a year and the successful part in it, and also in number of wells needed for exploitation, give an idea about the number of fields, which may be evaluated (evaluation drills) and exploited (exploitation drills). Average drilling depths were kept equal to the 1980 figures. This analysis resulted in a total oil production in 1990 and a total depth bored.
- Average values of waste drilling liquid (0.33 m^3/m) and concentrations of substances in drilling liquid and product water of 1980 were applied (table 5.5).
- Product water in oil will have risen in 1990 due to aging of the production fields. Therefore the average figure of 20% water in oil in 1980 is raised to an average level of 35% in 1990.

5.2 DESCRIPTION OF NATURAL SYSTEMS

Marine ecosystems consist of a complex system of biotic and abiotic elements and their interrelations. Various institutes have carried out research on specific subjects related to the ecosystem of the North Sea but little is known on the functioning of the ecosystem as a whole. In order to use the results of specific studies for the analysis of the effects of the disposal of wastes on ambient water quality and marine organisms and ecological processes, the North Sea ecosystem has been described based on a review of available recent literature. A summary of this description is given in section 3.1. The following topics have been studied:

- geography, morphology, meteorology;
- water movements and mixing;
- sediment transport;
- ambient water quality and sedimental pollution;
- primary production (phytoplankton);
- secundary production (zooplankton, copepods, benthos);
- mineralization (heterotrophic bacteria);
- fish;
- birds and mammals;
- ecosystem structure and relations (carbon cycle); and
- accumulation of toxics in organisms and toxic effects.

Major relations between above items are presented in figure 5.1.

In order to facilitate a future possible definition in the North Sea of more or less vulnerable areas in ecological terms, special attention has been paid to the following subjects:

- spatial distribution of organisms;
- structure of the ecosystem and carbon cycle; and
- impacts of toxic substances on marine organisms.

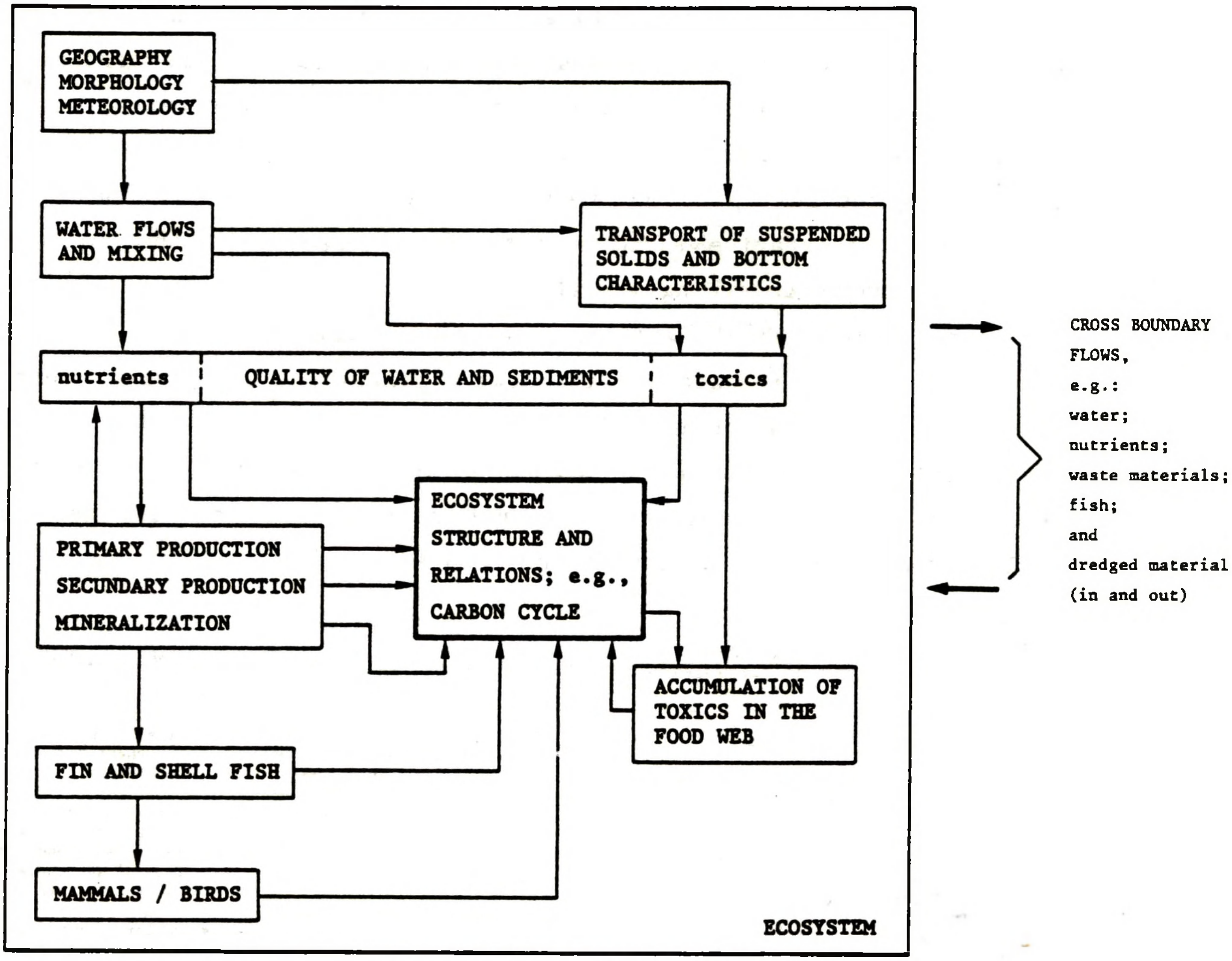


Figure 5.1 Relation diagram for considered elements of the North Sea ecosystem

5.3 QUANTITATIVE ANALYSIS

This section describes the quantitative analyses of the natural system for estimating the concentrations of various substances in water and sediments. Results are presented in section 6; analysis conditions are given in section 4.3

The major components of the analysis are the hydrodynamic modelling (ESTFLO programme, section 5.3.1) and the water quality modelling (DELWAQ programme, section 5.3.2). Analyses of eutrophication and processes of sedimentation, including long term development of concentrations of substances in bottom sediments, have been carried out on a different scale not covering the full planning area. Purpose of these analyses has been to gather more quantitative insight in these processes, in order to be able to find the major governing variables, to estimate the relevance of these processes for the ambient water and sediment quality and to specify priorities for possible research in the coming years. The analyses on eutrofication and sedimentation have been described in sections 5.3.3 and 5.3.4 respectively. Figure 5.2 presents a relation between the above mentioned components of the analyses of natural systems and presents the major results produced by the different components.

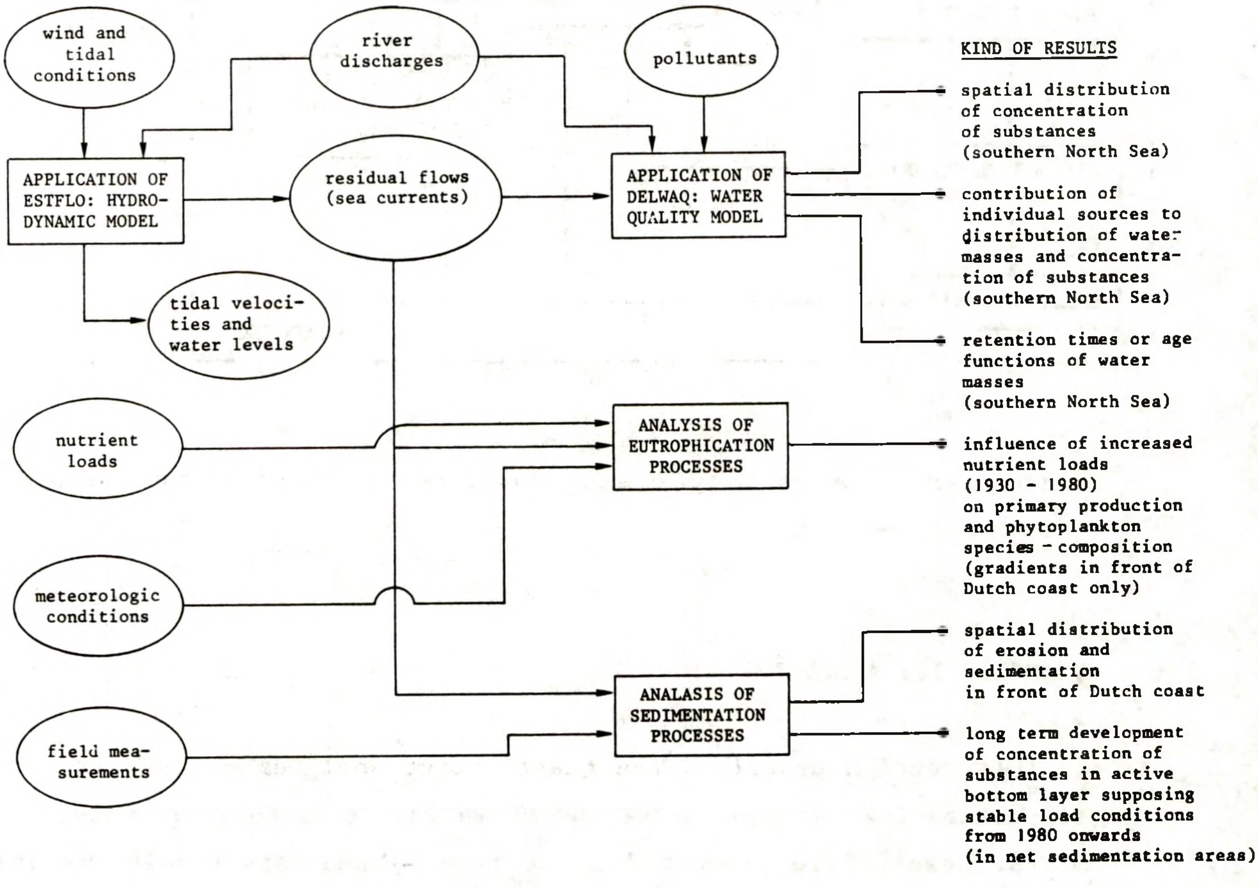


Figure 5.2 Relation between major components of quantitative analysis

5.3.1 Hydrodynamic modelling (ESTFLO)

Within the framework of applied research for the Dutch Ministry of Public Works, Rijkswaterstaat, a two-dimensional depth averaged hydrodynamic model, called ESTFLO, was developed and applied on the southern part of the North Sea [16]. The model calculates water levels and depth average flow velocities induced by tide and wind action.

The differential equations governing the mathematical model are so-called shallow water equations which are derived under the assumption of hydrostatic pressure.

$$-\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} - fV + g\frac{\partial \zeta}{\partial x} - k\left(\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2}\right) + g\frac{U(U^2+V^2)^{\frac{1}{2}}}{C^2(h+\zeta)} - \frac{1}{\rho(h+\zeta)}\tau_x^s = 0 \qquad (1)$$

$$-\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + fU + g\frac{\partial \zeta}{\partial y} - k\left(\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}\right) + g\frac{V(U^2+V^2)^{\frac{1}{2}}}{C^2(h+\zeta)} - \frac{1}{\rho(h+\zeta)}\tau_y^s = 0 \qquad (2)$$

$$-\frac{\partial \zeta}{\partial t} + \frac{\partial((h+\zeta)U)}{\partial x} \quad \frac{\partial((h+\zeta)V)}{\partial y} - S = 0 \qquad (3)$$

where

U = depth averaged velocity in x direction
V = depth averaged velocity in y direction
ζ = water elevation relative to the reference plane (see figure 5.3)
h = distance from the bottom to the reference plane (see figure 5.3)
τ_x^s τ_y^s = wind stress components in x and y direction
f = Coriolis parameter
g = acceleration due to gravity
k = horizontal momentum diffusion coefficient
ρ = density of the water
C = Chezy parameter for bottom friction
S = source or sink term

Using an explicit numerical method the schematization of the area under consideration is covered by a two-dimensional rectangular grid presented in figure 5.3. Figure 5.4 shows the schematization of the considered part of the North Sea between the Strait of Dover (at a latitude of 50°50') in the South and a fictitious line Edinburgh-Copenhagen (at a latitude of 56°) in the North. Grid dimensions were 10 x 10 km. To drive the model, a set of boundary conditions for the water levels was obtained from a larger model operated by the Rijkswaterstaat covering the whole of the North Sea as well as a part of the Channel in the South and part of the Kattegat in the East [24].

For a better representation of river inflows and interactions with adjacent water bodies, the model was extended outside the planning area boundaries, including: the Eastern and Western Scheldt Estuary; the Wadden Sea; and the Ems and Elbe Estuaries.

For the considered area 20 river inflows and water discharge locations have been specified with a total discharge of $5.8 * 10^3$ m^3/s. No differentiation has been applied over the year. An overview of the specified discharges is given in table 5.7. Characteristic winter and summer situations were simulated with respect to wind conditions. Vectorial averaged wind conditions in January '79 and August '79 were taken representative for winter and summer conditions respectively. The water level driven model yields, among other things, residual flows, including in- and outflows through Channel and North Atlantic Ocean boundaries. Results are given in table 5.8. The Channel inflow corresponds well with the estimates, given in section 5.1.1 of 100,000 and 200,000 m^3/s for summer and winter conditions respectively.

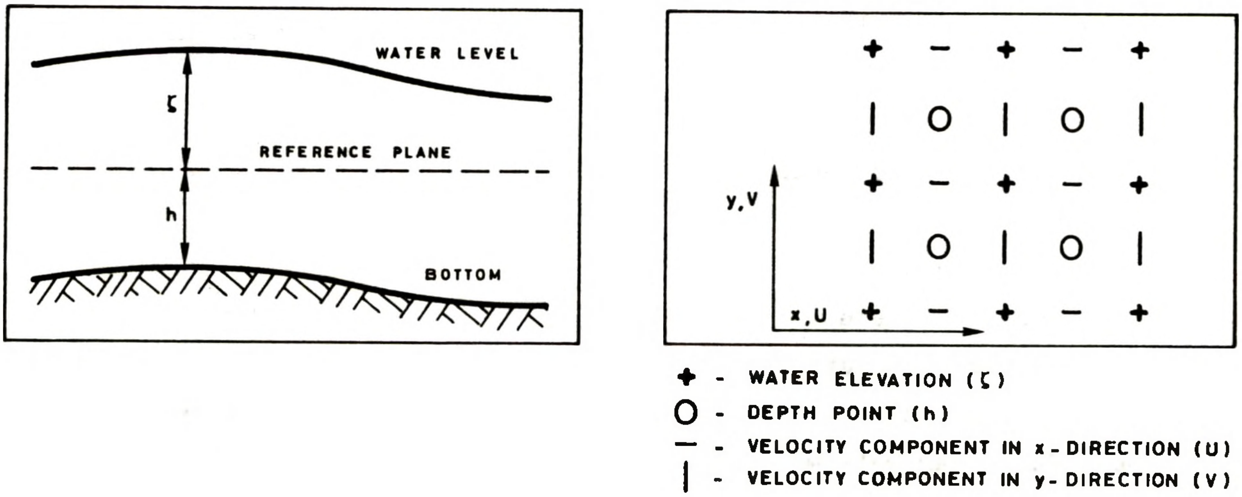


Figure 5.3 Schematization of some ESTFLO computational characteristics

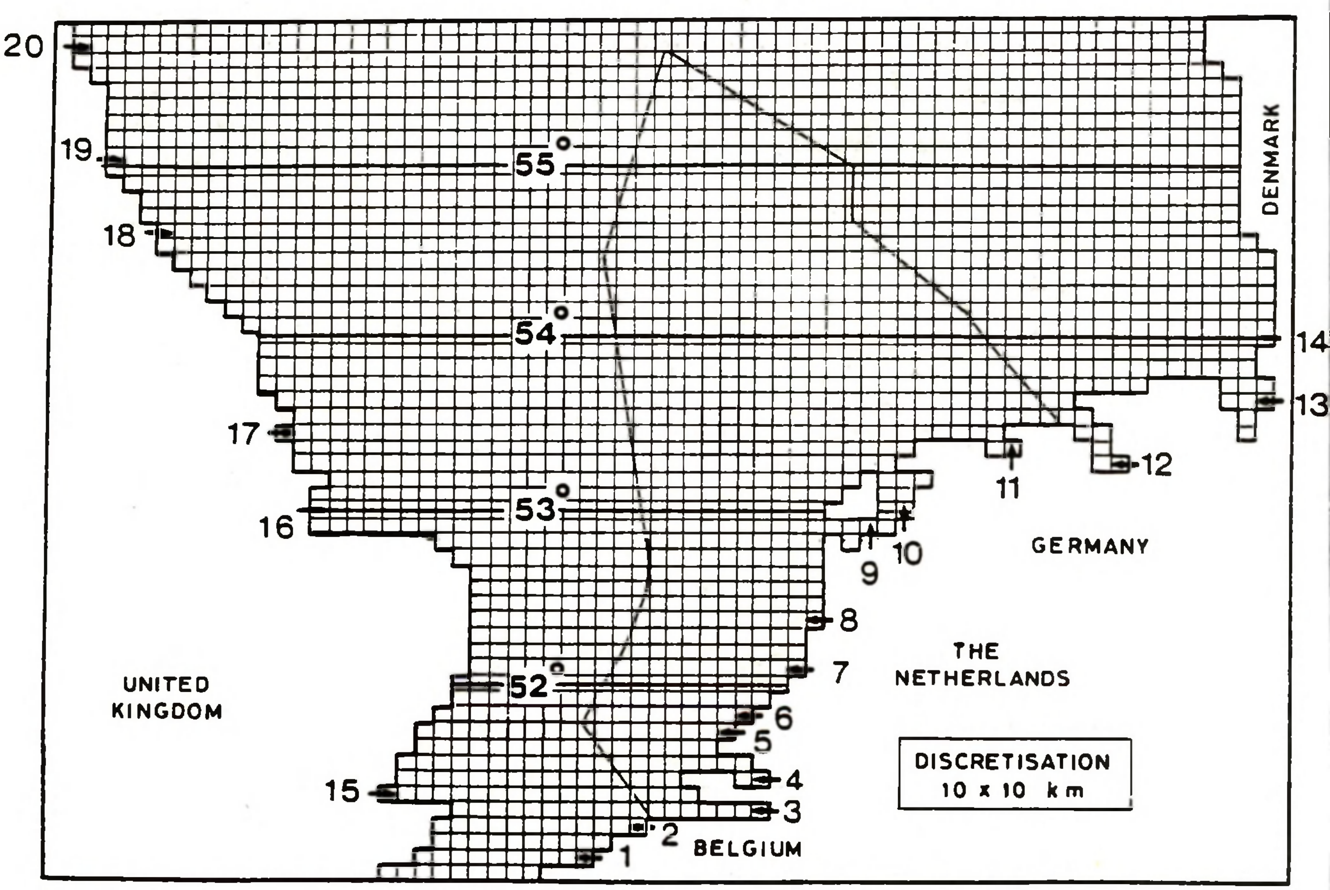


Figure 5.4 Model schematization ESTFLO-DELWAQ: grid and location of river inflows (table 5.7)

Rivers or coastal outfalls	Discharges (m^3/s)
Belgium	
1. IJzer	5
2. Oostende/Zeebrugge	15
The Netherlands	
3. Western Scheldt	150
4. Eastern Scheldt	66
5. Haringvliet	900
6. Rotterdam Waterway	1,525
7. Old Rhine	10
8. North Sea Canal	81
9. Lake IJssel: Den Oever	262
10. Lake IJssel: Kornwerderzand	344
11. Lauwers Sea	41
12. Ems-Dollard Estuary	120
Germany	
13. Weser	500
14. Elbe	1,150
United Kingdom	
15. Thames	154
16. Forth	65
17. Thyne	51
18. Tees	17
19. Humber	280
20. Wash	48
Total	5,784

For location see figure 5.4

Table 5.7 Fresh water inflow into southern North Sea (yearly averages 1980)

	discharges * 1000 m^3/s	
	winter	summer
Inflowing:		
Channel	196.2	107.3
North Atlantic Ocean	195.4	178.7
rivers	5.8	5.8
Outflowing:		
North Atlantic Ocean	397.4	291.8

Table 5.8 Cross boundary flows southern North Sea for summer and winter conditions

Calculations for above mentioned average conditions were made for a tidal period of 24 hours and 50 minutes. The spatial distribution of residual flows and water transport velocities have been calculated for this tidal period, using the following equations:

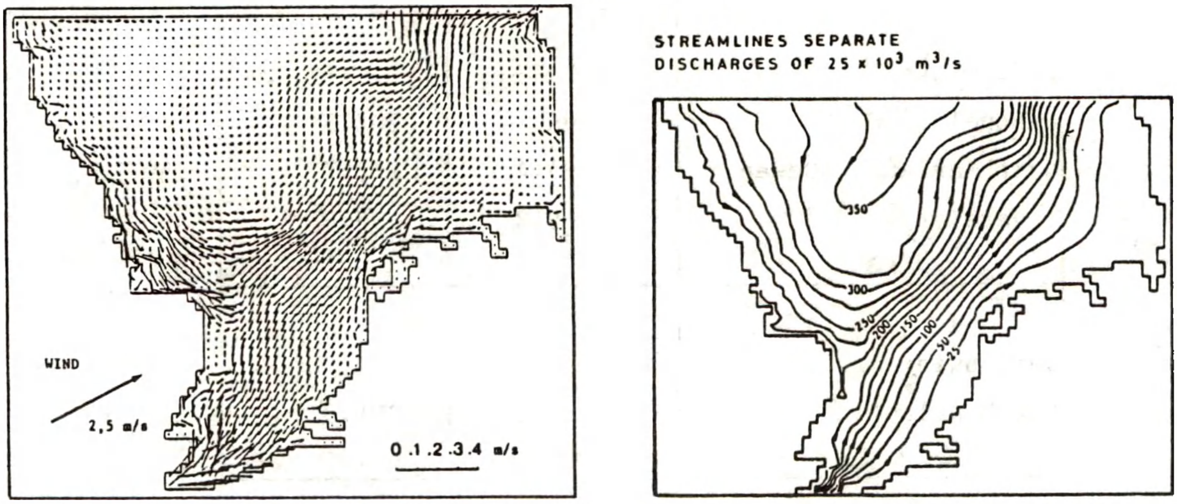
$$\bar{U} = \frac{\int_t^{t+T} (h+\zeta)U \, dt}{\int_t^{t+T} (h+\zeta) \, dt} \qquad \bar{V} = \frac{\int_t^{t+T} (h+\zeta)V \, dt}{\int_t^{t+T} (h+\zeta) \, dt} \tag{4}$$

where:

T = the tidal period of 24 h 50 min

$\bar{U}$, $\bar{V}$ = the residual water transport velocities in X and Y directions

Figure 5.5 presents examples of results of residual flow and water transport velocity calculations.



WATER TRANSPORT VELOCITIES
OF RESIDUAL CURRENTS

RESIDUAL WATER FLOWS

Figure 5.5 Examples of ESTFLO-output (winter conditions)

5.3.2 Water quality modelling (DELWAQ)

Based on the calculated residual flows by the hydrodynamic model ESTFLO (section 5.3.1), the mass transport and water quality model DELWAQ has been used to calculate: the spatial distribution of the concentration of substances in water; the contribution of sources to the distribution of water masses and the concentration of substances; and the retention times or age functions of water masses.

The DELWAQ model solves the advection-dispersion equation with reaction terms and waste loads for simulated constituents in the water phase.

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial_x} (D_x \frac{\partial C}{\partial_x}) + \frac{\partial}{\partial_y} (D_y \frac{\partial C}{\partial_y}) + \frac{\partial}{\partial_z} (D_z \frac{\partial C}{\partial_z}) - U_x C - U_y C - U_z C + \\ + \text{reactions} + \text{waste loads} \qquad (5)$$

with

C = local concentration

$D_{x,y,z}$ = dispersion coefficients in x, y and z directions

$U_{x,y,z}$ = velocities in x, y and z directions

t = time.

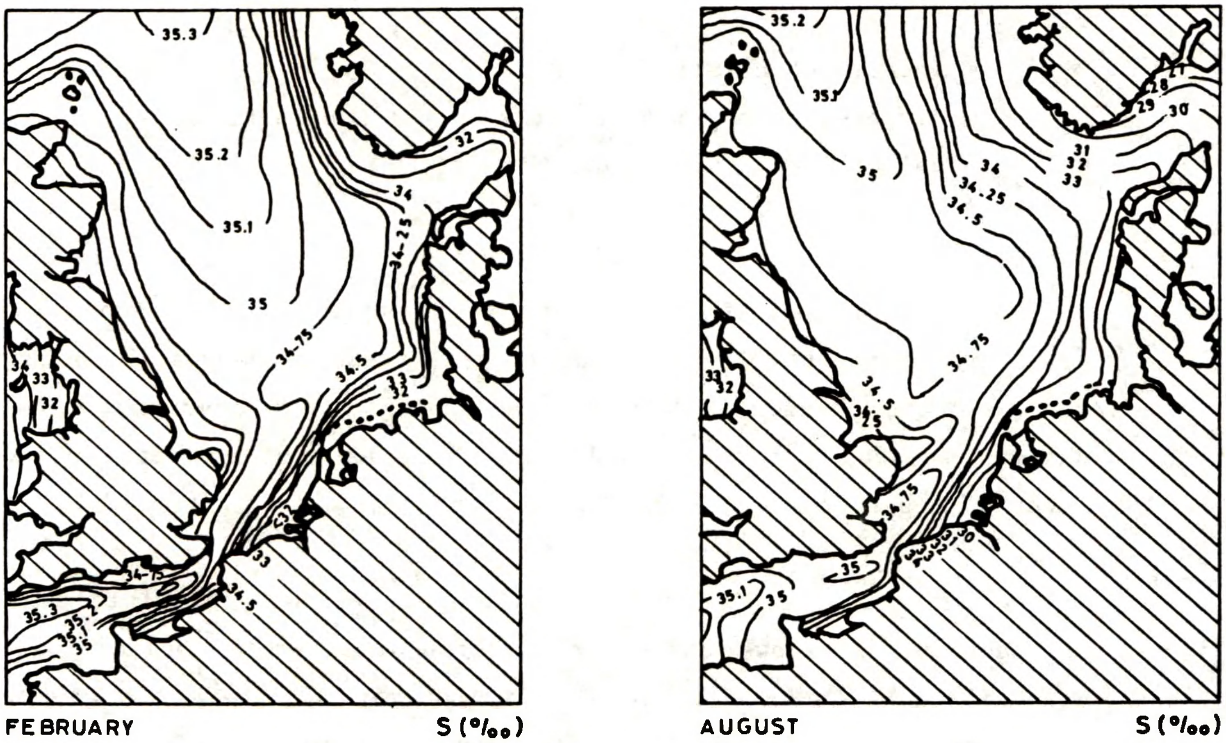
The first three terms represent the dispersive, the second three the adversive transport. The reaction terms represent changes in concentration due to other physical, chemical and biological processes, including exchanges between water and sediment. The waste loads term includes the external input from waste discharging sources.

The numerical methods of the model are based on a flexible compartment approach which allows one, two or three-dimensional applications, using computational elements of regular or non-regular shape. In order to use the flows as calculated by ESTFLO, the schematization of the area considered, was restricted to a two-dimensional configuration with 2199 computational elements of 10 x 10 km (see figure 5.4).

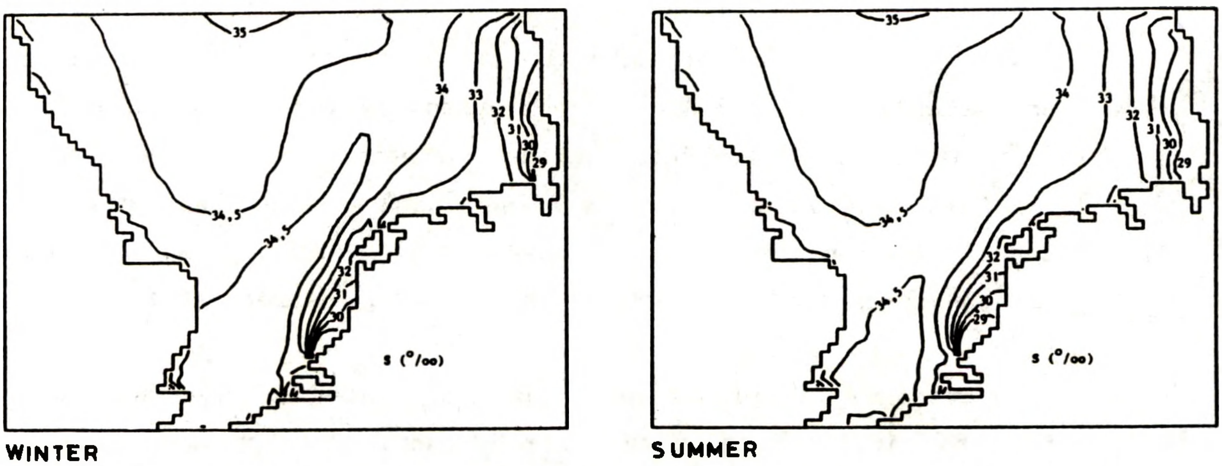
Although the model is suitable for simulating time dependent situations, steady flows and average pollution loads have been used to simulate the transport of pollutants in the southern part of the North Sea. An implicit numerical solution technique has been used to solve the mass balance equation for each computation element. The method immediately gives the so-called steady-state concentration pattern at infinite time.

Dispersion coefficients have been calibrated on a comparison of measured and simulated salinity distributions. Although a detailed calibration was not possible, because of limitations in measuring salinity distributions for the whole area considered, a dispersion coefficient of 150 m^2/s provided acceptable results (figure 5.6).

For the calculation of the spatial distribution of the concentration of substances in the southern North Sea and the fractional contribution of the individual sources to these concentrations a three step approach has been followed.



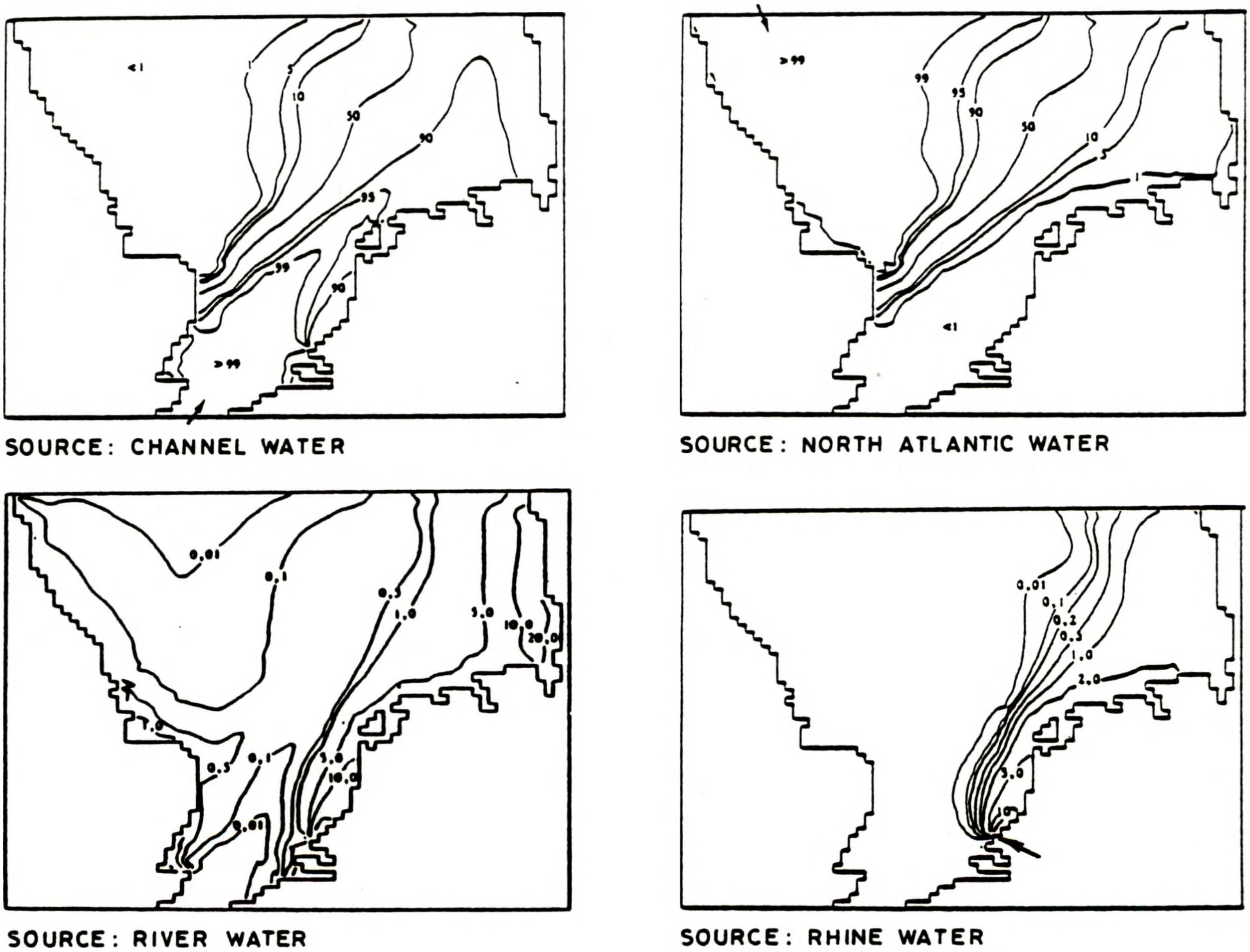
A: Observed salinity distribution over the period 1905-1954 for the months February and August [25]



B: Calculated salinity distribution for winter and summer conditions ($D = 150\ m^2/s$)

Figure 5.6 Observed and (A) calculated (B) salinity distributions

In a first step, the contribution of inflowing waters through the Channel and North Atlantic Ocean boundaries and of atmospheric deposition, to the spatial distribution of (conservative) substances have been estimated. For the inflowing waters this was done by applying a fictitious concentration to Channel and North Atlantic waters separately and making corresponding DELWAQ-runs. The resulting, spatially defined, concentrations can be considered as well as percentages of the locally present water masses, originating from the corresponding boundary. Figure 5.7 gives the results under winter conditions, including as well outcomes of DELWAQ-runs, in which the above procedure was applied on inflows of all rivers and the river Rhine separately. A similar procedure in the first step was followed for atmospheric deposition, using a fictitious deposition rate of 1 $kg/km^2/year$. Figure 5.8 presents the results.



Observations: • Calculations made for winter conditions
• numbers represent fraction in % of locally present water, originating from respective sources

Figure 5.7 Spatial distribution of water masses for inflowing water from different sources

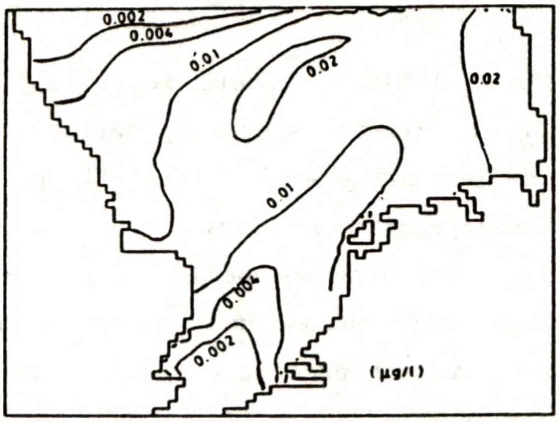


Figure 5.8 Spatial distribution of concentrations of contaminant X due to atmospheric deposition at a rate of 1 kg/km^2/year

In a second step, the contribution of rivers and direct sources in the southern North Sea (including coastal outfalls, dumpings, etc.) to the spatial distribution of (conservative) substances was determined. This was done by applying the estimated loads directly in DELWAQ-calculations.

In a third step, local concentrations were calculated by superposition, using the following mathematical description.

$$C^p(x,y) = C^p_{ch} * P_{ch}(x,y) + C^p_{na} * P_{na}(x,y) + L^p_{atm} * \frac{C^{fc}_{atm}(x,y)}{1} + C^p_{dis}(x,y) \tag{6}$$

where

C^p = calculated concentration distribution for pollutant p (g/m^3)

P_{ch} = calculated proportional water mass distribution for inflowing Channel water

P_{na} = calculated proportional water mass distribution for inflowing North Atlantic Ocean water

C^{fc}_{atm} = calculated concentration, using a fictitious deposition rate of 1 kg/km^2/year from the atmosphere (g/m^3)

C^p_{ch} = concentration of pollutant p in Channel water (g/m^3)

C^p_{na} = concentration of pollutant p in North Atlantic Ocean water (g/m^3)

L^p_{atm} = deposition rate of pollutant p from atmosphere (kg/km^2/year)

C^p_{dis} = calculated concentration distribution for pollutant p discharged through rivers and all considered direct sources (table 4.1) (g/m^3)

An example of the results of the above calculation procedure is given in figure 5.9.

Three different situations related to the values of $C^{p}_{dis}(x,y)$ have been simulated:

- loads of 1980 (tabel 5.9);
- loads of 1990 (table 5.10); and
- natural loads from inflowing rivers.

Input values for atmospheric deposition and for natural concentrations of rivers and sea currents are given in tables 5.1, 5.2 and 5.3 respectively. For the 1990 situation the high scenario for waste loads in rivers has been applied (table 5.6) in combination with a low scenario for dumping of dredged spoils from Rotterdam harbours.

The age (in days) of a given water mass after the moment of inflow into the southern North Sea was estimated by comparing the calculated distribution of a conservative substance with one which is subject to 1st order decay, using the following formula:

$$t = \frac{1}{K} \ln \left(\frac{C_o}{C_k}\right) \qquad \text{(days)} \qquad (7)$$

where

C_o = concentration of the conservative tracer

C_k = concentration of the decaying tracer

K = decay constant (10^{-3}/day)

Thus it is possible to calculate the age of a water fractions from any source. In figure 5.10 examples are given for North Atlantic Ocean water, Channel water and river inputs from the Rhine.

5.3.3 Modelling of eutrophication processes

The purpose of the eutrophication modelling was to evaluate the potential influence of increased nutrient concentrations on primary production and phytoplankton biomass and on species composition. The increase of dissolved Si, N and P loads is illustrated in table 5.11, presenting 1930 and 1980 conditions. The considered area for this analysis is indicated in figure 5.11.

source	discharge km^3/y	N 1000 t/y	P 1000 t/y	Hg t/y	Cd t/y	Pb t/y	Cu t/y	Cr t/y	Zn t/y
Belgium:									
1. IJzer	0.2	0.3	0.24	0.05	-	1.0	1.0	1.0	5
2. Oostende/ Zeebrugge	0.5	4.5	0.71	0.07	0.2	2.0	3.0	2.0	25
Various	-	2.2	0.25	0.98	-	243.0	1.0	1.0	101
The Netherlands:									
3. Western Scheldt	3.8	42.5	5.50	1.50	12.0	120.0	70.0	120.0	500
4. Eastern Scheldt	2.1	2.9	0.20	0.10	0.4	1.0	2.0	2.0	4
5. Haringvliet	28.4	120.0	12.00	3.70	23.0	100.0	145.0	115.0	1,200
6. Rotterdam Waterway	48.0	260.0	34.00	3.80	43.0	340.0	480.0	630.0	2,800
7. Old Rhine	0.3	2.0	0.40		0.2	3.0	4.0	2.0	9
8. North Sea Channel	2.6	17.9	2.30	0.70	1.5	97.0	21.0	26.0	490
9. IJssel Lake: Den Oever	9.0	34.0	2.10	0.72	2.1	44.0	33.0	39.0	246
10. IJssel Lake: Kornwerderzand	6.0	28.0	1.60	0.50	1.2	29.0	28.0	26.0	174
11. Lauwers Sea	1.4	5.2	0.90	0.14	2.0	21.0	17.0	7.0	67
12. Eems-Dollard Estuary	3.3	35.0	3.10	0.76	3.4	20.4	51.5	13.0	95
Various	5.1	35.5	10.40	9.00	46.0	389.6	273.5	543.0	2,042
Total the Netherlands (rounded)	110	583	72	21	135	1,165	1,125	1,523	7,627
Germany:									
13. Weser	15.8	42.0	8.60	1.18	4.7	83.4	191.0	54.0	1,655.0
14. Elbe	36.2	250.0	14.00	7.50	15.0	135.0	300.0	200.0	2,500.0
Various	-	17.0	2.50	0.42	1.0	25.6	221.0	12.0	273.0
United Kingdom:									
15. Thames	4.9	32.8	0.11	1.29	2.2	16.5	16.5	15.0	72.0
16. Forth	2.0	0.8	0.20	0.54	1.5	29.0	30.0	17.5	72.5
17. Tyne	1.6	0.9	0.19	0.43	1.5	26.5	26.5	17.5	199.0
18. Tees	0.5	1.8	0.22	0.16	0.6	12.5	10.0	8.0	56.0
19. Humber	8.8	43.5	0.57	2.36	8.6	132.0	162.0	100.0	470.0
20. Wash	1.5	17.7	1.14	0.43	1.6	50.0	44.0	48.0	175.0
Various	-	98.5	25.60	15.00	32.4	839.5	863.0	489.0	3,108.0
Denmark:									
Various	2.5	4.0	0.30	-	3.6	32.0	21.0	21.0	140.0
Total southern North Sea (rounded)	184	1,099	127	51	208	2,793	3,015	2,509	16,478

Observations:
- numbers of sources refer to figure 5.4
- various include all direct sources, including dumping
- Western Scheldt does not include the discharge through the Gent-Terneuzen Canal, which is comprised under various

Table 5.9 Overview of 1980 waste discharges into the southern North Sea through rivers and direct sources

source	discharge km^3/y	N 1000 t/y	P 1000 t/y	Hg t/y	Cd t/y	Pb t/y	Cu t/y	Cr t/y	Zn t/y
The Netherlands:									
3. Western Scheldt	3.8	43.20	5.68	0.75	6.04	56.5	90.50	61.0	382.0
4. Eastern Scheldt	2.1	2.90	0.21	0.10	0.40	2.0	1.00	2.0	4.0
5. Haringvliet	28.4	118.00	11.00	2.00	15.00	74.0	108.00	58.0	650.0
6. Rotterdam Waterway	48.0	257.00	31.00	2.00	27.00	249.0	355.00	310.0	2,350.0
7. Old Rhine	0.3	1.53	0.31	-	-	3.0	4.00	1.0	9.0
8. North Sea Channel	2.6	13.80	1.90	0.80	0.70	20.0	18.00	15.0	142.0
9. IJssel Lake:									
Den Oever	9.0	32.50	2.10	0.44	0.90	27.0	34.00	21.0	178.0
10. IJssel Lake:									
Kornwerderzand	6.0	28.16	2.46	0.32	0.60	27.0	25.00	15.0	130.0
11. Lauwers Sea	1.4	4.56	0.76	0.14	2.00	21.0	17.00	7.0	67.0
12. Eems-Dollard									
Estuary	3.3	35.00	3.10	0.38	1.80	15.3	39.00	8.0	72.0
Various	2.2	21.81	6.30	4.77	17.14	78.4	95.35	23.0	520.0
Total the Netherlands (rounded)	107	558	64	11	71	573	786	523	4,504

Observations:
- numbers of sources refer to figure 5.4
- various include all direct sources, including dumping
- waste discharges in other countries than the Netherlands are kept equal to the 1980 conditions (table 5.9)
- Western Scheldt does not include the discharge through the Gent-Terneuzen Canal, which is comprised under various

Table 5.10 Overview of 1990 waste discharges into the southern North Sea through rivers and direct sources

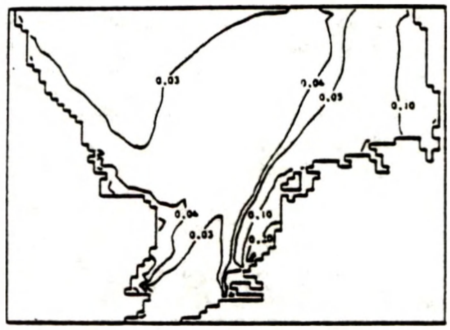
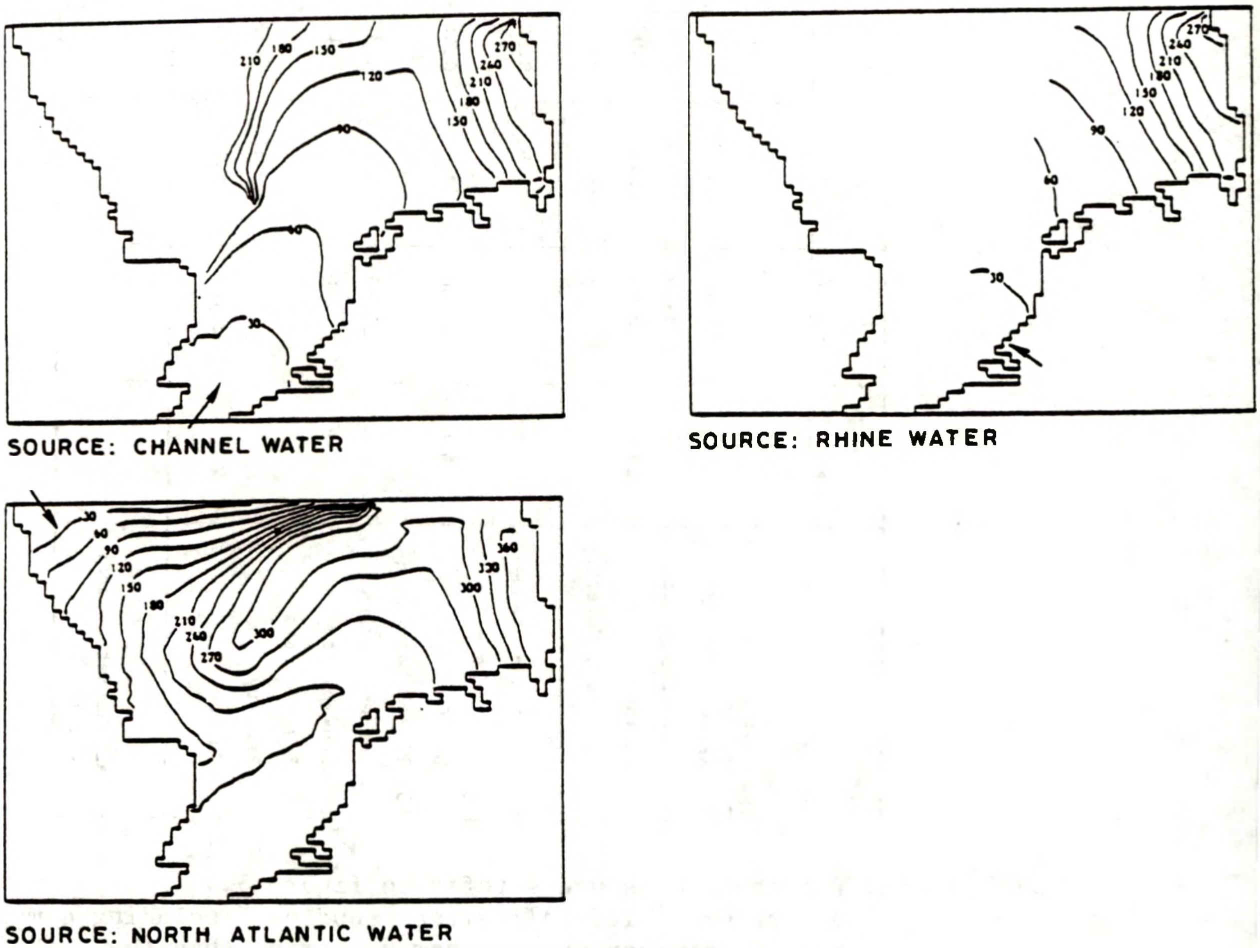


Figure 5.9 Examples calculated concentration distribution for cadmium (mg/m^3)



Observation: numbers reflect age in days

Figure 5.10 Examples of results of age distribution calculations (winter conditions)

Numbers	Loads in 1000 t/year		Quarterly distribution			
	1930	1980	1	2	3	4
Si	340	199	42	12	8	28
N	65	297	35	24	16	25
P	3	27	29	22	21	28

Observations: 1980 condition represent averages over the years 1976-1982
: 1930 conditions are based on natural concentrations as given in table 5.2
: loads into compartment I in figure 5.11

Table 5.11 Yearly loads of dissolved Si, N and P and quarterly distribution around 1930 and 1980

For the computations a numerical model SEAWAQ has been used, which describes the carbon and nutrient (Si, N and P) cycles, schematized in figure 5.12. The following includes a rough description of the basic relations simulated in the model. Further information can be found in [26].

As shown in this schematization the following state variables have been simulated:

- phytoplankton: specified as 'diatoms' and 'other phytoplankton' with a distinction into spores, young and old populations;
- suspended detritus: specified in pools of carbon, phosphorus, nitrogen and silicate;
- bottom detritus: specified in pools of carbon, phosphorus, nitrogen and silicate; and
- dissolved nutrients: specified in pools of anorganic phosphorus, nitrogen and silicate.

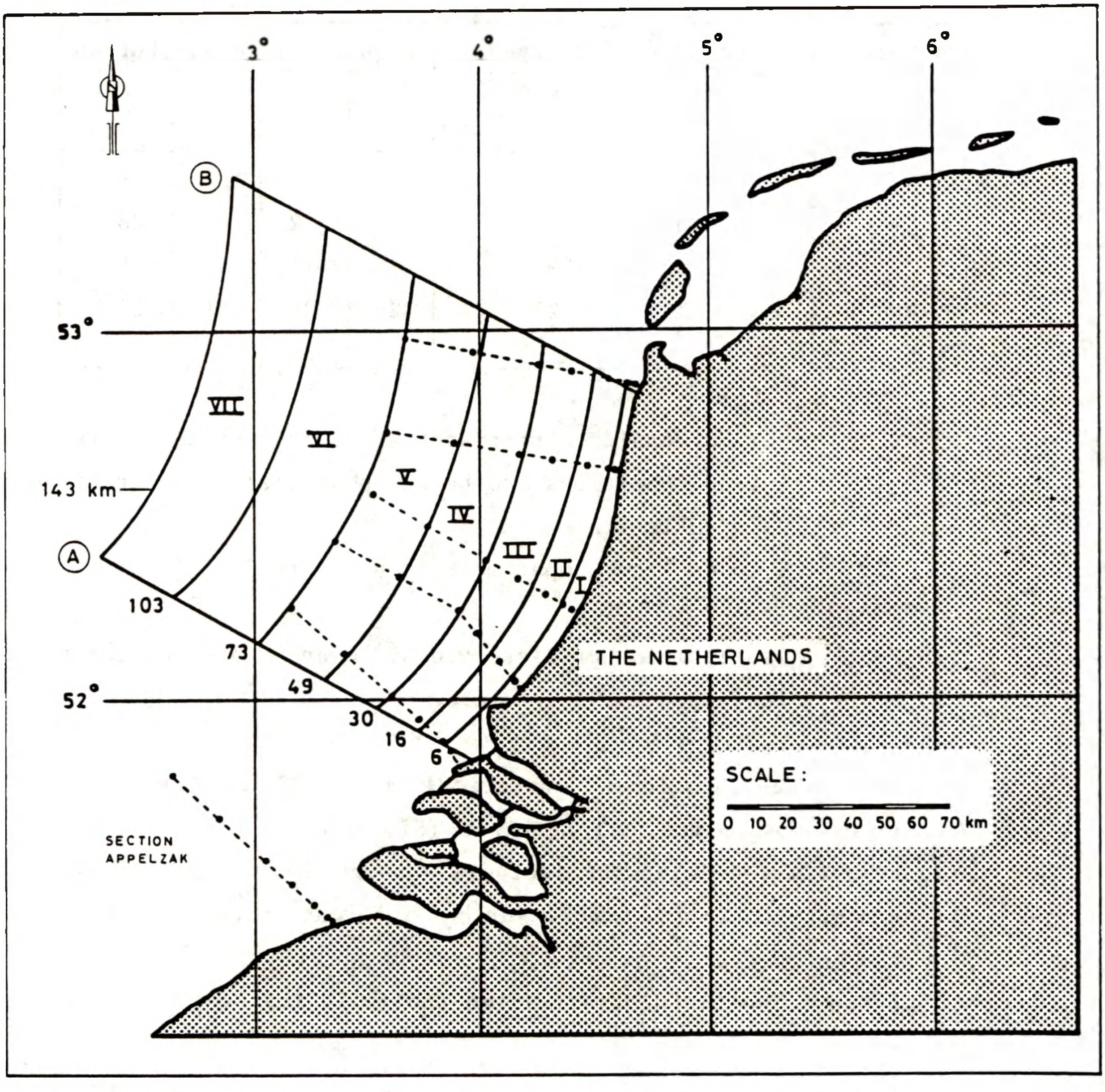


Figure 5.11 The partitioning of the Dutch coastal area as used in the eutrophication modelling

External, steering variables include light, temperature, background extinction and grazing by zooplankton.

The eutrophication model SEAWAQ was developed as a kinetic subroutine of the water quality model DELWAQ (described in section 5.3.2) [26]. Apart from transport phenomena and pollution inputs, the changes in phytoplankton, suspended detritus, bottom detritus and nutrients are described by the following equations:

$$\frac{dA}{dt} = (G\ (1-E_a) - R - GZ - GB - M) * A \tag{8}$$

$$\frac{dD}{dt} = M * A + (1-E_z) * GZ * (A+\alpha D) + \frac{fB}{H} - k_d D - \frac{V_s}{H} D - (GZ+GB) * \alpha D \tag{9}$$

$$\frac{dB}{dt} = V_s D + (1-E_b) * GB * (A+\alpha D) * H - k_b B - fB - k_r * (B-B_o) \tag{10}$$

$$\frac{dN}{dt} = -(G\ (1-E_a) - R) * A + k_d D + \frac{k_b B}{H} + (GZ*E_z + GB*E_b) * (A+\alpha D) \tag{11}$$

A	= 4 groups of phytoplankton	$[gm^{-3}]$
D	= 4 pools of suspended detritus (C, N, P, Si)	$[gm^{-3}]$
B	= 4 pools of bottom detritus (C, N, P, Si)	$[gm^{-2}]$
N	= dissolved nutrients (N, P, Si)	$[gm^{-3}]$
G	= growth rate phytoplankton	$[d^{-1}]$
R	= respiration rate phytoplankton	$[d^{-1}]$
GZ	= grazing rate zooplankton	$[d^{-1}]$
GB	= grazing rate zoobenthos	$[d^{-1}]$
M	= mortality rate phytoplankton	$[d^{-1}]$
E_a	= excreted fraction phytoplankton	-
E_z	= excreted fraction zooplankton	-
E_b	= excreted fraction zoobenthos	-
α	= fraction of detritus grazed by zooplankton and zoobenthos	-
k_d	= mineralization rate suspended detritus	$[d^{-1}]$
k_b	= mineralization rate bottom detritus	$[d^{-1}]$
k_r	= formation rate refractory bottom detritus	$[d^{-1}]$
B_o	= refractory bottom detritus	$[gm^{-2}]$
V_s	= sedimentation rate suspended detritus	$[md^{-1}]$
f	= resuspension rate bottom detritus	$[d^{-1}]$
H	= depth	[m]

The growth rate of phytoplankton in the model depends on temperature, available light and nutrients. Nitrogen and phosphates can be limiting nutrients for both diatoms and other phytoplankton, silicate can only be a limiting nutrient for diatoms.

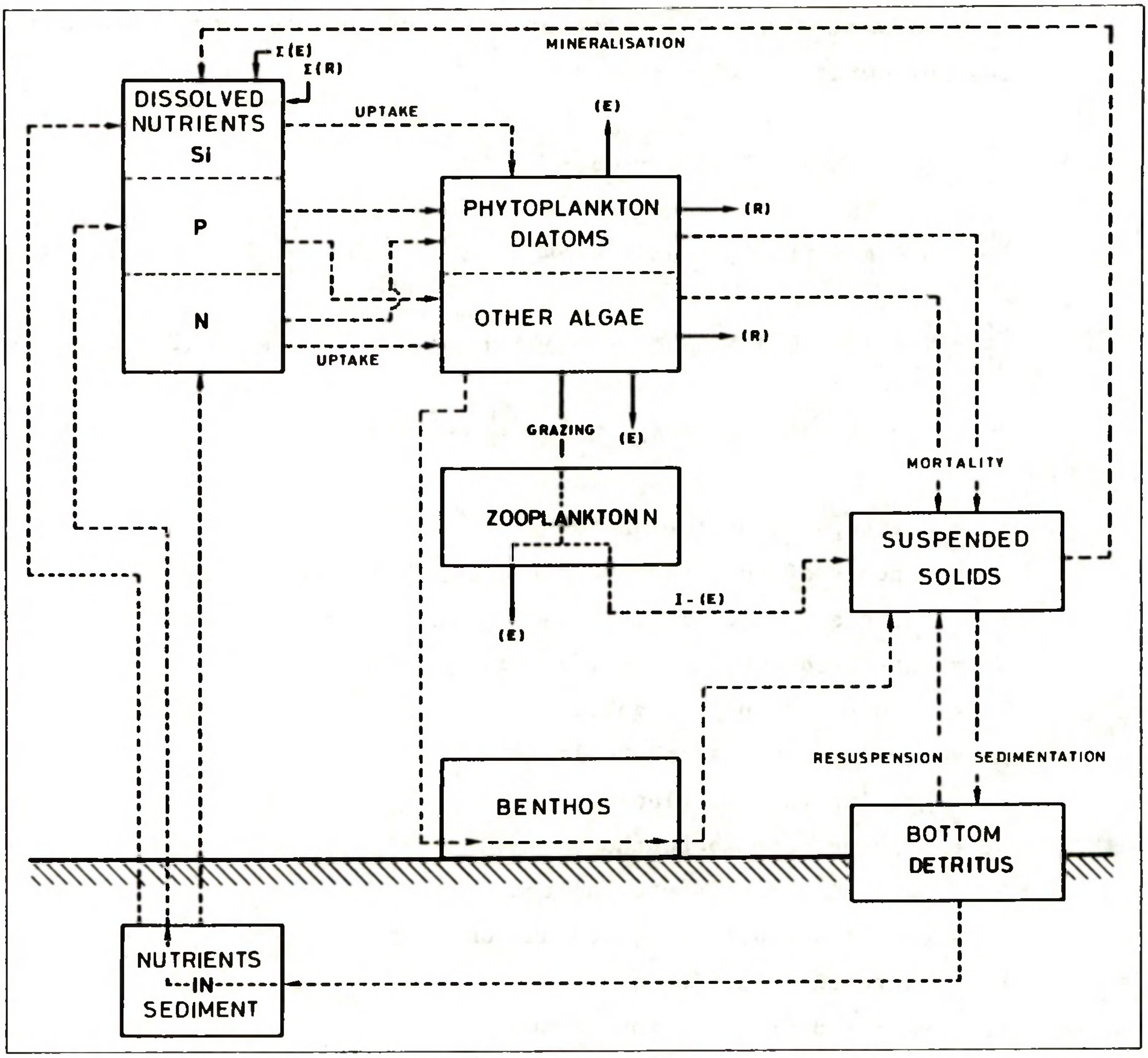


Figure 5.12 Carbon and nutrient cycles in the SEAWAQ model

The specific loss rates for the two phytoplankton groups depend on respiration, grazing by herbivores (zooplankton) and natural mortality. Natural mortality is modelled in such a way as to simulate the effect of increased mortality rates in populations which are subject to nutrient or light limitation. In the model growing, non limited populations ("young") have a lower mortality rate than limited populations ("old").

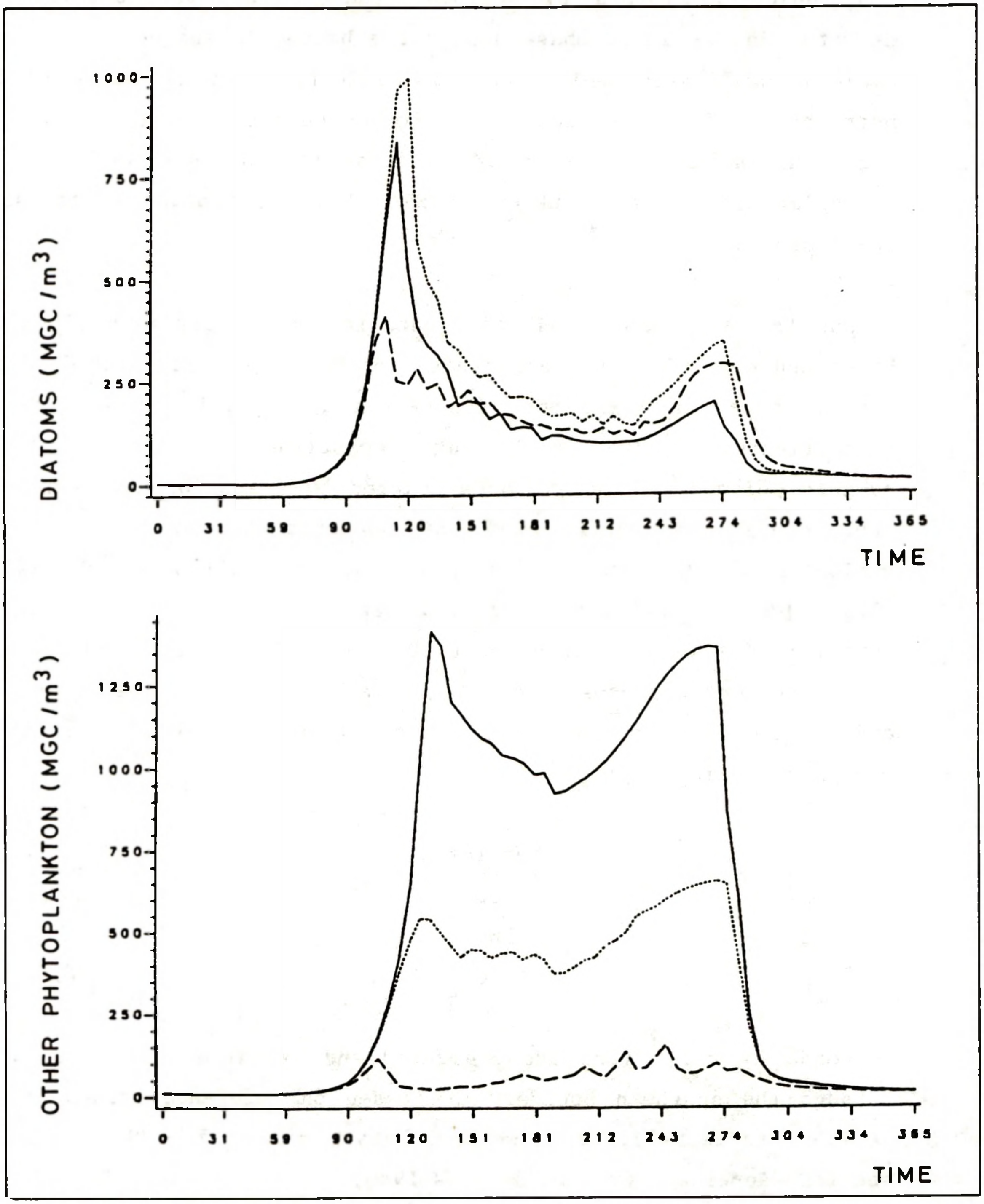
The increase of the concentrations of suspended detritus in terms of carbon and nutrients is depending on phytoplankton mortality, part of the mortality due to grazing (pseudo faeces) and resuspension of bottom detritus, which is formed by sedimentation of suspended detritus. Organic detritus in the water phase and in the bottom is subject to nutrient specific mineralization which leads to an increase in the amount of dissolved nutrients. A fixed portion of the bottom detritus is lost to the nutrient cycle due to the formation of a refractory nutrient pool. Excretion by phytoplankton and zooplankton in SEAWAQ is also directly transferred to the dissolved nutrient pool.

Due to the lack of validation data for the larger part of the southern Bight and central North Sea, the use of SEAWAQ was restricted to the Dutch coastal zone. In its first application a simplified discretisation of 7 compartments parallel to the Dutch coastline was considered. This area roughly coincides with the area covered by a monitoring programme of the Dutch Ministry of Public Works (Rijkswaterstaat). Monitoring data for the period 1975-1982 have been used to calibrate the model described above [27]. Flow conditions refered to a season-dependent average water transport parallel to the Dutch coast. Perpendicular to the coast only dispersive transport was considered. As far as the nutrient loads through rivers and the southern boundary are considered, three different situations have been simulated:

	river inflow	southern boundary
1.	1980	1980
2.	1980	1930
3.	1930	1980

Loads by the rivers are indicated and explained in table 5.11. Loads through the southern boundary are based on reference values (referred to as 1930, table 5.3), or on measurements between 1975-1982 in the so-called section "Appelzak" (referred to as 1980).

An example of the results of the calculations is given in figure 5.13. The time step used was 1/4 day.



Observation: results refer to compartiment I, figure 5.11

Legend: rivers 1980, southern inflow 1980
rivers 1980, southern inflow 1930
rivers 1930, southern inflow 1930

Figure 5.13 Example of results of SEAWAQ application: development of biomass of diatoms and other phytoplankton species over the year

It was concluded from the analysis that the eutrophication of the North Sea has had little effect on the total biomass of diatoms, probably because Si is the limiting factor for diatom biomass bloom and the Si-load has been decreased between 1930 and 1980. This decrease may be caused by the canalization of the Rhine, including the construction of many weirs, which, together with increased concentrations of N and P in river waters, create good conditions for diatoms and consequently for Si removal from the water.

A major effect was calculated for other phytoplankton species. Where diatoms where dominating in 1930: ratio other phytoplankton to diatoms about 0,5-1, the increase of biomass of other species created a reversed ratio: 3-5 in 1980.

The effects described above have to be attributed to the changing ratio of Si-loadings versus N and P-loadings, and the overall increase of N and P-concentrations in coastal waters. Where long time series of phytoplankton data are lacking, it is, at present, difficult to assess the relevance of the 1930 model output and the reality of the calculated trends.

Recent model versions of SEAWAQ, which incorporate density dependent phytoplankton mortality, show an increasing agreement with resent chlorophyll and nutrient monitoring data in the Dutch coastal zone.

5.3.4 Analysis of sedimentation processes

Contaminants may enter the North Sea dissolved in water and adsorbed to suspended sediments. Adsorbed to sediments they may accumulate in coastal sedimentation areas and may become a source of contamination for marine organisms either through chemical processes resulting in dissolution of adsorbed substances or through direct consumption of benthic fauna. In establishing which part of the settled contaminants may enter into the food web, man induced and natural perturbations of the bottom layer have to be taken into account. Examples of an induced perturbation refer to: fishery, dredging and sand and gravel mining. Natural perturbations include morphologic erosion processes, which might be involved by human actions elsewhere.

Knowledge of processes and actual situation is limited. Preliminary data analyses have been carried out: to assess the actual situation in relation to erosion and sedimentation areas; to estimate erosion and sedimentation rates; and to quantify related time scales.

For these purposes, the results of measurements of suspended solids in the Dutch coastal waters have been analyzed. These data were collected in bi-weekly monitoring of water quality parameters over a period from 1975 till 1983 at 76 locations [27]. The sampling locations and average suspended sediment concentrations are presented in figure 5.14.

Yearly mass balances have been worked out between the sections indicated in figure 5.14 for a 80 km wide zone along the Dutch coast. For these calculations quaterly weighted average concentrations of suspended sediments have been computed for each section, and based on the 1975-1983 measurements, using the formula:

$$C_{wi} = \frac{S\ A_{ij} * C_{ij}}{S\ A_{ij}} \qquad (12)$$

where:

C_{wi} = weighted concentration in segment i

C_{ij} = measured concentration in location j of segment i

A_{ij} = representative cross section area of segment i.

Segments (i) correspond to representative areas around sampling locations (j).

Quarterly residual flows have been calculated with ESTFLO, using "1980" conditions (section 5.3.1). The results of these calculations are given in figure 5.15. The Channel section represents the southern boundary of the ESFLO-model. From this analysis it was concluded that erosion of sediments mainly takes place in the southern part of the Dutch coastal waters whereas sedimentation occurs in the Dutch delta region. Net sediment transport is directed to the Wadden Sea and to the German Bight Area, north of the Wadden Islands.

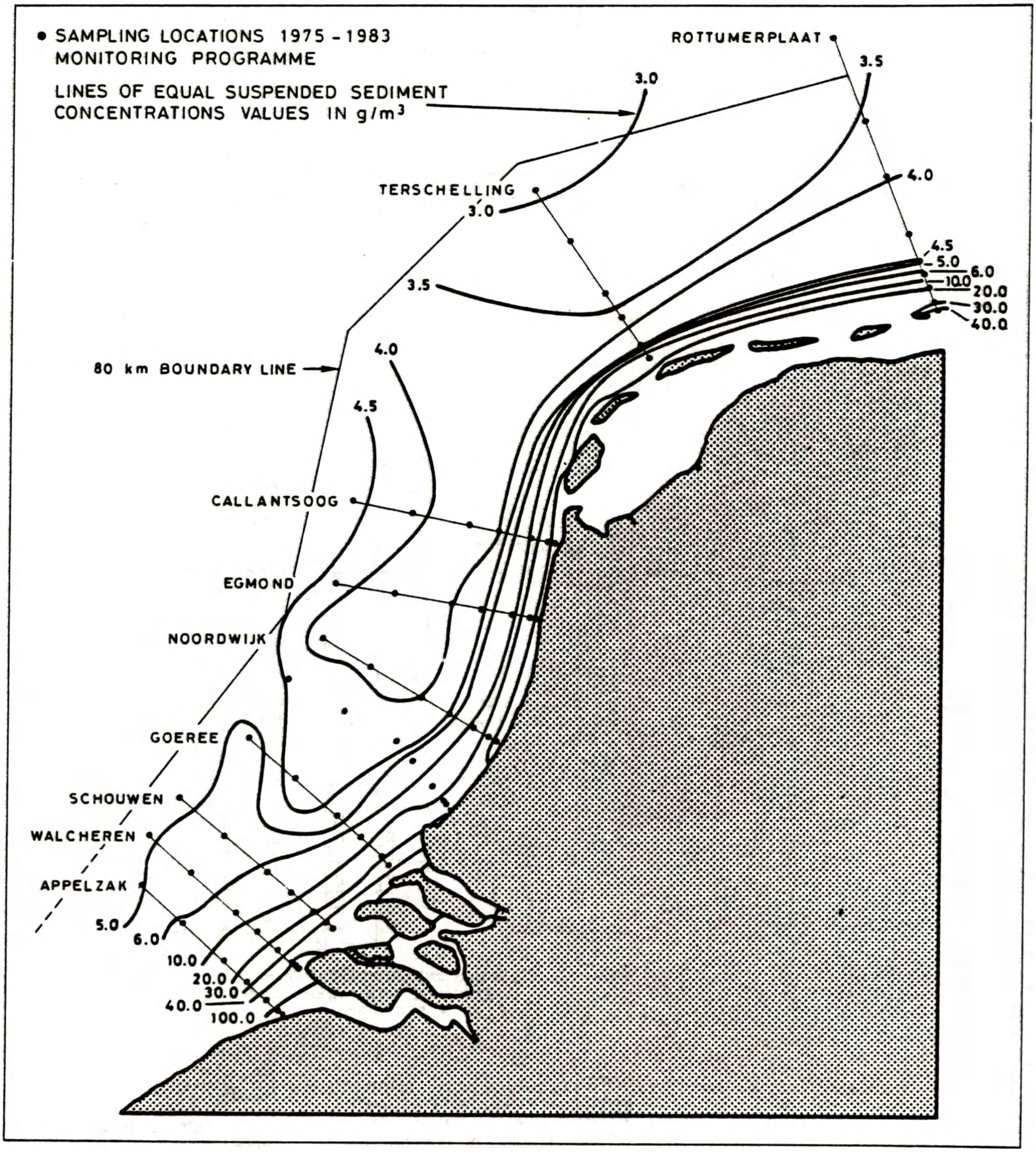
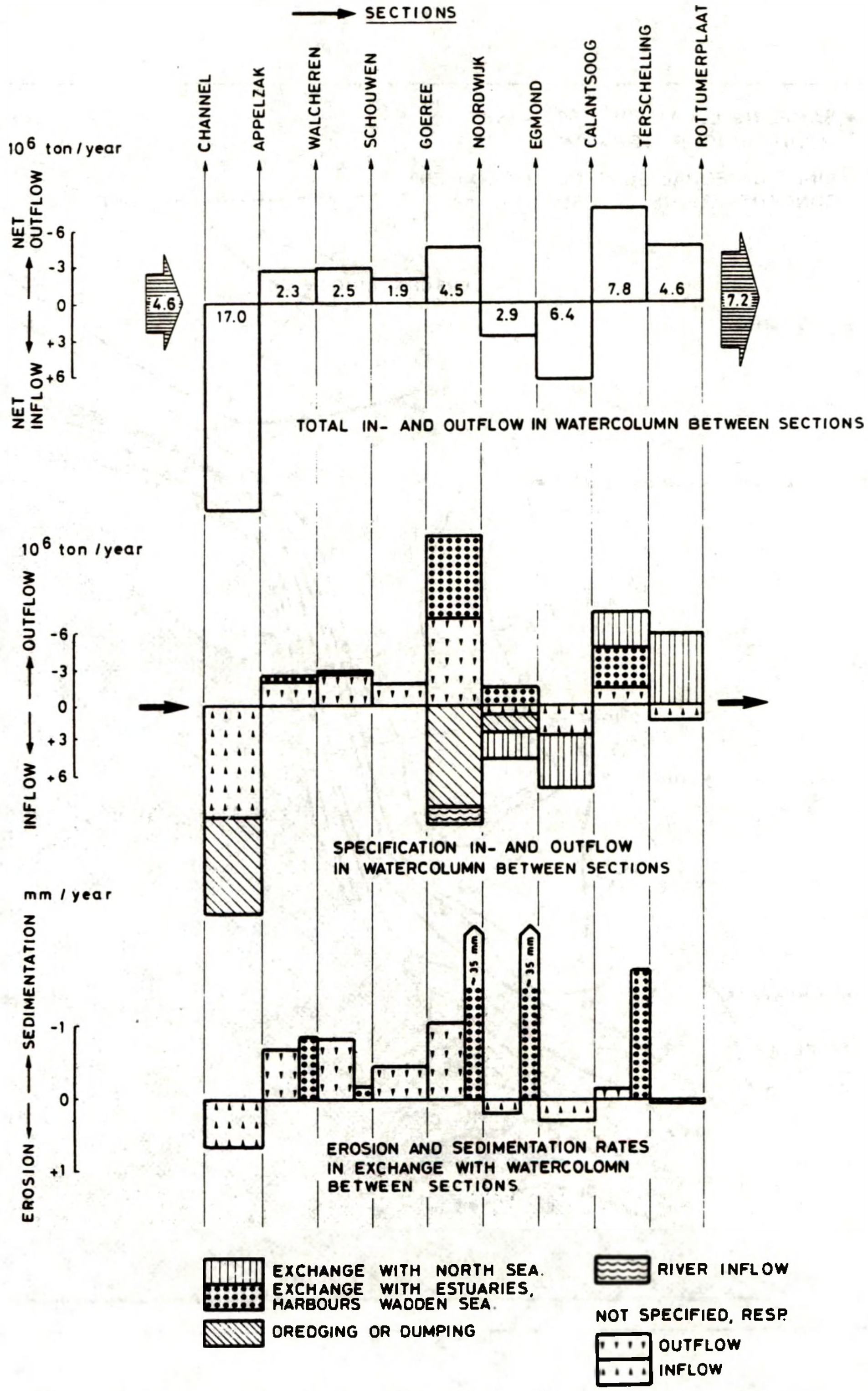


Figure 5.14 Average suspended sediment concentrations in front of the Dutch coast for the period 1975–1983



Observation: sections are indicated in figure 5.14

Figure 5.15 Mass balances suspended sediments in front of the Dutch coast for the period 1975-1983 (averaged)

To get an indication of the time scale involved in the building up of contaminants in bottom sediments in sedimentation areas, a first question to be answered is how the concentration of substances in an active surface layer develops over time as a function of the time dependent development of concentrations of these substances in suspended sediments from rivers and from marine origin. The active layer is defined as the benthic layer which has an active interaction with the aquatic ecosystem. This includes both physical (diffusion, turbation by human activities, morphological processes), chemical (adsorption, desorption) and biological (bioturbation, benthic organisms) activities. Based on the morphological situation and the type of benthic organisms present, the active layer thickness varies between 5-50 cm.

Characteristic sedimentation rates lie between 0.5-5 mm/year. To illustrate the long term development of bottom pollution, the accumulation of pollutants in the surface layer of the bottom can be estimated for a specified 'active' bottom surface layer by the following mass balance equation; supposing complete mixing between settled sediments and receiving active bottom layer:

$$\frac{dC_b}{dt} = \frac{S}{H} (C_{ss} - C_b) \tag{13}$$

where

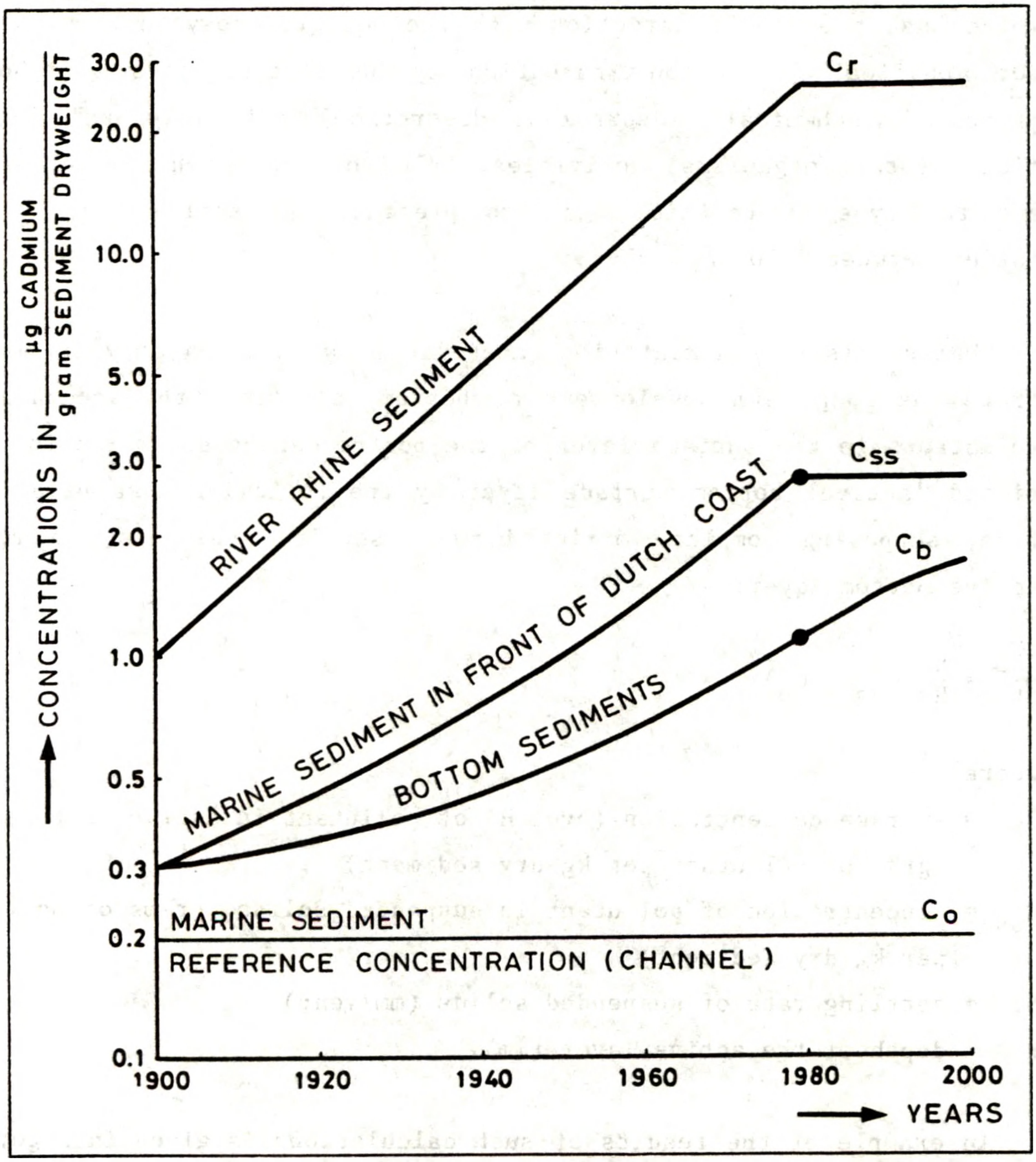
C_b = average concentration (over H) of pollutant in active surface layer (gram of pollutant per kg dry sediment)

C_{ss} = concentration of pollutant in suspended solids (grams of pollutant per kg dry sediment)

S = settling rate of suspended solids (mm/year)

H = depth of the active layer (mm).

An example of the results of such calculations is given in figure 5.16. In this example, in which concentrations are representative for cadmium, it was estimated that the suspended sediment in front of the Dutch coast consisted of 90% marine sediments (concentration of contaminant: C_o) and 10% of Rhine sediment (concentration of contaminant: C_r). Based on measured developments for C_r [23] the concentration C_{ss} can be estimated. For a value of $\frac{H}{S}$ =50 years, which implies that after 50 years the total thickness of the settled sediments equals the depth of the active layer, the concentrations in the bottom sediments (C_b) are indicated in figure 5.16. The graph shows that 20 years after a stand still of the concentrations C_o, C_r and consequently C_{ss} since 1980, the average concentration in the active bottom layer is still increasing and far from the asymptotic value of C_{ss}.



Observations: • Concentrations are representative for cadmium concentrations in front of Dutch coast

• Value of $\frac{H}{S}$ = 50 years

Figure 5.16 Development of concentrations of contaminants in suspended sediments and active bottom layer

5.4 ESTIMATING EFFECTS OF POLLUTION ON ORGANISMS

In this section attention will be paid to the methods used for quantification of possible effects of ambient water quality on organisms in the North Sea. In the following, distinction is made between the influence of nutrients on primary production and consequently on the higher levels of the food chain, and influence of toxics on primarily the physiological functioning of organisms.

Nutrients

The effects on nutrients on primary production are assessed using the SEAWAQ model for the part of the planning area directly in front of the Dutch coast. In section 5.3.3 the major conclusions of this analysis are given; they refer to the indication that the observed increase between 1930 and 1980 in the concentrations of the dissolved nutrients P and N did not result in an increase of the biomass of diatoms but caused a rather important increase in the biomass of other species of phytoplankton. These effects probably have resulted in a major change in the total species composition: the ratio between the biomasses of diatoms and other phytoplankton species decreased in this period from between about 1.5 to about 0.25.

Within the study supporting the water quality management plan, a literature search has been carried out to find quantitative information on the influence of the changes in the primary production on the higher levels in the food chain. If indeed primary biomass production is increasing in certain areas of the North Sea, most likely in the coastal waters, it is feasible that both beneficial and detrimental effects may result from this development. Increased food availability for fish may lead to higher fish production which could be regarded as beneficial from a fisheries point of view, assuming that the increased fish production includes commercial fish species. On the other hand the increased primary production of biomass may lead to a higher mineralization. In stratified zones, as for example the German Bight and central parts of the North Sea, the increase of oxygen consumption may result in poor oxygen conditions in the deeper water layers which may result in adverse effects on the production of demersal fish and benthic organisms.

Using data from the literature [29,30,31,32,33,34] the nett biomass production for different levels in the food web has been quantified. Results are given in figure 5.17. This figure illustrates that only about 1% of all primary organic matter produced ends up in the biomass of North Sea fish and other predators. This common phenomenon illustrates the difficulties encountered when one tries to extrapolate changes at the primary production level (as studied by the eutrophication model, section 5.3.3) to possible changes at the top predator level.

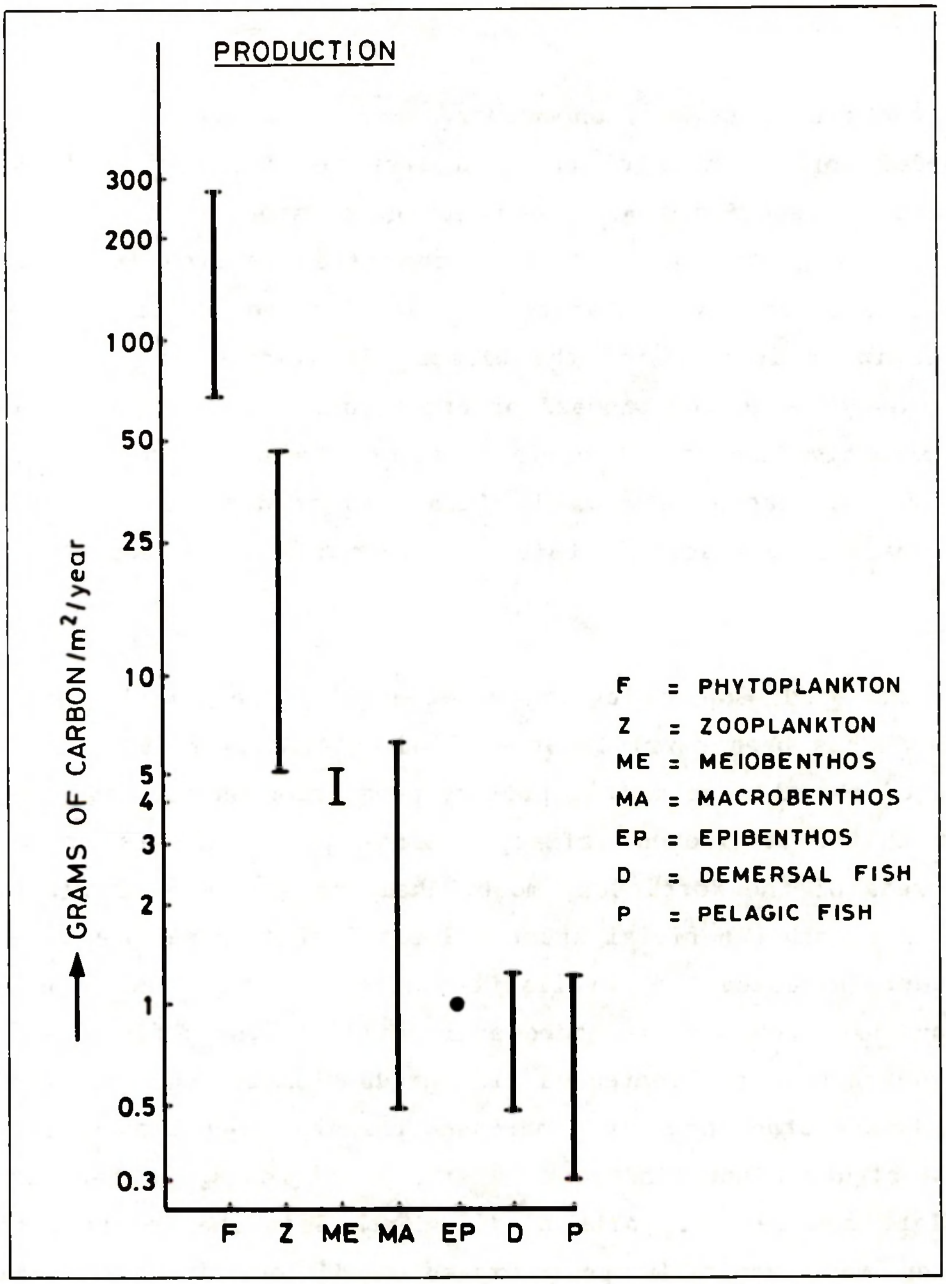


Figure 5.17 Biomass production for different levels in the food web

Toxics

To evaluate results of computed concentrations of toxic substances (section 5.3.2) in the southern North Sea, in terms of possible effects on marine ecosystems, operationally, such values can be compared with concentrations which are considered to present no adverse effects on marine organisms. To determine such concentration levels three possible ways have been considered:

- using existing field observations;
- using exposure tests under laboratory conditions; and
- using existing standards for ambient water quality for the North Sea or other aquatic ecosystems.

In such tests basically three types of effects are studied in a specified time span of, e.g., 96 hours, resulting in different kinds of effect levels or critical concentrations for organisms:

- no-effect levels (NEL), at which no effect is observed,
- sub-lethal concentrations (SLC), at which various types of effects are observed, but test organisms do not die,
- lethal concentrations (LC), at which a certain percentage (e.g. 50%) dies.

There are only few examples in which the presence of toxic substances in water or sediments can be linked to observed damage to the ecosystem (see, e.g., section 3.1). In many observed cases, however, effects are only suspected to be partly induced by such toxic substances. Rather than focussing on the scarcely available field observations, it was decided to base the assessment of the effects of toxics on marine organisms in the North Sea on concentration levels (called hereinafter assessment levels) derived from exposure tests and/or standards used in management of other marine ecosystems.

In interpreting the exposure tests only the results related to marine species present in the North Sea have been used. The species were grouped in the following six categories:

- phytoplankton;
- zooplankton;
- benthos;
- demersal fish;
- pelagic fish; and
- mammals.

For each of the metals, the ranges of the critical levels found in the literature was established [35,36,37,38,39,40,41]. An example is given in figure 5.18. In the procedure of defining the assessment levels, the lowest values out of these ranges have been taken. It has to be borne in mind however, that toxicological experiments often deal with total dissolved concentrations in the water, since soft bottoms or suspended sediments are absent in most set ups. So the assumption is made that all of the toxics are indeed dissolved and biologically available both in the experiments determining toxic levels and in the water quality modelling (c.f. section 5.3).

Substance	No Effect Level (NEL)	Sub-Lethal Concentration (SLC)	Lethal Concentration (LC)	EPA Standard	Assessment levels used in North Sea study	Main ref.
	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	
Cadmium	<1	1	5	5	0.05	[35]
Cromium	1,000	-	30,000	-	300	[42]
Copper	0.2	8	14	1.4	0.14	[40]
Mercury	0.05	0.1	1	0.1	0.01	[36]
Lead	<150	150	340	-	3.4	[37]
Zinc	<120	120	25,000	250	250	[39]

Table 5.12 Overview of effect levels and standards of concentrations of toxic substances in sea water

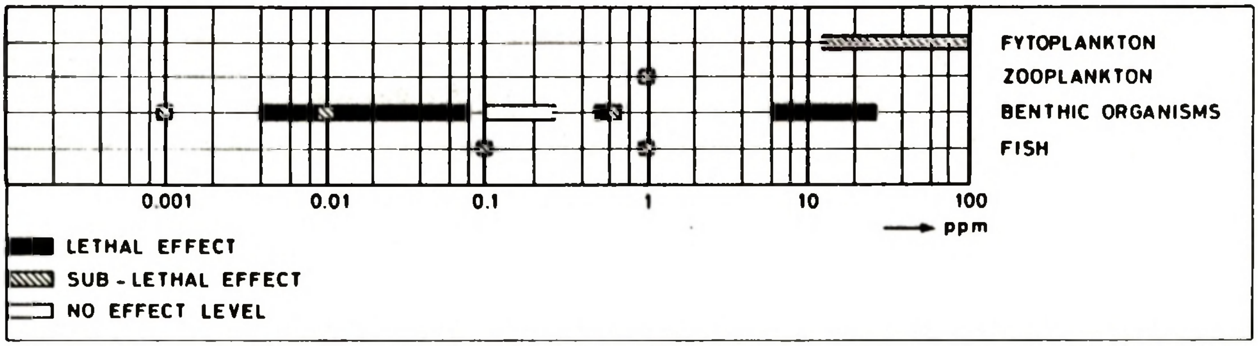


Figure 5.18 Toxic effects of cadmium on aquatic organisms

Utilization of critical levels, as presented in table 5.12, is hampered by, among other things, the following major uncertainties:

- Exposure in the field through water, sediments and food is different from laboratory conditions, where mainly exposure to dissolved toxic substances occur.
- Effects in laboratory tests are measured after short exposures. Longer exposures, as will occur under field conditions, may increase the effect.
- Possible synergetic or antogonistic influences in the field, in case of a exposure to a mixture of pollutants, are not occurring in laboratory tests.

Given such uncertainties, in particular, in relation to the definition of no effect levels and sub-lethal concentrations, it was decided to use the lethal concentrations in defining so called assessment levels, to be used for the evaluation of calculated concentrations. A safety factor of about 100 was applied, in accordance with EPA procedures [43]. Using different safety factors result in different assessment levels, e.g., cadmium assessment levels of 0.25, 0.05 and 0.005 correspond with safety factors of 20, 100 and 1000 respectively.

5.5 METHODS FOR ASSESSMENT OF THE AMBIENT WATER QUALITY SITUATION

Basically the spatial distribution of the following two indicators has been used in comparing the ambient water quality situations of 1980 and 1990.

• The relation between the calculated concentrations and the assessment levels. Using the concentrations of contaminants as calculated by the DELWAQ model, the areas can be indicated in which given assement levels are exceeded. An example of such results is given in figure 5.19. Based on these maps the fraction of the total area of the southern North Sea or the planning area can be determined for which the assessment levels are exceeded. This can be done for different assessment levels. An example for cadmium is given in table 5.13.

Assessment levels	0.5	0.25	0.05	0.025	0.005
Corresponding safety factors	10	20	100	200	1000
Area in % of southern North Sea	0	1	25	100	100
Area in % of planning area	0	1	27	100	100

Table 5.13 Example of percentage of areas were concentrations exceed different assessment levels (cadmium 1980)

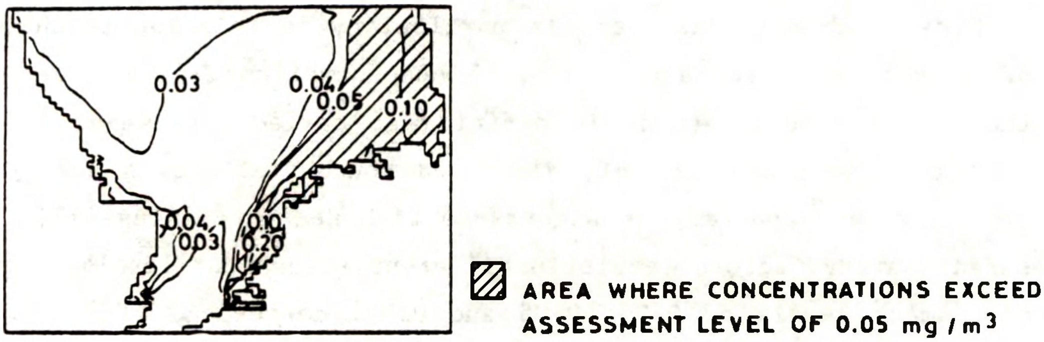


Figure 5.19 Example of indication of areas exceeding assessment levels (cadmium 1980, mg/m^3)

• The anthropogenic fraction. The anthropogenic fraction (A) of the total concentration of a substance at a specific location is defined as:

$$A = \frac{C - C_{nat}}{C} * 100 \qquad (14)$$

in which:

C_{nat} = the concentration calculated with the DELWAQ-model, using as an input the natural concentrations for river inputs (table 5.2) and not including direct sources

C = the concentration calculated for a waste disposal pattern for a given year

Based on the results of the DELWAQ-model, areas can be indicated where anthropogenic fractions exceed certain values. Figure 5.20 presents an example for mercury under 1980 conditions.

A next step in assessing the ambient water quality is to take into account the spatial and time differentiation of assessment levels and anthropogenic fractions in relation to:

- ecological characteristics, such as: species composition and fish life history;
- economic activities, such as: fisheries and recreation; and
- sources of contamination and their contribution to local contamination.

In addition the analyses should be extended to the full range of interaction between human activities and the North Sea ecosystem, including e.g., perturbations due to dredging, fishing, land reclamation and navigation. Such specification requires handling of great amounts of field data and model results. For such purpose a data base management system has been developed: COWADAT (COastal WAter DATa base) which is further described in the annex. COWADAT only has been tentatively used during the 18 month study.

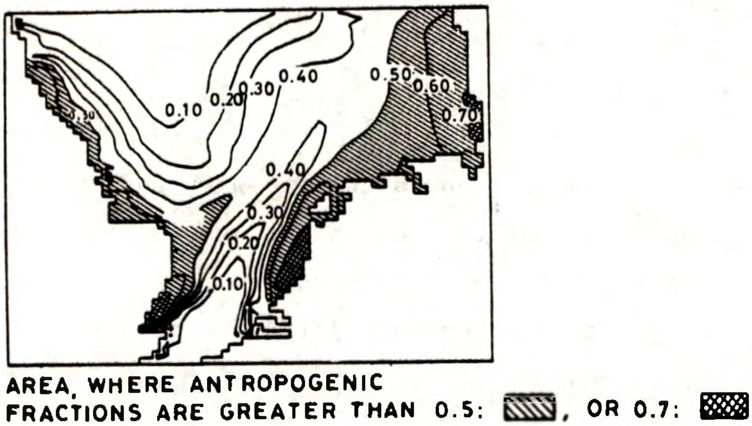


Figure 5.20 Example of indication of areas exceeding anthropogenic fraction values (mercury 1980)

6 RESULTS

6.1 DISCHARGES IN 1980

Tables 6.1 through 6.4 give an overview of the discharges to the southern North Sea and the Dutch portion of the North Sea in yearly quantities and in percentages of total loads for nutrients and heavy metals.

From these tables it can be concluded that rivers constitute the major source of pollutant discharges into the North Sea. Nutrient inputs originate almost entirely, for more than 70%, from river inflow. For the heavy metals the atmospheric deposition, in particular of lead, the dumping of dredged spoils and coastal outfalls, in particular for the southern North Sea, are significant. Discharges by other sources are relatively small, except for chromium entering the North Sea by industrial waste dumping.

Tables 6.1 and 6.2 present also an estimation of the inflow into the southern North Sea of substances via the Channel in the south and from the Atlantic Ocean in the North. For nitrogen (N), cadmium (Cd) and copper (Cu) this inflow is of the same order of magnitude as the total of the considered discharges; for mercury (Hg), lead (Pb) and zinc (Zn) the inflow amounts to 20 to 10% of the total discharges; and for phosphates (P) and chromium (Cr) the inflow is 1.6 to 2 times larger. These inflows are computed on the basis of natural sea water concentrations (see section 5.1.1) and do not include major anthropogenic influences, e.g., through discharges along the French coast, south of the boundary of the southern North Sea.

Tables 6.3 and 6.4 include data on the inflow through the southern boundary of the Dutch portion of the North Sea. This information was taken from [12] and include rough estimates based on actual water quality data and an estimated residual current of 2-3 cm/s in the southern part of the North Sea near the Channel, directed in northern direction along the coast. From tables 6.3 and 6.4 appears that the inflow of Hg, Cu and Cr through the southern boundary of the study area exceeds the total amounts of pollutants, discharged into this area. With respect to the other substances, the inflow through the southern boundary is of the same order of magnitude as the inflow of other sources into the planning area.

Sub-[2] stance	Atmo- sphere	Rivers	Coastal outfalls	Dumping by ship: Dredging spoils	Dumping by ship: Industrial waste	Dumping by ship: Sewer sludge	Incin- eration	Marine transport	Offshore oil/gas	Total discharges	Bound-[1] aries
N	220	1,000	96	2.6	0	15	0	?	0.02	1,300	1,700
P	10	96	25	2.2	0.6	3.6	0	?	0.04	140	230
Hg	8.8	28	8.8	13	0.5	1.6	0.004	<	0.2	61	32
Cd	66	140	24	40	1.2	4.7	0.04	<	0.5	280	280
Pb	2,400	1,500	160	840	260	115	0.6	<	5	5,300	1,100
Cu	1,300	1,850	280	440	200	120	1.6	<	1.2	4,200	3,600
Cr	66	1,500	360	330	390	14	0.3	<	50	2,700	5,500
Zn	8,800	12,000	1,400	2,200	570	410	4	<	8	25,000	6,000

1) Total inflow from the Channel in the south and the Atlantic Ocean in the north

2) N and P in 1000 tons/year; others in tons/year

Legend:

0 = known; non existing or negligible

? = unknown

< = unknown, but expected to be negligible

Table 6.1 Pollutant discharges to the southern North Sea around 1980

Values in %

Sub-stance	Atmo-sphere	Rivers	Coastal outfalls	Dumping by ship: Dredging spoils	Dumping by ship: Industrial waste	Dumping by ship: Sewer sludge	Incin-eration	Marine transport	Offshore oil/gas	Total2) discharges (100%)	Bound-aries1)
N	17	75	7	0	0	1	0	?	0	1,300,000	130
P	7	70	18	2	0	3	0	?	0	140,000	160
Hg	14	47	14	21	1	3	0	<	0	61	50
Cd	24	51	9	14	0	2	0	<	0	280	100
Pb	46	28	3	16	5	2	0	<	0	5,300	20
Cu	31	44	7	10	5	3	0	<	0	4,200	85
Cr	2	56	13	12	14	1	0	<	2	2,700	200
Zn	35	46	6	9	2	2	0	<	0	25,000	25

1) Total inflow from the Channel in the south and the Atlantic Ocean in the north

2) Percentages related to total discharges (in tons/year) excluding inflow through boundaries

Legend:

0 = known; non existing or negligible

? = unknown

< = unknown, but expected to be negligible

Table 6.2 Proportional contributions of different sources to total pollutant discharges to the southern North Sea around 1980

Sub-[3] stance	Atmo- sphere	Rivers	Coastal outfalls	Dumping by ship[1] Dredging spoils	Dumping by ship[1] Industrial waste	Incin- eration	Marine transport	Offshore oil/gas	Total discharges (rounded)	Bound-[2] aries
N	60	575	12	2.6	0	0	?	0.01	650	575
P	2.6	66	3.4	2.2	0.6	0	?	0.02	75	90
Hg	2.3	13.1	1.0	6.6	0.14	0.004	<	0.07	23	32
Cd	17	95	2.6	37	0.8	0.04	<	0.1	150	125
Pb	630	850	24	310	7	0.6	<	2.5	1,800	1,900
Cu	340	925	40	190	4.4	1.6	<	0.7	1,500	2,500
Cr	17	1,000	10	250	270	0.3	<	25	1,600	3,500
Zn	2,300	5,900	180	1,600	40	4	<	4	10,000	7,500

1) Sewer sludges are not dumped in the Dutch portion of the North Sea

2) Inflow through the southern boundary

3) N and P in 1000 tons/year; others in tons/year

Legend:

0 = known; non existing or negligible

? = unknown

< = unknown, but expected to be negligible

Tabel 6.3 Pollutant discharges to the Dutch portion of the North Sea around 1980

Values in %

Substance	Atmosphere	Rivers	Coastal outfalls	Dumping by ship[1]: Dredging spoils	Dumping by ship[1]: Industrial waste	Incineration	Marine transport	Offshore oil/gas	Total[3] discharges ton/yr (100%)	Boundaries[2]
N	10	88	2	0	0	0	?	0	650,000	82
P	3	88	5	3	1	0	?	0	75,000	120
Hg	10	56	4	29	1	0	0	0	23	139
Cd	11	62	2	24	1	0	0	0	150	83
Pb	35	47	1	17	0	0	0	0	1,800	106
Cu	23	61	3	13	0	0	0	0	1,500	167
Cr	1	63	1	16	17	0	0	2	1,600	219
Zn	23	59	2	16	0	0	0	0	10,000	75

1) Sewer sludges are not dumped in the Dutch portion of the North Sea
2) Inflow through the southern boundary
3) Percentages related to total discharges excluding inflow through boundaries

Tabel 6.4 Proportional contributions of different sources to total pollutant discharges to the Dutch portion of the North Sea around 1980

6.2 DISCHARGES IN 1990

An overview of the estimated pollutant discharges to the Dutch portion of the North Sea in 1990 is presented in tables 6.5 and 6.6. Ranges in discharges for rivers and dredged spoils reflect low and high scenarios.

Compared to 1980, discharges in 1990 will be lower. Especially the discharges of chromium will decrease strongly mainly as a result of the intended stop of dumping of industrial wastes from ships in Dutch waters Due to the decrease of total discharges in 1990 the inflow of substances via the southern boundary of the study area has become relatively more important compared with the 1980 situation.

In 1990 rivers still contribute most to total discharges. Atmospheric deposition and dredged spoils contribute significantly; other contributions are small.

Substance 2)	Atmosphere	Rivers 3)	Coastal outfalls	Dredging spoils 3)	Offshore oil/gas	Total discharges	Boundaries 1)
N	57	450- 560	6	2	0.01	510- 620	540
P	2.6	49- 62	1.7	1.7	0.01	56- 68	90
Hg	2.3	6.2- 7.4	0.3	2.1- 3.4	0.05	11- 13	33
Cd	17	45- 61	1.3	11- 20	0.6	75- 100	125
Pb	630	550- 640	4	80- 200	3	1,300-1,500	1,900
Cu	340	530- 700	8	63- 126	1	900-1,200	2,500
Cr	17	400- 540	2.7	5- 100	17	440- 680	3,500
Zn	2,300	3,200-4,300	39	620-1,130	3.6	6,200-7,800	7,500

1) Inflow through the southern boundary

2) N and P in 1000 tons/year; others in tons/year

3) Ranges for rivers and dredging spoils reflect low and high scenarios

Table 6.5 Pollutant discharges to the Dutch portion of the North Sea in 1990

Values in %

Sub-stance	Atmo-sphere	Rivers 2)	Coastal outfalls	Dredging spoils 2)	Offshore oil/gas	Average total discharges (100%)	Bound-aries 1)
N	10	79- 98	1	0	0	570,000	95
P	4	80-100	3	3	0	62,000	145
Hg	19	51- 61	2	17-28	0	12	270
Cd	19	51- 70	1	13-23	1	87	145
Pb	46	40- 47	0	6-15	0	1,400	140
Cu	32	50- 66	1	6-12	0	1,050	235
Cr	3	72- 97	0	1-18	3	560	625
Zn	33	46- 62	1	9-16	0	7,000	110

1) Inflow through the southern boundary

2) Ranges for rivers and dredging spoils reflect low and high scenarios

Table 6.6 Proportional contributions of different sources to total pollutant discharges to the Dutch portion of the North Sea in 1990

6.3 AMBIENT WATER QUALITY 1980

For 1980 winter conditions the major results of the DELWAQ computations (section 5.3.2) for the southern North Sea are summarized in the following figures:

- Figure 6.1: Maps presenting the distribution of total concentrations for nitrogen (N), phosphate (P), cadmium (Cd), mercury (Hg), lead (Pb), copper (Cu), zinc (Zn) and chromium (Cr).
- Figure 6.2: Maps showing the anthropogenic fraction of the total concentrations presented in figure 6.1.
- Figure 6.3: Maps representing the proportional distribution of different sources to the total concentration of cadmium.
- Figures 6.4 and 6.5: Cross-sections at 53° and 54° latitude respectively, presenting the concentration build up for the above mentioned substances.

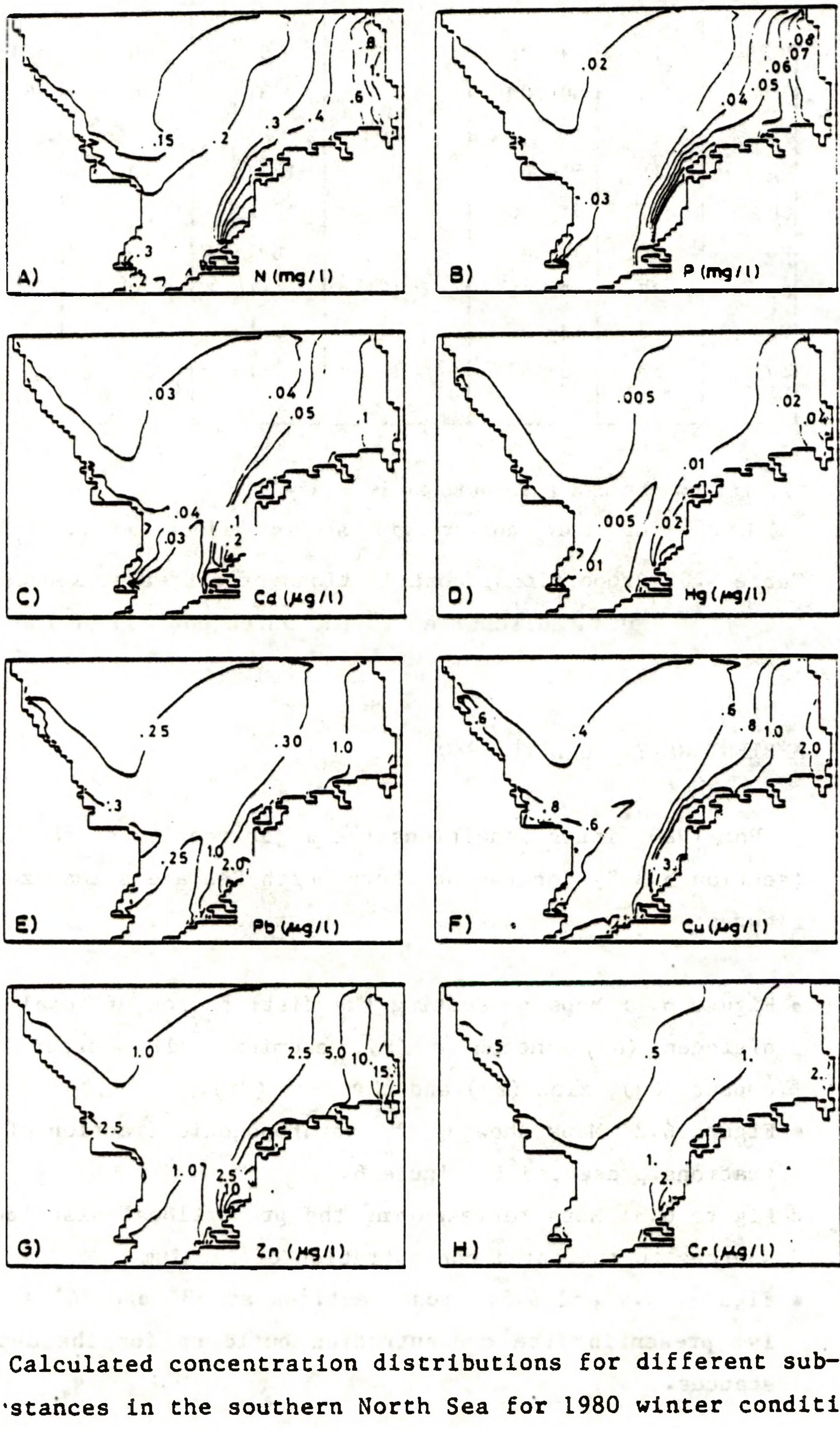


Figure 6.1 Calculated concentration distributions for different substances in the southern North Sea for 1980 winter conditions

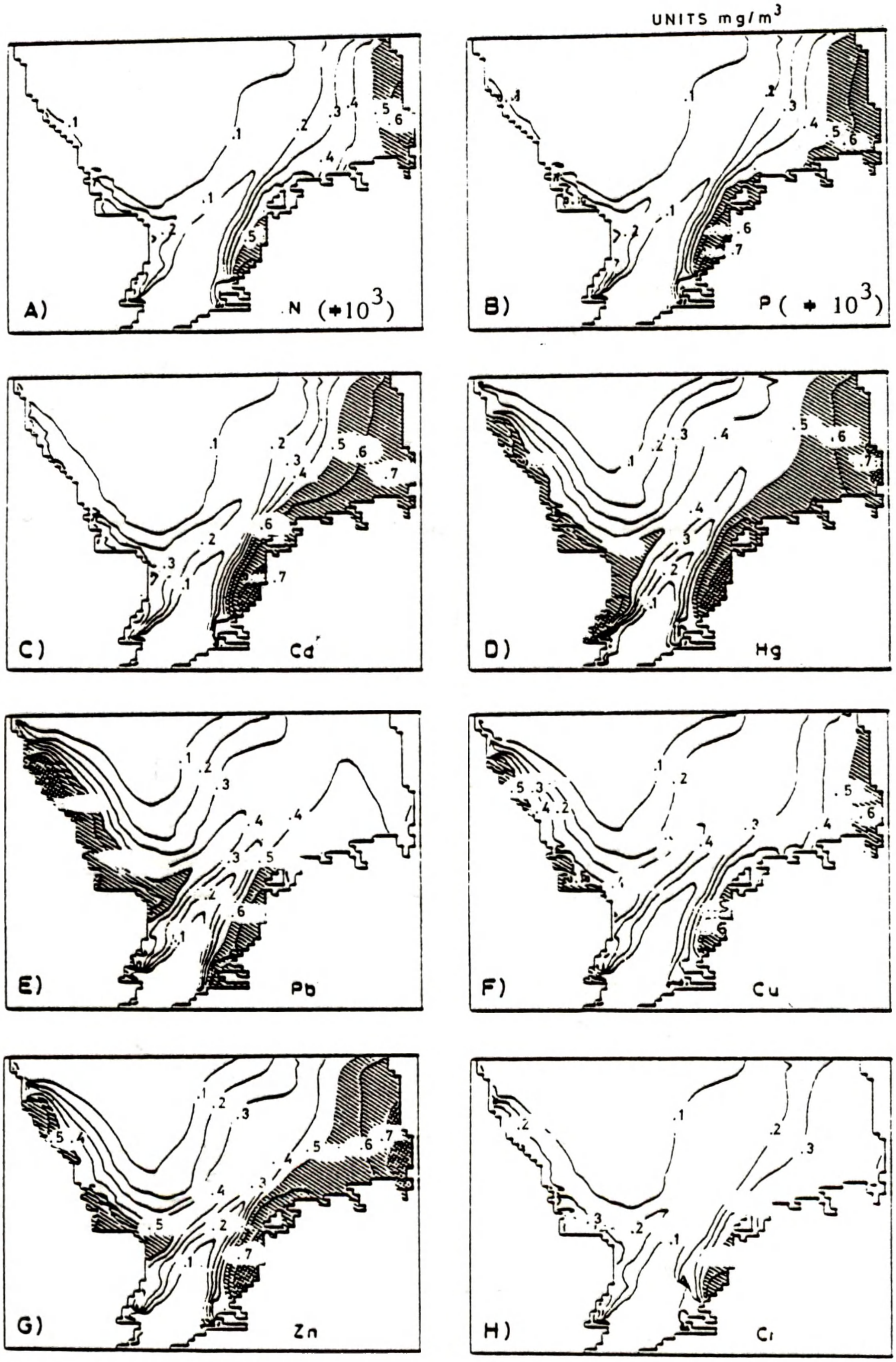


Figure 6.2 Anthropogenic fractions for different substances in the southern North Sea for 1980 winter conditions

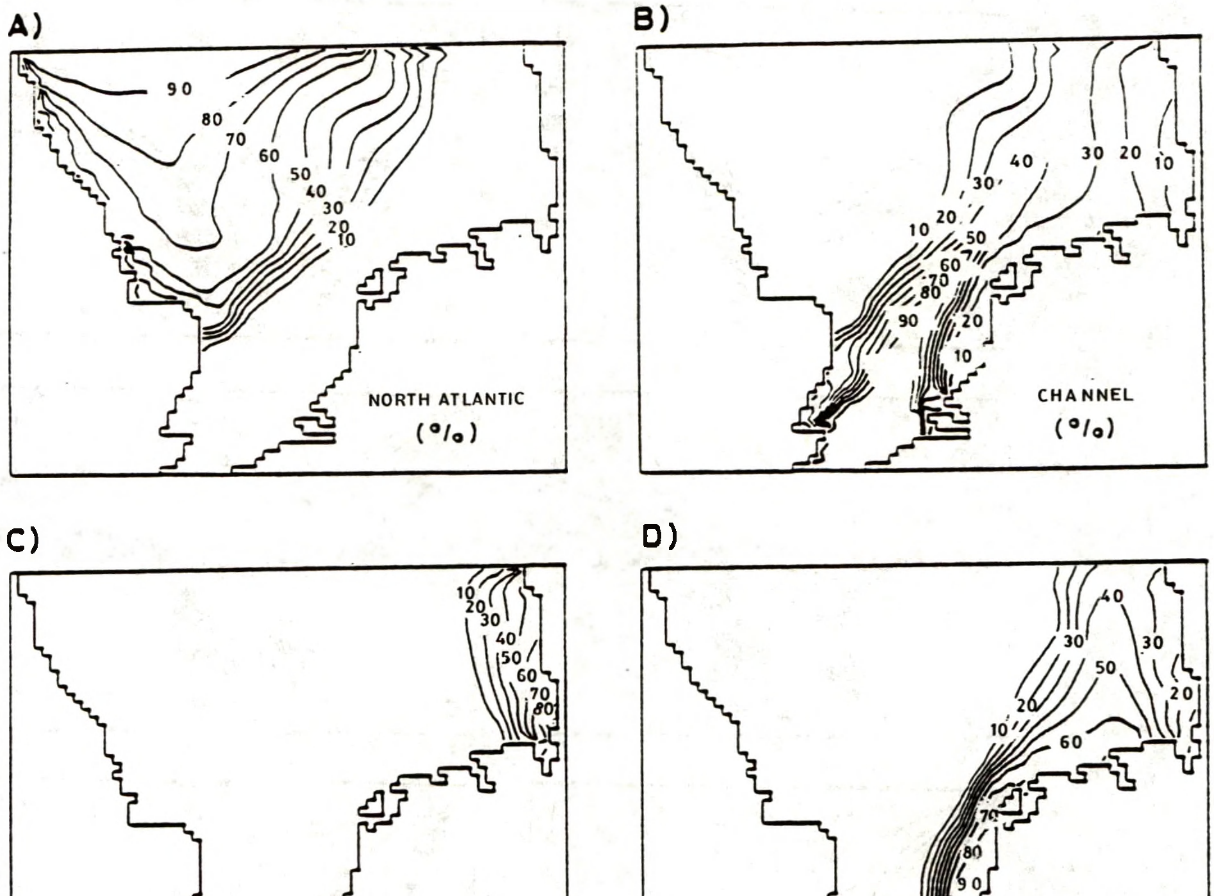
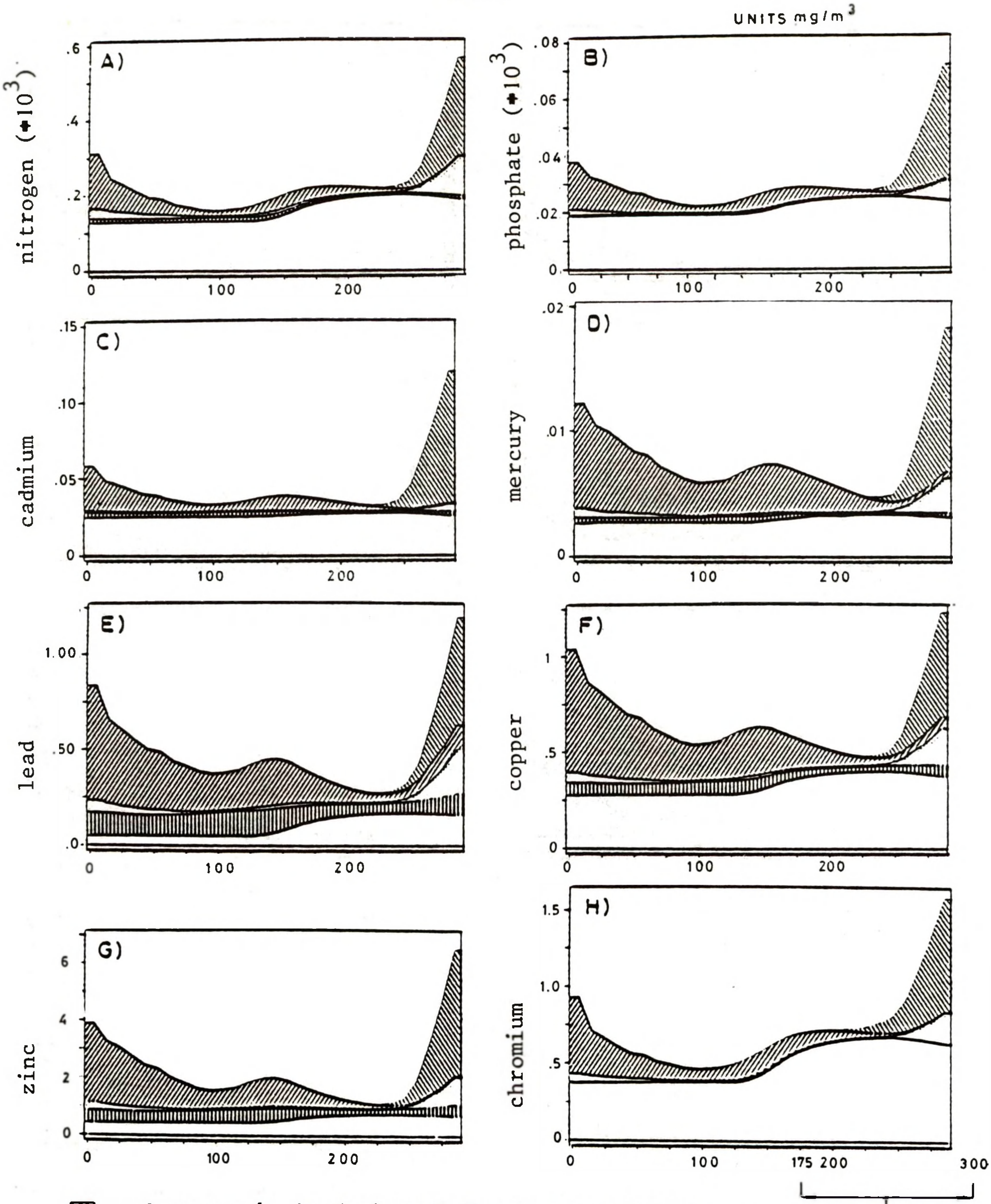


Figure 6.3 Proportional contribution of different sources to cadmium distribution in the southern North Sea for 1980 winter conditions



anthropogenic load through Dutch coastal zone

other anthropogenic loads

natural loads through rivers

atmospheric depositia

input through boundaries (Channel and North Atlantic Ocean)

Dutch portion of the North Sea

Figure 6.4 Concentration "cross-sections" along 53° latitude for different substances and different sources for 1980 winter conditions

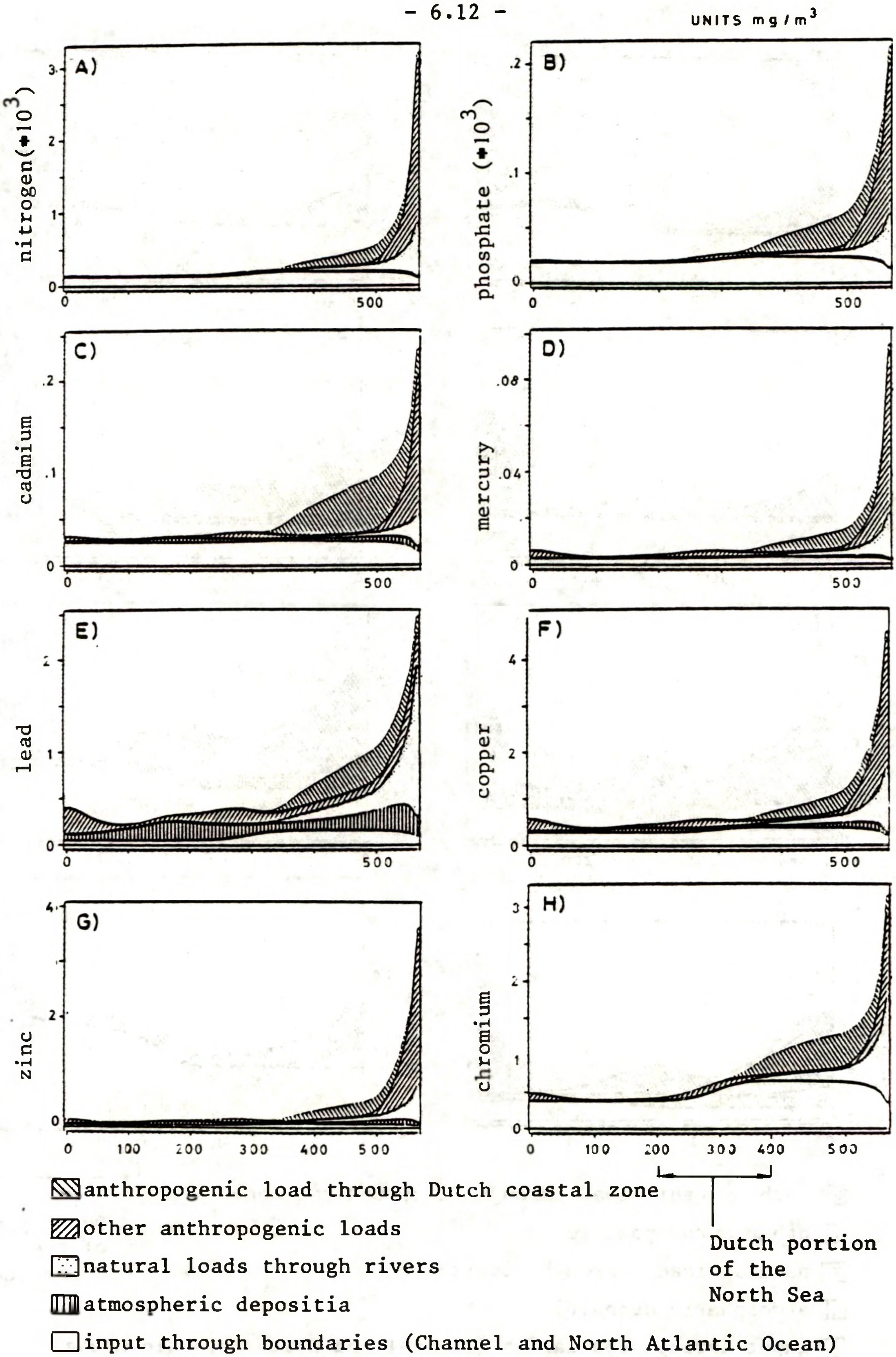


Figure 6.5 Concentration "cross-sections" along 54° latitude for different substances and different sources for 1980 winter conditions

The results clearly show the high concentrations and high anthropogenic fractions along the Dutch coast and German Bight due to discharges in the Dutch and German coastal zones (mainly Rhine and Elbe) and along the southern U.K. coast due to discharges from the Humber and direct dumping (compare table 5.9).

Contribution of atmospheric deposition is highest in zones with high retention times: Doggersbank and German Bight (figure 6.5). For lead, for example the atmospheric contribution to the concentrations on the Doggersbank mount to about 70% in the German Bight to about 30%.

Major uncertainties in obtaining the presented results are summarized in section 4.3 and 6.5.

For the toxic substances concentration distributions are compared with assessment levels. For different safety factors tables 6.7 and 6.8 summarize areas where corresponding assessment levels are exceeded in the southern North Sea and the Dutch portion of the North Sea respectively.

substances	lethal concentration	% of area where assessment levels corresponding with indicated safety margings, are exceeded					
	(mg/m^3)	10	20	100	200	1000	(safety factors)
Cd	5	0	1	25	100	100	
Hg	1	0	1	21	59	100	
Pb	340	0	0	0	3	58	
Cu	14	2	7	100	100	100	
Zn	25,000	0	0	0	1	7	
Cr	30,000	0	0	0	0	0	

Table 6.7 Areas in the southern North Sea where assessment levels are exceeded (1980 winter conditions)

substances	lethal concentration (mg/m^3)	% of area where assessment levels corresponding with indicated safety margings, are exceeded					
		10	20	100	200	1000	(safety factors)
Cd	5	0	1	27	100	100	
Hg	1	0	0	20	78	100	
Pb	340	0	0	0	4	84	
Cu	14	6	24	100	100	100	
Zn	25,000	0	0	0	0	0	
Cr	30,000	0	0	0	0	0	

Table 6.8 Areas in Dutch portion of the North Sea where assessment levels are exceeded (1980 winter conditions)

Using a safety factor of 100, table 6.7 shows that the calculated concentration of Cu is higher in the North Sea than the critical level. For Cd and Hg calculated concentrations exceed the corresponding assessment level in large parts of the North Sea, whereas the concentrations of Pb, Zn and Cr in the whole of the southern North Sea stay below the assessment level. It has to be mentioned in this respect that the applied safety factor for Cu is probably too high since the assessment level, based on 1/100 of the lethal concentration is already exceeded in the inflowing water from the Atlantic Ocean.

Using the indicators, presented in section 5.5, figure 6.6 gives an overview of the ranges of these indicators for the six heavy metals considered, in waters in front of the Dutch coast (0-60 km).

Applying a safety factor of 100 it can be concluded that the coastal zones are severely polluted with Cd, Hg and possibly Cu. Anthropogenic fractions for all substances are roughly around 50%. This holds for Dutch coastal waters and the German Bight as well. Also because these zones play an important role in the recruitment of fish and other organisms and produce many other goods and services which depend on good water quality, extra attention has to be paid to the reduction of mentioned pollutants in these areas.

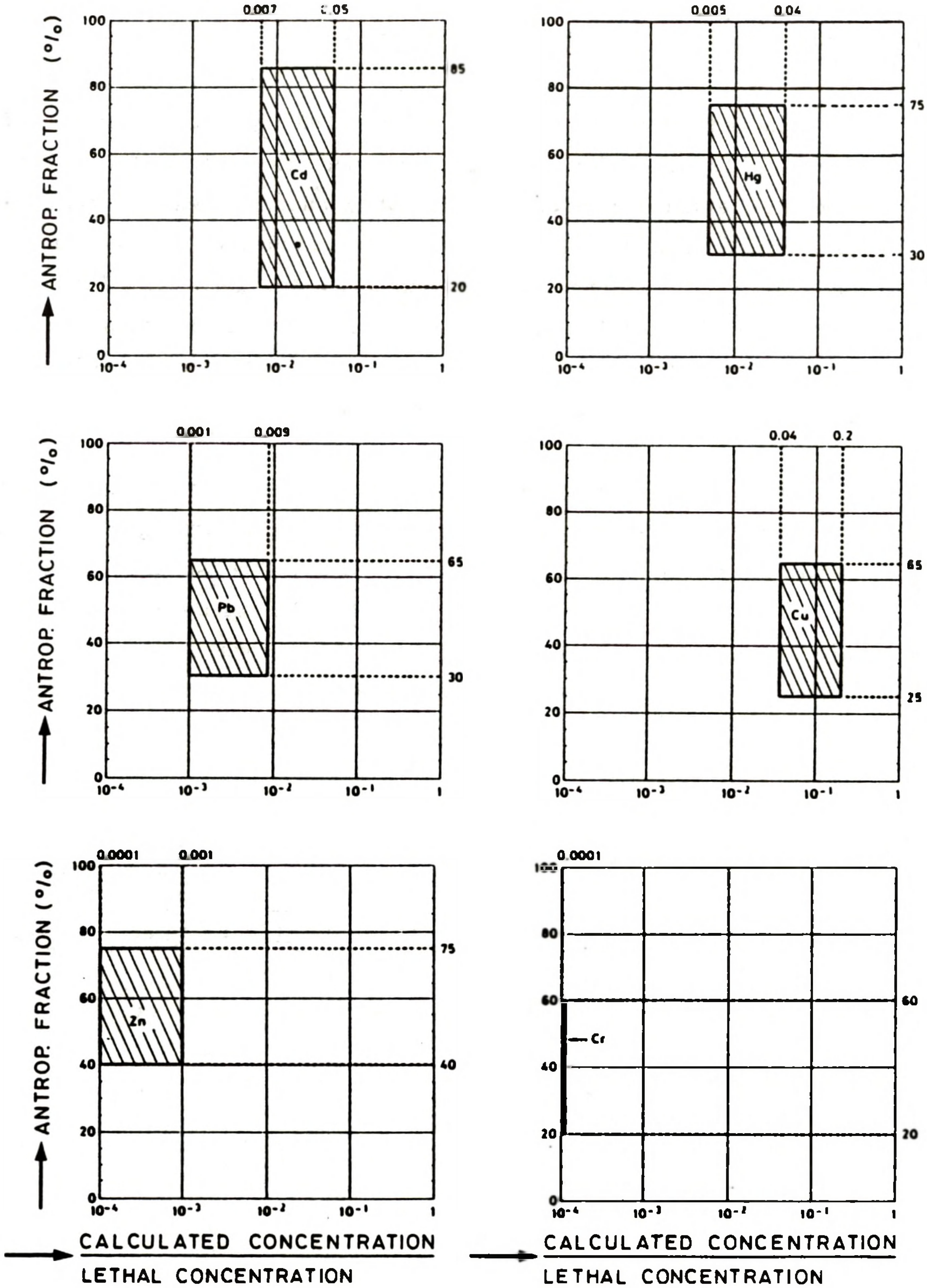


Figure 6.6 Assessment of ambient water quality situation in front of the Dutch coast (0-60 km) for 1980 winter conditions using as indicators the anthropogenic fractions and relations between calculated and lethal concentrations

6.4 DEVELOPMENT OF AMBIENT WATER QUALITY

Expected developments, as represented by the estimates of discharges for a 1990 situation take into account existing Dutch policies such as: complete elimination of dumping of industrial wastes from ships. A comparison between the DELWAQ results for 1980 and 1990 winter conditions was made in order to evaluate the expected developments. Tables 6.9 and 6.10 summarize the results in terms of areas exceeding assessment levels (safety factor 100) and anthropogenic fractions respectively, both for the planning area and the southern North Sea.

Tables 6.9 and 6.10 show a considerable improvement for the toxic substances, both in concentrations and in anthropogenic fractions. With respect to the values given for N and P, it should be mentioned again, that the DELWAQ calculations do not take into account any chemical or biological process. This goes fòr heavy metals too; all substances are considered to be conservatively transported by physical mechanisms in the water phase alone.

Substance	Assessment level (safety factor 100) (mg/m^3)	Area (%)			
		Planning area		Southern North Sea	
		1980	1990	1980	1990
Cd	0.05	27	20	25	21
Hg	0.01	20	9	21	14
Pb	3.4	0	0	1	1
Cu	0.14	100	100	100	100
Zn	250	0	0	0	0
Cr	300	0	0	0	0

Table 6.9 Areas in the southern North Sea and planning area where assessment levels are exceeded (1980 and 1990 winter conditions)

Substance	Area (%)			
	Planning area		Southern North Sea	
	1980	1990	1980	1990
N	6	6	8	8
P	10	8	12	11
Cd	23	9	21	9
Hg	22	5	29	16
Pb	15	3	16	12
Cu	6	1	9	6
Zn	24	8	25	15
Cr	6	0	2	1

Table 6.10 Areas in the southern North Sea and planning area where anthropogenic fractions are higher than 50% (1980 and 1990 winter conditions)

6.5 METHODOLOGICAL LIMITATIONS

Although the method which was developed and used in assessing the present and future ambient water quality situation proves to be a powerful instrument in the quantification and assessment of hazardous pollution situations on a macro-scale, there are some arbitrary choices made during the analyses which have to be borne in mind. The major uncertainties, related to these choices, are summarized below, grouped into two categories.

i. Uncertainties in the calculation of concentrations, both for the natural, the actual ("1980"), and the future situation (1990).

   Model calculations were necessary to estimate concentrations, not only under natural and future conditions, but as well under actual conditions, because of lack of adequate field information. In addition to uncertainties, related to the lack of information on discharged wastes and to model simplifications of natural processes, e.g., due to the coarse grid applied, the following is worth mentioning. The calculation values represent yearly averages under winter wind-conditions. No information is generated on possible, time and space dependent, variations of these averages, due to, e.g., tidal currents, exchange processes between water and sediments, and stratification (temperature, salinity). For such reasons, calculated values should be used only as rough indicators and in a comparative way and not as absolute values to quantify the risk of high concentrations of toxics on the ecosystem. Such risks may depend up to a large degree on locally and temporarily present high concentrations.

ii. Uncertainties in assessing the effects of the calculated concentrations on the ecosystem.

With regard to toxic substances, assessment levels were determined to evaluate calculated concentrations. Such levels were based on lowest lethal concentrations found in literature, applying a safety factor of 100. Taking into account uncertainties, involved in using results of (single species) experiments under laboratory conditions (c.f. section 5.4) application of this safety factor leads to operational no-effect-levels: "safe concentrations" to be used in the assessment of calculated concentrations. The procedure followed does not differentiate according to species or speciation of toxic substances.

The influence of nutrients on primary production and composition of phytoplankton only was analysed in an indicative way. A major point of concern, not included in the analyses, is the risk of low oxygen contents in the German Bight and central parts of the North Sea.

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ANNEX A : Description of COWADAT; a COastal WAter DATa management system

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A.1 INTRODUCTION

The COWADAT-system was established as a tool for analyzing interrelations between physical, chemical and biological characteristics of mariene ecosystems. With such a tool the effects of management measures or strategies on ambient water quality can be evaluated as well as the impacts of ambient water quality on the ecosystem. COWADAT consists of an actual data base, containing the spatial distribution of selected variables, and of facilities for manipulating these variables, including in- and output facilities. The version of COWADAT described in this report was developed during the study supporting the formulation of the water quality management plan for the Dutch portion of the North Sea.

The selected variables are related to characteristics of the natural system and human use of the area under consideration, and might include:

- physical characteristics, e.g., geomorphology, depth, sediment type;
- chemical characteristics, e.g., the spatial distribution of water and sediment quality parameters, for the present situation as well as for an expected future situation;
- biological characteristics, e.g., the spatial distribution of species, spawning and nursery areas and benthic communities; and
- use characteristics, e.g., the distribution of shipping, off shore activities, fishing, coastal recreation, sand and gravel extraction, and dumping sites for industrial waste and dredging spoils.

The facilities for manipulating data are designed to generate overlays of spatial distributions of two or more variables and to assess surface areas where certain values or ranges of variables available in the data base coincide with specified values.

Input facilities enable the user to introduce items in the data base, starting from mapped information or from in- and output files of models used in the analysis. A generally applicable procedure was developed and used for processing mapped information. In the case of the North Sea study a number of variables, like depth and various water quality parameters, were directly introduced by using existing data from the water quality model DELWAQ. Output facilities include programmes for generating plotted or printed maps of single or composite variables, and tables containing calculated areas or information for specific locations.

In this report the basic concepts of the system are described, serving two purposes. The first one is to provide Rijkswaterstaat with a general description for operating COWADAT as the North Sea data base. The second one is to inform interested persons on the main characteristics and applicability of the COWADAT data management system. The description starts with a brief sketch of the background and the purpose of the data base (section A.2). The approach adopted for schematizing the area under consideration and the way in which the data base and the computer program are structured is described in section A.3. To illustrate the way COWADAT can be used, some examples derived from the North Sea study, are given in section A.4.

It is emphasized that the COWADAT program is generally applicable. In this annex application for the North Sea is explained and used for illustrative purposes. As all presented maps and tables have illustrative value only, no specific references are given to sources, years or special conditions.

A.2 BACKGROUND AND PURPOSE OF COWADAT

Analyses to support the formulation of coastal water management strategies (being a combination of management measures) generally include identifying and evaluating the impacts of present and expected future use of (the resources of) the region under different sets of management strategies. Such analyses cover:

- activities inside and outside the region as far as related to the system under consideration, including sources of pollution;
- the natural system, e.g., water movement, ambient water quality, living environment;
- costs and benefits associated to the use of the region and management strategies;
- the impacts of activities, direct and indirect, on the ecosystem and actual or potential use; and
- the legal and institutional context dealing with implementation of the formulated management strategies.

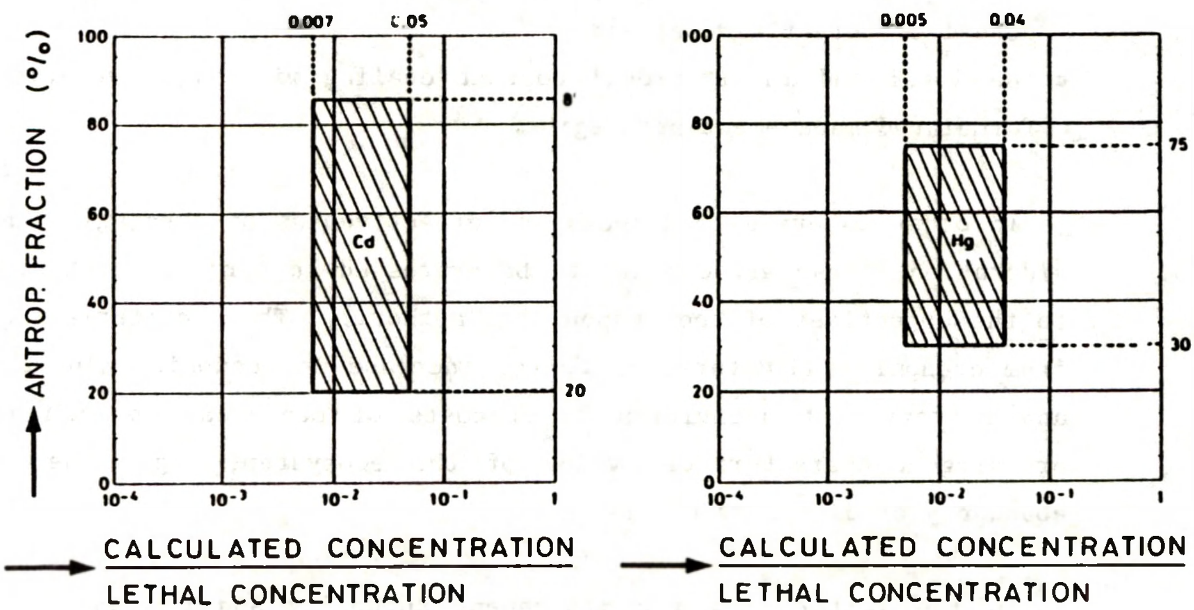
In order to evaluate effects and effectiveness of strategies under consideration, these effects are to be expressed in terms of criteria related to the objectives of the responsible authority. These criteria might range from economic indicators, e.g., the increase in economic value of fishing and recreational activities minus costs of measures, to indicators expressing a characteristic value of the ecosystem, e.g., the change in abundancy or diversity of species.

In the latter case the management authority and the analyst have to agree upon practical, meaning quantifyable, criteria. Due to gaps in knowledge and constraints on available time and effort, these criteria usually are more or less rough approximations of the actual objective function. In case of the North Sea study two indicators were used in order to make an assessment of a specific ambient water quality situation:

- Anthropogenic fraction: the ratio between water quality as a result of loads by all sources <u>with</u> and <u>without</u> the contribution induced by human activities (total versus natural or reference concentrations expressed for single parameters); and

- The ratio between calculated or measured concentrations and lethal concentrations, resulting from exposure tests under laboratory conditions. This ratio in the North Sea study was considered to have to be at least 1/100 (safety factor = 100), but may be varied for different substances.

Priorities with respect to specific pollutants and sources were based on the combination of both indicators, thus reflecting the <u>need</u> to take managerial action, as well as the <u>potential</u> to reduce loads. Examples are given in figure A.1.



Observation: situation represents ambient water quality in front of the Dutch coast (0-60 km) for 1980 winter conditions

Figure A.1 Examples of assessments of the water quality situation using as indicators the anthropogenic fraction and the ratio between the calculated and lethal concentration

It was recognized that in the approach as represented in figure A.1, the spatial and temporal distributions of potentially affected species were neglected, e.g., the lethal concentrations used for cadmium were the same for all areas, indifferent to the actual presence or absence of specific organisms. In order to enable a more appropriate evaluation of potential effects of a certain ambient water quality, COWADAT was established.

From this, the first type of use of the data base becomes clear. With COWADAT, areas in which specific (ambient water quality) characteristics coincide with one or more specified ecosystem characteristics can be assessed. For example: an ambient water quality characteristic could be a certain concentration range for a specific parameter, i.e., a cadmium concentration above one hundredth of the lethal concentration, and the ecosystem characteristic could be the presence, or spawning area, of a specific (group of) organism(s). From such a single overlay, aggregated areas can be derived for "all" water quality parameters and "all" organisms, once included in the data base.

Secondly, as soon became apparent during the execution of the study, the data base can be used to identify potential conflicts between different types of use of the region. Examples of conflicts include:

- off shore oil and gas mining and fishing or shipping activities;
- sand and gravel extraction and dumping of industrial wastes or dredging spoil; or
- activities resulting in habitat destruction and conservation of unique benthic communities.

Thirdly, due to the availability of a coherent set of information contained in the data base, a comprehensive overview can be generated of all information included for a given location, for sub-regions or for the region as a whole. A variant of this type of use of the data base is identifying all locations or areas meeting a specified set of conditions reflecting physical, chemical, biological and/or use characteristics.

<u>Fourthly</u>, and finally, the data base can be used to generate and/or process in- and output data for mathematical models. Such models might concern the natural system as well as specific activities and associated emissions like offshore mining activities or shipping.

A.3 STRUCTURE AND LAY-OUT OF COWADAT

A.3.1 GENERAL

The lay-out of COWADAT is shown in figure A.2. The two central elements are the actual data base and an interactively run operating program. The data base consists of two files: (i) a data-file (FILE DATBAS), containing records with information on characteristics of the region; and (ii) a descriptor-file (FILE DATDIC), containing name, dimension, type and source of the stored information, protection codes, selection arguments, etc. The operating program consists of a standard FORTRAN main program and subroutine library, each subroutine executing a specific type of operation on one or more of the records in DATBAS.

With respect to the hardware involved the terminal and line printer are necessary elements. Other components like a digitizer for input- or a plotter for output-operations are optional.

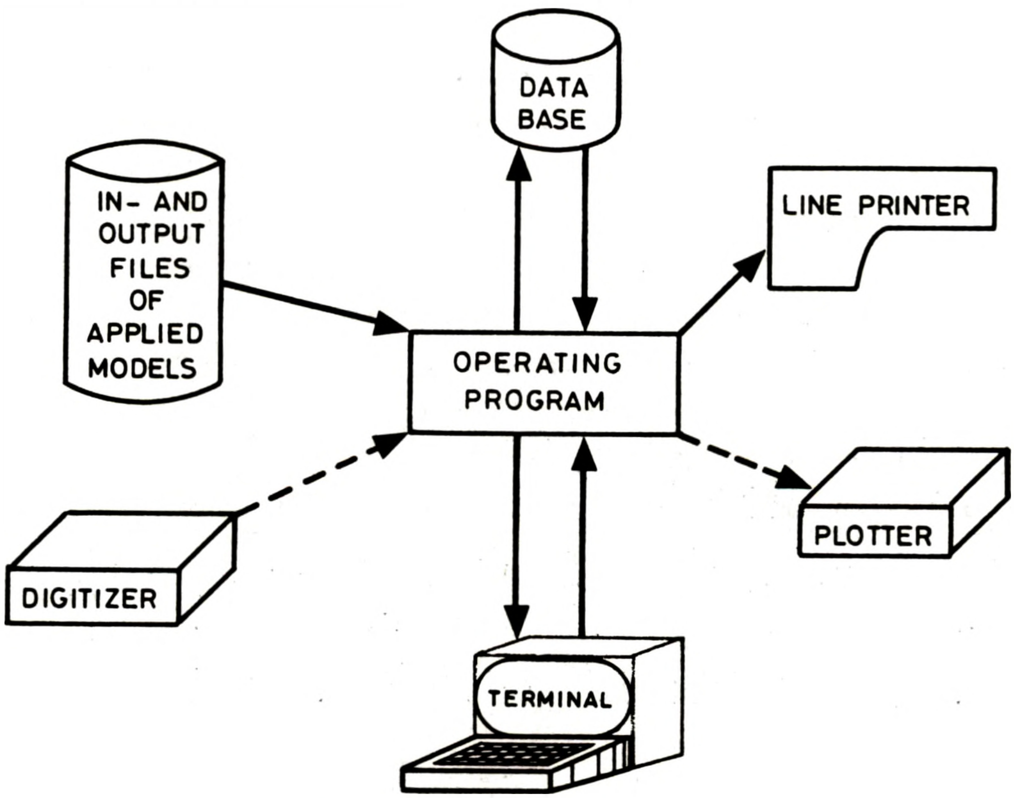


Figure A.2 Lay-out of COWADAT

A.3.2 SCHEMATIZATION OF THE REGION

In order to interrelate the spatial distributions of characteristics of a region, these characteristics have to be coded and stored in a spatial schematization or spatial grid defined beforehand. The grid would preferably, but not necessarily, be identical for every characteristic. The choice of grid-size and -orientation depends on both the level of detail and schematization of the data to be included, as well as on the level of detail or spatial resolution required for the analysis. The boundary of the region considered is of course derived from the objectives of the analysis, or the envisaged use of the data base.

In case of the North Sea, two grids were used as shown in figure A.3. The grids are latitude and longitude oriented. As a consequence the grid cells vary in area, increasing southward. An equidistant grid, however, would be handled in a similar way by COWADAT. The total area covered ranges from 51 up to 62 degrees North latitude and 4 degrees West up to 9 degrees East longitude. For this area a coarse grid was defined with grid cells of 10 minutes latitude by 20 minutes longitude, the area of each cell being about 18 by 20 km. For the southern half of the area, 51 up to 56 degrees latitude, a fine grid was defined with cells of 5 minutes latitude by ca. 7 minutes longitude, each about 9 by 7 km. Based on these grids a characteristic included in the data base is described in either a 60 x 39 matrix (coarse grid, total North Sea), or a 60 x 117 matrix (fine grid, southern North Sea only). As can be seen in figure A.3, only a part of the matrix based on the grid coincides with the actual North Sea area. The land area occupies about 27% of the coarse grid cells or about 37% of the fine grid cells. The consequences for data storage and operations will be discussed later. The schematization is summarized in table A.1.

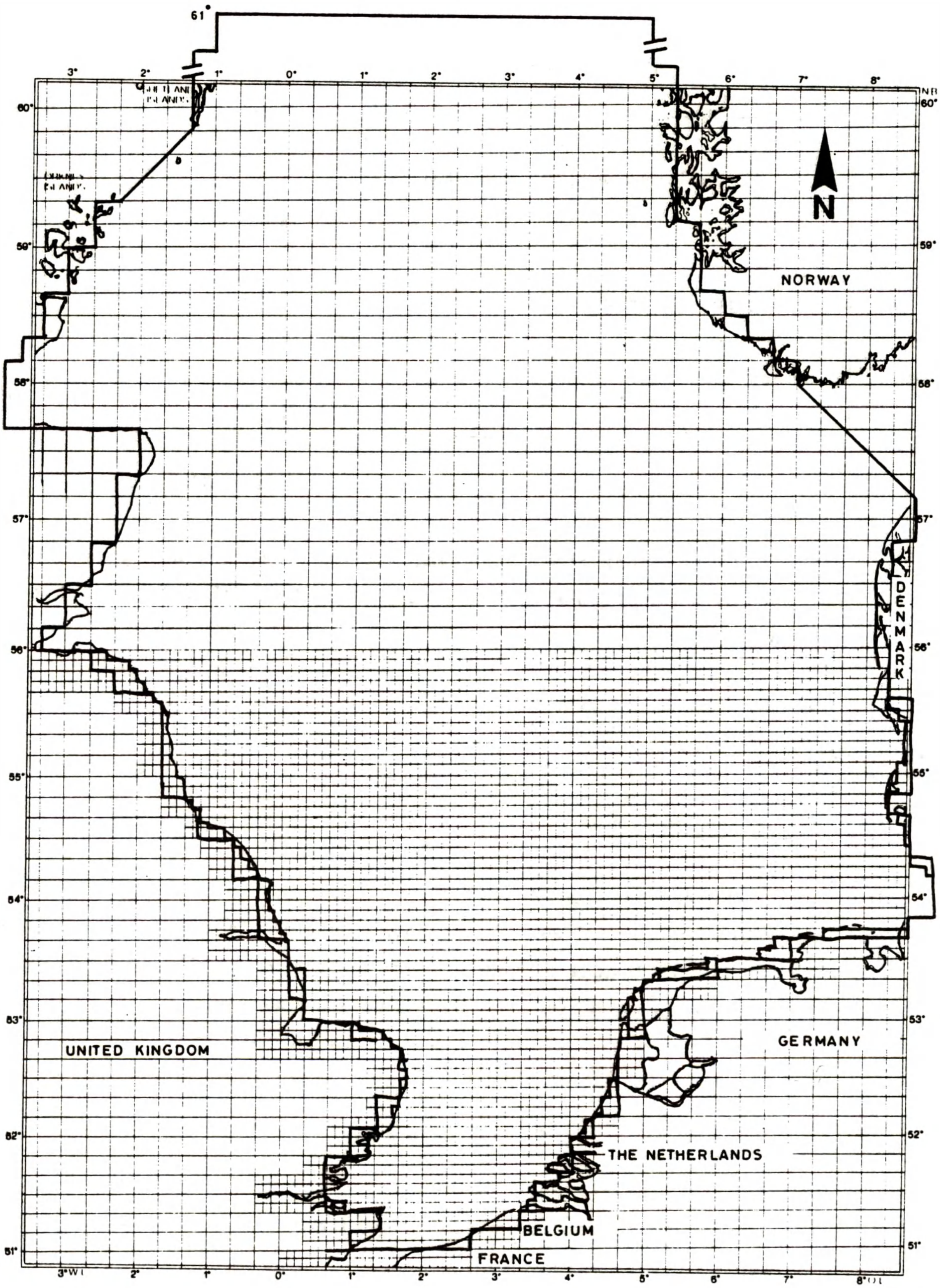


Figure A.3 Schematization of the North Sea area

Area covered							Grid cells	
	Degrees longitude	Degrees latitude	Longitude min	Longitude km	Latitude min	Latitude km	Total number	Number with excl. sea
North Sea coarse grid	4W-9E	51-62	20	18-23	10	18	2340	± 1700
southern N.S. fine grid	4W-9E	51-56	$6^2/3$	6- $7^2/3$	5	9	7020	± 4400

Table A.1 Summary of schematization North Sea for COWADAT

It will be clear that any area, sea or land, and any grid can be schematized in an analogous way. The use of COWADAT therefore is not restricted to a specific region.

A.3.3 DATA STORAGE

A.3.3.1 Type of information

The characteristics included in the data base are real, integer or character type variables. Each characteristic is described as an 60 x 39 or 60 x 117 rectangular matrix (coarse grid resp. fine grid). Examples of characteristics of which the spatial distribution can be included in the data base are given below. Not all items in this list are included in the North Sea version of the data base, nor can the list be considered to be exhaustive.

1. Physical characteristics:
   - mean depth, area and volume of grid cell;
   - sediment type, relief;
   - mean summer and winter flow velocities, tidal fluctuation;
   - mean summer and winter surface and bottom temperature; and
   - areas of temperature or saline stratification.

2. Chemical characteristics:
   - salinity;
   - present and future concentration distribution for all parameters of interest; and
   - natural or reference concentration for those parameters.

3. Biological characteristics:
   - species-distribution or -abundancy by life-history stage, season etc.;
   - spawning and nursery areas, migratory routes;
   - types of benthic or aquatic communities; and
   - primary production.

4. Use characteristics:
   - navigation by type of ship;
   - off shore oil and gas mining, recoverable reserves, present and expected future production and drilling activities;
   - sand and gravel extraction, present locations and extent, potential areas;
   - fishing activities, demersal and pelagic fishing;
   - dumping activities for chemical waste, sewage sludge and dredging spoils;
   - recreational activities at coastal or nearshore areas; and
   - locations and type of land-based sources like rivers, sewer outlets.

5. Load-characteristics:
   - atmospheric deposition;
   - immissions resulting from sea-based activities; and
   - immissions resulting from land-based activities or sources.

6. Legal and institutional characteristics:
   - boundaries of exclusive economic zones on the continental shelf;
   - oil contingency monitoring areas;
   - 12 and 50 mile prohibitive zones according to MARPOL-regulations.

Most of the information included is real type information, i.e. physical and chemical characteristics, use and load characteristics etc.. Information concerning the biological characteristics might be integer or real type, e.g., species distribution or spawning area as integer type (yes/no, or major/minor/absent), and abundancy or primary production as real type. Obviously real type information can also be inserted as integer type by using classes, e.g., 1 for less then X_1, 2 for $X_1 - X_2$, etc..

The characteristics included can reflect past, present or future situations, the latter as a result of estimations under different development scenario's, single measures or management strategies. Also they can reflect yearly mean, mean summer and winter, seasonal or monthly values. The limitations for including and differentiating characteristics are twofold: both information and sufficient storage capacity should be available.

In section A.4.1 an illustration is given of the content of the data base for the North Sea, and the way the characteristics are coded according to type, group, time aspect, etc..

A.3.3.2 The data file DATBAS

The data file consists of a single file, unformatted and directly accessable. Thus every record in the file can be read or written by just specifying the record number and the number of values to be processed. Every record contains one variable or characteristic: a complete 60 x 39 resp. 60 x 117 matrix is written in one record. The record length accordingly is 60 x 117 x 4 = 28080 bits.

It should be noted that the storage is not as efficient as it could be. Firstly the required record length of the file is bound to the fine grid based records, leaving 67% of each coarse grid based record empty. Secondly 30 to 40% of the grid cells coincide with land area, and in consequence the associated part of a record is unused. For reasons of simplicity this inefficiency was accepted for the present. The first cause cannot be overcome easily when keeping to the higher resolution grid. As the southern part of the North Sea is the area of interest, most of the characteristics will preferably and if possible be inserted in fine grid format. The second cause can be overcome by only storing active fields of the matrix, which will be done in an adapted version of COWADAT.

The extent of the file can be defined according to the number of items included. In case of the North Sea a file was used containing 200 records. Of this a number of records are actually filled with information. A new record is written in the first empty record in the data base. As some results of operations are intermediates and are not to be stored definitely, the last 20 records are used for temporarily storing these intermediates. The first 5 records are fixed and contain specific information as described below. The data base thus contains:

Record nr. 1 : date of last update of the data base, the number of the first available (empty) permanent record, the number of the first available temporal record, and a password (unformatted only) for checking authorization of a user.

Record nrs. 2 and 3 : character type information describing the areas outside the active fields of the matrix, i.e. coastline, names of countries etc., which is used for generating maps on the line printer. Record nr. 2 covers the northern half and record nr. 3 the southern half of the area.

Record nrs. 4 and 5 : definition of the active fields in each row of the matrix, sea area fractions of the coast line grid cells, and the total area (km^2) of a grid cell for each row. Record nr. 4 is used for coarse grid and record nr. 5 for fine grid matrices.

Record nrs. 6 t/m 180 : permanent records containing the information of characteristics which is to be kept permanently.

Record nrs. 181 t/m 200: temporal records containing intermediate results of operations.

A.3.3.3 The descriptor file DATDIC

The descriptor file DATDIC consists of a single, formatted and directly accessible file. Each record in the file corresponds to a record in DATBAS, and contains a description of the variable stored in that record. The record length of the DATDIC file is 132 characters and it therefore can be printed on the line printer. The first record in DATDIC contains the same information as described for record nr. 1 of DATBAS, excluding the password. The other records in DATDIC contain information as described below.

1. Record number, format I3.

2. Date of entry of the record and name of the user at that time, format A20, e.g.: 08/10/84 PETER B.

3. Item and selection codes up to five levels, format A15, e.g.: 03.04.08.04.00.
   This code is used for list operations, in which operations are executed on all records with specific codes at one or more of the five levels. The records can be coded according to both the type of information, as well as the need to select a certain subgroup of records. An example of a type based coding is given in table A.2. It will be clear that the actual coding system strongly depends on the practical use one wants to make of the data base.

   An example of a coding for a specific selection, for instance the spawning areas of all demersal fish species, would be to code the appropriate records with 99 at one of the five levels and then execute the operation wanted on all records thus coded. After the operation the code could be changed.

4. Type and dimension of the variable, format A9, e.g.:
   VR 60 x 117: real variable, fine grid; or
   VI 60 x 39: integer, coarse grid.
   The type and dimension is used in almost all subroutines in order to control the correct execution of an operation.

5. Number of values in a record, format I5, e.g.: 2340 or 7020.

6. Protection code, format I3.
   This code prevents the accidental loss of a record when inserting a new record at an incorrect record number. At code 001 the program prompts the user to consider what he is doing. At code 002 the user is forced to end the session and to change the code if he still wants to remove the record from the data base.

7. Dimension of the variable, format A7, e.g.: (--), km**3, g/l.

8. Item description, format A40, e.g.:
   plaice, fishing areas, 1: minor, 2: major; or
   number of ship movements * E-3; oil tankers < 3000 ton.

9. Source description, format A30, e.g.:
   generated at set-up; or
   mask of record nr. 39; or
   sum of records 14 and 24; or
   external, water quality model.

The information in DATDIC is introduced automatically when a new record is inserted. Some of the items are generated by the program itselve and some of the items are specified by the user when executing an operation resulting in the introduction of a new record.

First level, main groups of characteristics, e.g.:
01 physical
02 chemical
03 biological
04 use characteristics, use affecting ambient water quality
05 use characteristics, use affected by ambient water quality
06 immissions
..
..
09 masks for sum and area calculations (see section 4).

Second level, specific items, sub-groups of characteristics, e.g.:
02.01 parameter 1
02.02 parameter 2, or:
.. ..

03.01 general habitat
03.02 micro flora and fauna
03.03 benthic organisms
03.04 fish
03.05 birds, or:
.. ..

04.01 offshore activities
04.02 shipping
.. ..

Third level: specific species within subgroups, scenario number, etc., e.g.:
02.03.01 concentration 1980
02.03.02 concentration 1990, or:
.. .. ..

03.04.01 plaice
03.04.02 herring
.. .. ..

Fourth level: life-history stages
03.04.02.01 spawning area
03.04.02.02 nursery area
03.04.02.03 distribution adults
.. ..

Fifth level: time aspect
03.04.02.03.00 yearly mean
03.04.02.03.01 mean summer
03.04.02.03.02 mean winter
03.04.02.03.11 january
.. ..
03.04.02.03.22 december

Table A.2 An example of type based selection codes

A.3.4 DATA-MANIPULATION

Operations on the data base include: input operations; processing of one or more records in the data base; and output operations. For each operation the user has to specify which operation is to be performed on which record or records. The specification of the type of operation is part of the main program of COWADAT. By means of a menu the user indicates what he wants to do (figure A.4). The operations as such are programmed in separate subroutines, called by the main program. In general an operation or subroutine passes through the following steps:

- specification of the record(s) to process;
- description of the record generated;
- reading record(s) in DATDIC;
- test on type and dimensions of the records (matrices) concerned;
- reading record(s) in DATBAS or external file;
- specification of auxiliary information required;
- executing the operation; and
- writing results in DATDIC and DATBAS, or in an external file, or in the output file.

The operations included in the North Sea version of COWADAT are listed below.

<u>Input operations</u>

- purge: remove records from the data base;
- external input: read an external file (matrix) and insert the record in the data base;
- move: move a record in the data base;
- sort: sort all records according to increasing selection-codes;
- change gridsize: transformation of a 60 x 39 record into a 60 x 117 record; and
- change type: transformation of a real type record into an integer type record.

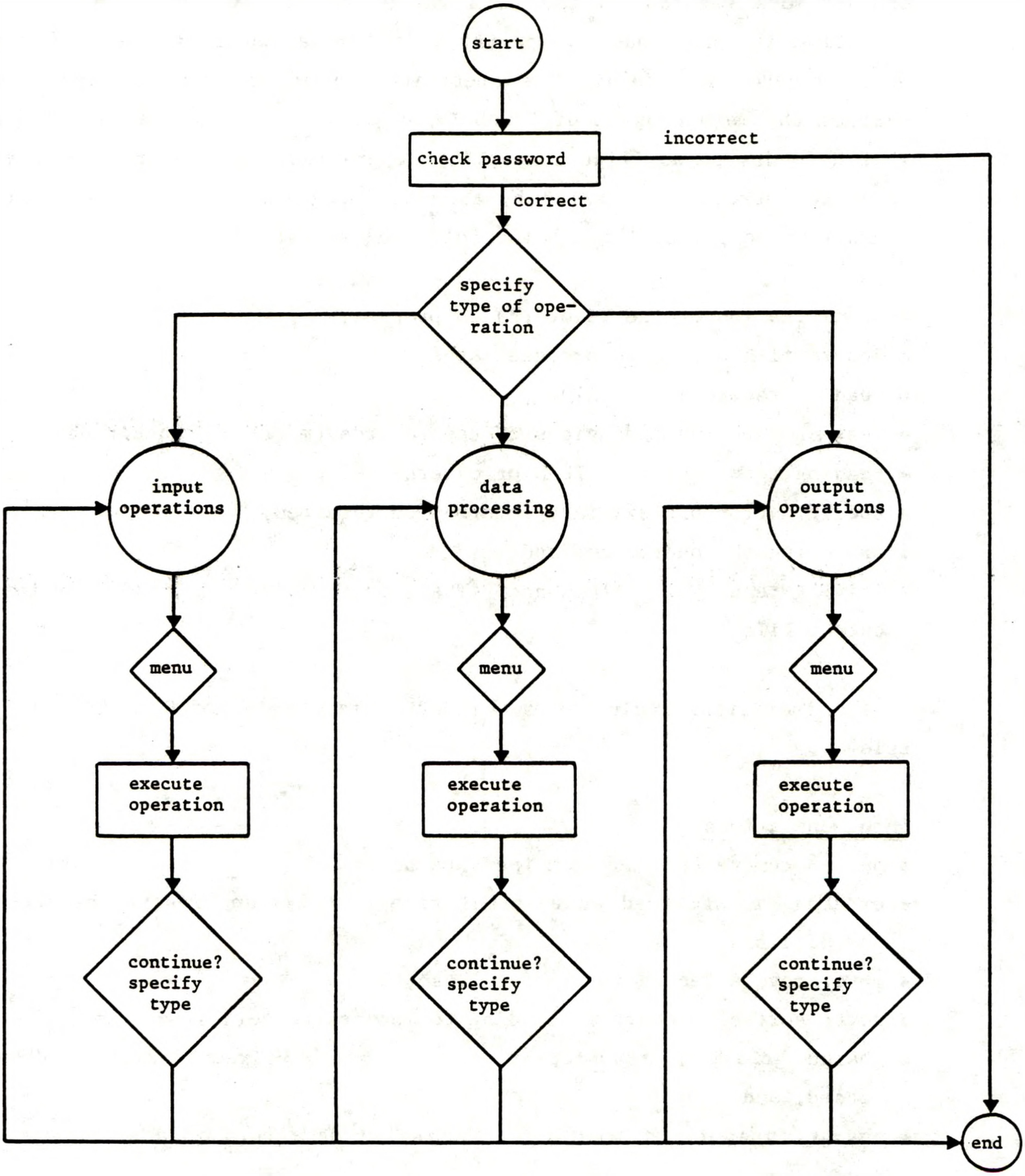


Figure A.4 Flow diagram of main program COWADAT

Processing of records

- sum: add two records, add a constant;
- sum list: add all records with a specified selection code;
- substract: substract two records, substract a constant;
- product: multiply two records, multiply by a constant;
- divide: divide two records, divide by a constant;
- unit: unite two records (R3 = 1 if R1 $> X_1$ or R2 $> X_2$);
- unit list: unite all records with a specified selection code;
- cross: derive cross section of two records (R3 = 1 if R1 $> X_1$ and R2 $> X_2$);
- cross list: derive cross sections of all records with a specified selection code;
- conditional sum: sum all values of record 1 for equal (interval) values of record (mask) 2;
- compute area: calculate areas for equal (interval) values of a record, calculate areas for intervals of record 1 and for equal (interval) values of record (mask) 2;
- mask: generate a mask for computing areas or total value according to a mask;
- anthropogenic fraction: calculate an anthropogenic fraction from total and reference concentrations; and
- risc index: calculate the ratio between the calculated and lethal concentration for a given safety factor.

Output operations

- write: write a record in DATDIC and DATBAS;
- map line printer: generate a map of a record on the line printer;
- external file: generate an external file containing one or more rows, one or more columns, a part of or the complete matrix for further external processing like for instance generating plots;
- tabel: list a selection or all information included for one or more location; and
- list: list all values of a record on the line printer.

A.4 ILLUSTRATIVE EXAMPLES

In order to illustrate the use of COWADAT some examples of the North Sea study are given in this section; tables and figures are inserted at the end of the text.

A.4.1 CONTENTS OF THE DATA BASE, NORTH SEA VERSION

In table A.3 the descriptor file DATDIC is shown. The records 1 up to 5 contain general information, including the coastline definition, grid cell area and numbers of coastal grid cells representing the boundaries of the active fields of the matrix. The records 6 up to 11 include depth, volume and type of sediment. Figure A.5 shows an interval map of mean depth and figure A.6 the type of sediment in an integer representation. Both maps are coarse grid, total North Sea. Each block of 6 characters in these maps represent one cell, coarse grid. The records 12 up to 27 (table A.3) contain results of the simulation of the water quality for 6 heavy metals and nitrogen and phosphorus, both the present and expected future (1990) situation. Figure A.7 shows an interval map of cadmium concentrations in 1980 in fine-grid, southern North Sea. In this map each character corresponds to one cell in fine grid, being the highest level of detail possible in this schematization. The records 28 up to 54 (table A.3) contain information of the distribution of biota, including some commercial fish species. The information is mainly taken by processing maps published by the British Ministry of Agriculture, Fisheries and Food. The figures A.8-A.11 represent spawning-areas resp. adult distribution of sole and plaice.

It will be clear that the value of the data base increases as the contents is expanded by including information related to other species important from the point of the ecosystem or food web (fish and other organisms), as well as on life history and seasonal differences in the distributions. Considering the fact that readily available information concerned about 5% of all fish species present in the North Sea, the effort of expanding the database is not to be underestimated. On the other hand some interesting patterns already occur when aggregating the information presently included. For example, the records 55 and 59 (table A.3), shown in figures A.12 and A.13, contain the results of sum list operations on all spawning areas resp. adult distributions of fish species included in the data base (12 species). In figure A.12 an area in the southern North Sea can be identified with a relatively high spawning activity. With respect to the distribution of adult fish, another pattern evolves. Figure A.13 shows the occurrences in the North Sea, pelagic and demersal species contributing differently to the occurrences in the northern and southern part respectively.

The records 61 up to 80 contain information on activities on the North Sea, including off shore mining, navigation and fishing activities. Examples of this type of information are given in figures A.14-A.16. Figure A.14 shows the distribution of recoverable gas reserves in the North Sea area in 10^9 m^3. Figure A.15 shows the distribution of the intensity of route bound navigation, expressed as the number of ships per year passing through each grid cell. Figure A.16 shows the intensity of fishing by the Dutch fishing fleet, expressed as hours per year. These examples show that there is a wide range with respect to the level of detail at which the information is available, ranging from site specific information (offshore mining) to information available for areas of about 4000 km^2 (fishing intensity).

The records 81 up to 84 contain masks for calculating sums or areas and reflect various zones which may be of interest for the assessment of impacts of management strategies. Examples of these operations are given in the next paragraph. Here the mask reflecting the exclusive economic zones, fine grid, is shown in figure A.17.

Based on the distribution of source type activities the immissions also can be represented in grid schematization and be used as an input for further water quality modelling. Some results were included in the data base concerning oil discharges by navitation: records 85 up to 90. Figure A.18 gives an example of the immission of oil by deballasting and tank cleaning operations of oil tankers. This particular case can be considered to be a non-restricted, worst-case scenario. About 70-80% of the immission coincides with the MARPOL 50-mile zone which would restrict discharges to the central and northern North Sea area, were intensive traffic by oil-tankers does not occur, and a part of the German Bight which is intensively used.

Records 91 up to 114 contain the results of operations on the distribution of of water quality parameters: the anthropogenic fractions and the ratio between calculated concentrations and lethal concentrations. The anthropogenic fraction reflects the fraction of the total concentration which is induced by human activities (value = 0: concentration fully natural; value = 1: concentration fully man induced). The ratio between calculated concentrations and lethal concentrations reflects the danger of effects to occur on marine organisms by the presence of toxic substances in the North Sea. Considering an acceptable safety factor of 100, this ratio should be smaller than 0,01. Aggregating these indicators has been done in two ways in the figures A.19 and A.20. Figure A.19 (record 113) shows the spatial distribution of intervals of average anthropogenic fractions. Figure A.20 (record 114) presents for individual grid cells the number of heavy metals (out of 6) for which the ratio between calculated concentrations and lethal concentrations are greater than 0,0075.

A.4.2 SOME EXAMPLES OF OPERATIONS

The records included in the database have been either incorporated by reading and processing external files, sometimes modified by changing grid (from coarse to fine grid) or type (from real to integer), or are the results of data-processing with COWADAT. Examples of the former are shown in the previous paragraph. The number of spawning fish species per grid cell (figure A.12) was generated with the operation unit list (see section A.3.4), processing all records coded as spawning areas. In this case all species spawning in each grid cell were counted. The same operation could optionally result in a record indicating the area were at least one species, or any other number of species, are known to spawn. The example presented, the number of spawning species, could alternatively be generated with the operation sum list (see section A.3.4), in which case however, a major spawning area for a single species (value = 2 in the record concerned), would contribute equally to the total as two minor spawning areas of two different species (each valued 1 in the records concerned). The mean anthropogenitic fraction of the six heavy metals included in the data base (figure A.19) was generated with the operation sum list, processing all records coded as anthropogenic fraction, heavy metals, 1980. The sum list operation optionally generates three types of sums: total value, mean value or weighted sum. The record identifying the number of metals for which the ratio between calculated and lethal concentrations, applying a safety factor of 100, was greater than 0.0075 (figure A.20) was generated with the operation unit list. An example were aggregate ecosystem characteristics are related to activities is shown in figure A.21. This figure shows the number of spawning fish species in each grid cell were actual or potential off shore mining activities occur or might be expected. This record was generated in two steps. Firstly a record was generated containing a value 1 for each grid cell were the recoverable reserves of gas resp. oil exceeded 0.1 (operation: unit - see section A.3.4). Secondly the product of this record and the record with the total number of spawning species was calculated. Using the operation cross (see section A.3.4) would result in a comparable record, for instance in a map indicating all grid cells where the recoverable oil or gas reserve exceed a value X_1 and the total number of spawning species exceeds a value X_2.

Although these kind of maps contribute to the insight in spatial relations between the various characteristics of the area, they have to be aggregated one step further for the purpose of evaluating management strategies. This aggregation mainly consists of calculating total sums or areas. Some examples of these type of operations will be given here. Table A.4 shows the total area were the value of the number of spawning species (see figure A.12) falls within certain ranges. In addition the areas are given for each exclusive economic zone. Table A.5 shows the total oil discharge associated to deballasting and tank cleaning operations (see figure A.17) in the different zones. Tables A.6 and A.7 give areas for ranges of the mean anthropogenic fractions (see figure A.18) resp. areas in which the relation between calculated and lethal concentrations exceed the value 0.0075 (see figure A.19 and A.20) for a specific number of metals. In table A.7 also the changes in areas are indicated when comparing the 1980 and 1990 situation, thus enabling an evaluation of the management strategie resulting in the 1990 situation (in this case changing sources in or via the Netherlands only). As the presented relation between calculated and lethal concentrations implicitly reflects both water quality and potential damage to the ecosystem, these changes in areas could be used as a proxy for the criteria reflecting an intrinsic "natural value" and/or an economic value related to fishing activities. It is evident that other combinations would be suitable also. In table A.8 the areas are shown for which both the number of metals exceeding the 0.0075 ratio and the number of spawning species fall within certain ranges. In this case the potential effect of a given distribution of ambient water quality is being related to a more specific, vulnerable, class of biotic ecosystem characteristics. The evaluation would then be based on comparing changes in areas over the 1980-1990 period for different 1990 water quality scenarios, each due to a specific set of managerial actions. The approximation could become still more specific if the aggregate for spawning activities was based on a weighted sum, using the relative contribution of each fish species to the value of the total catch as weights.

A final example of the possibilities of COWADAT is given in table A.9. Here the information included in the database is presented for 3 different locations (immediate coastal zone at Rotterdam, German Bight, and central southern North Sea). When locations or zones for starting new activities or zone specific regulations for activities are selected, the information included for potential locations could thus be retrieved. The selection as such could be carried out with COWADAT by repeating the unit, cross and other operations on all records containing information on variables reflecting selection criteria.

FILE: R2000 ZMEER3 A WATERLOOPKUNDIG LABORATORIUM DELFT PAGE 001

LAST UPDATE 29/04/85 TEST W&M FIRST AVAILABLE RECORD 115 FIRTS TEMPORARY RECORD 187

2	26/04/84	13:25:41	01.01.01.01.00	VC	60*117	7020	02	------	COASTDEFINITION, NORTHERN PART	GENERATED AT INIT.	
3	26/04/84	13:25:41	01.01.01.02.00	VC	60*117	7020	02	------	COASTDEFINITION, SOUTHERN PART	GENERATED AT INIT.	
4	26/04/84	13:25:41	01.01.02.01.00	VR	60* 15	900	02	KM**2	COASTAL GRIDCELLNRS., AREA AND FRACTION	GENERATED AT INIT.	
5	28/01/85	17:03:08	01.01.02.02.00	VR	60* 5	300	02	KM**2	COASTAL GRIDCELLNRS., AREA AND FRACTION	GENERATED AT INIT.	
6	01/10/84	17:44:35	01.02.01.01.00	VR	60* 39	2340	02	M	MEAN DEPTH, COARSE GRID	ESTFLO/GENO	
7	06/03/85	17:58:30	01.02.01.02.00	VR	60*117	7020	02	M	MEAN DEPTH FINE GRID	EXTERN ESTFLO	
8	01/10/84	17:58:17	01.02.02.01.00	VR	60* 39	2340	02	KM**3	VOLUME, COARSE GRID	CALCULATED FROM 4 AND 6	
9	06/03/85	17:58:30	01.02.02.02.00	VR	60*117	7020	02	KM**3	VOLUME FINE GRID	EXTERN ESTFLO	
10	11/03/85	14:46:06	01.02.02.03.00	VR	60*117	7020	02	KM**3	VOL. FINE GRID CALCULATED	CGRD 8	
11	29/04/85	TEST W&M	01.03.01.00.00	VR	60* 39	2340	1	8 INT	SEDIMENTTYPE, COARSE	EXTERN MAFF	
12	06/03/85	17:25:04	02.01.01.00.00	VR	60*117	7020	02	UG/L	CADMIUM 1980 *10	EXTERN WQ-MODEL	
13	06/03/85	17:32:45	02.01.02.00.00	VR	60*117	7020	02	UG/L	CADMIUM 1990 *10	EXTERN WQ-MODEL	
14	06/03/85	17:32:45	02.02.01.00.00	VR	60*117	7020	02	UG/L	MERCURY 1980 *100	EXTERN WQ-MODEL	
15	06/03/85	17:32:45	02.02.02.00.00	VR	60*117	7020	02	UG/L	MERCURY 1990 *100	EXTERN WQ-MODEL	
16	06/03/85	17:32:45	02.03.01.00.00	VR	60*117	7020	02	UG/L	COPPER 1980	EXTERN WQ-MODEL	
17	06/03/85	17:32:45	02.03.02.00.00	VR	60*117	7020	02	UG/L	COPPER 1990	EXTERN WQ-MODEL	
18	06/03/85	17:39:07	02.04.01.00.00	VR	60*117	7020	02	UG/L	CHROME 1980	EXTERN WQ-MODEL	
19	06/03/85	17:39:07	02.04.02.00.00	VR	60*117	7020	02	UG/L	CHROME 1990	EXTERN WQ-MODEL	
20	06/03/85	17:39:07	02.05.01.00.00	VR	60*117	7020	02	UG/L	LEAD 1980	EXTERN WQ-MODEL	
21	06/03/85	17:39:07	02.05.02.00.00	VR	60*117	7020	02	UG/L	LEAD 1990	EXTERN WQ-MODEL	
22	06/03/85	17:39:07	02.06.01.00.00	VR	60*117	7020	02	UG/L	ZINC 1980	EXTERN WQ-MODEL	
23	06/03/85	17:45:31	02.06.02.00.00	VR	60*117	7020	02	UG/L	ZINC 1990	EXTERN WQ-MODEL	
24	06/03/85	17:45:31	02.07.01.00.00	VR	60*117	7020	02	UG/L	TOT-N 1980	EXTERN WQ-MODEL	
25	06/03/85	17:45:31	02.07.02.00.00	VR	60*117	7020	02	UG/L	TOT-N 1990	EXTERN WQ-MODEL	
26	06/03/85	17:45:31	02.08.01.00.00	VR	60*117	7020	02	UG/L	TOT-P 1980 *10	EXTERN WQ-MODEL	
27	06/03/85	17:45:31	02.08.02.00.00	VR	60*117	7020	02	UG/L	TOT-P 1990 *10	EXTERN WQ-MODEL	
28	03/10/84	14:38:49	03.03.01.04.00	VR	60* 39	2340	02	1 INT	SHRIMP, ADULTS	EXTERN MAFF	
29	08/10/84	16:05:53	03.03.02.04.00	VR	60* 39	2340	02	1 INT	NEPHROPS, ADULTS	EXTERN MAFF	
30	08/10/84	16:04:47	03.04.01.01.00	VR	60* 39	2340	02	2 INT	POUT, SPAWNING, 1: MINOR, 2: MAIN	EXTERN MAFF	
31	08/10/84	16:03:15	03.04.01.04.00	VR	60* 39	2340	02	2 INT	POUT, ADULTS, 1: MINOR, 2: MAIN	EXTERN MAFF	
32	01/10/84	17:48:33	03.04.02.01.00	VR	60* 39	2340	02	1 INT	BL. WHITING, SPAWNING	EXTERN MAFF	
33	01/10/84	17:49:25	03.04.02.03.00	VR	60* 39	2340	02	2 INT	BL. WHITING, ADULTS 1: MINOR, 2: MAIN	EXTERN MAFF	
34	08/10/84	10:21:57	03.04.02.04.00	VR	60* 39	2340	02	1 INT	BL. WHITING, FISHING AREAS	EXTERN MAFF	
35	08/10/84	16:10:20	03.04.03.01.00	VR	60* 39	2340	02	1 INT	HERRING, SPAWNING	EXTERN MAFF	
36	08/10/04	16:00:18	03.04.03.02.00	VR	60* 39	2340	02	1 INT	HERRING, NURSERIES	EXTERN MAFF	
37	01/10/84	17:48:05	03.04.04.01.00	VR	60* 39	2340	02	2 INT	COD, SPAWNING 1: MINOR, 2: MAIN	EXTERN MAFF	
38	08/10/84	15:58:30	03.04.04.04.00	VR	60* 39	2340	02	1 INT	COD, ADULTS	EXTERN MAFF	
39	01/10/84	17:47:04	03.04.05.01.00	VR	60* 39	2340	02	1 INT	GREEN COD, SPAWNING	EXTERN MAFF	
40	10/10/84	10:34:09	03.04.05.04.00	VR	60* 39	2340	02	1 INT	GREEN COD, ADULTS	EXTERN MAFF	
41	08/10/84	10:37:05	03.04.06.01.00	VR	60* 39	2340	02	2 INT	MACKEREL, SPAWNING 1: MINOR, 2: MAIN	EXTERN MAFF	
42	08/10/84	10:37:44	03.04.06.04.00	VR	60* 39	2340	02	2 INT	MACKEREL, ADULTS 1: MINOR, 2: MAIN	EXTERN MAFF	
43	08/10/84	10:38:21	03.04.07.01.00	VR	60* 39	2340	02	1 INT	HADDOCK, SPAWNING	EXTERN MAFF	
44	11/10/84	09:21:39	03.04.07.04.00	VR	60* 39	2340	02	1 INT	HADDOCK, ADULTS	EXTERN MAFF	
45	10/10/84	10:39:12	03.04.08.01.00	VR	60* 39	2340	02	2 INT	PLAICE, SPAWNING 1: MINOR, 2: MAIN	EXTERN MAFF	
46	10/10/84	10:41:56	03.04.08.04.00	VR	60* 39	2340	02	1 INT	PLAICE, ADULTS	EXTERN MAFF	
47	10/10/84	10:44:10	03.04.09.04.00	VR	60* 39	2340	02	2 INT	SMELT, ADULTS 1: MINOR, 2: MAIN	EXTERN MAFF	
48	11/10/84	09:20:28	03.04.10.01.00	VR	60* 39	2340	02	1 INT	SPRAT, SPAWNING	EXTERN MAFF	
49	10/10/84	10:45:33	03.04.10.04.00	VR	60* 39	2340	02	2 INT	SPRAT, ADULTS 1: MINOR, 2: MAIN	EXTERN MAFF	
50	10/10/84	10:46:45	03.04.11.01.00	VR	60* 39	2340	02	1 INT	SOLE, SPAWNING	EXTERN MAFF	
51	10/10/84	10:47:53	03.04.11.02.00	VR	60* 39	2340	02	1 INT	SOLE, NURSERIES	EXTERN MAFF	
52	10/10/84	10:49:01	03.04.11.04.00	VR	60* 39	2340	02	2 INT	SOLE, ADULTS 1: MINOR, 2: MAIN	EXTERN MAFF	
53	08/10/84	10:58:11	03.04.12.01.00	VR	60* 39	2340	02	1 INT	WHITING, SPAWNING	EXTERN MAFF	
54	10/10/84	10:50:10	03.04.12.04.00	VR	60* 39	2340	02	1 INT	WHITING, ADULTS	EXTERN MAFF	
55	29/04/85	TEST W&M	03.04.99.01.01	VI	60* 39	2340	02	(--)	NUMBER OF SPAWNING SPECIES	UNTL	
56	08/11/84	12:55:16	03.04.99.01.02	VI	60* 39	2340	02	9 INT	MASK OF SUM OF SPAWNING SPECIES	MASK 182	
57	29/04/85	TEST W&M	03.04.99.01.03	VI	60*117	7020	2	(--)	NUMBER OF SPAWNERS, FINE GRID	CGRD 55	
58	29/04/85	TEST W&M	03.04.99.01.04	VI	60* 39	2340	02	(--)	NUMBER SPAWNERS AT OIL/GAS-EXPL. SITES	PRODS5 186	
59	29/04/85	TEST W&M	03.04.99.04.01	VI	60* 39	2340	02	(--)	NUMBER OF ADULTS	UNTL	
60	30/10/84	10:42:54	03.04.99.04.02	VI	60* 39	2340	02	9 INT	MASK OF SUM OF ADULTS	MASK 183	
61	17/10/84	12:38:28	04.01.01.01.00	VR	60* 39	2340	02	E9 M3	RECOVERABLE GASRESERVE 1980	OFFSHORE MODEL	
62	17/10/84	12:38:28	04.01.01.02.00	VR	60* 39	2340	02	E9 M3	GAS PRODUCTION 1980	OFFSHORE MODEL	
63	24/10/84	16:26:16	04.01.02.01.00	VR	60* 39	2340	02	E6TON	RECOVERABLE OILRESERVE 1980	OFFSHORE MODEL	
64	25/10/84	09:16:05	04.01.02.02.00	VR	60* 39	2340	02	E6TON	OIL PRODUCTION 1980	OFFSHORE MODEL	
65	15/03/85	16:58:59	04.02.01.01.00	VR	60* 39	2340	02	10**2	CHEMICAL TANKERS, MOVES PER GRID	EXTERN SHIPMOD	
66	15/03/85	16:58:59	04.02.01.02.00	VR	60* 39	2340	02	10**2	LPG/LNG TANKERS, MOVES PER GRID	EXTERN SHIPMOD	
67	15/03/85	16:58:59	04.02.01.03.00	VR	60* 39	2340	02	10**2	OIL TANKERS, MOVES PER GRID	EXTERN SHIPMOD	
68	15/03/85	16:58:59	04.02.01.04.00	VR	60* 39	2340	02	10**2	REST ROUTEBOUND TRAFFIC, MOVES PER GRID	EXTERN SHIPMOD	
69	15/03/85	16:58:59	04.02.01.05.00	VR	60* 39	2340	02	10**2	ALL SHIPS, MOVES PER GRID	EXTERN SHIPMOD	
70	15/03/85	16:58:59	04.02.02.01.00	VR	60* 39	2340	02	E7TKM	CHEMICAL TANKERS, TONKM	EXTERN SHIPMOD	
71	15/03/85	16:58:59	04.02.02.02.00	VR	60* 39	2340	02	E7TKM	LPG/LNG TANKERS, TONKM	EXTERN SHIPMOD	
72	15/03/85	16:58:59	04.02.02.03.01	VR	60* 39	2340	02	E7TKM	OILTANKERS LT 3.000 TON, TONKM	EXTERN SHIPMOD	
73	15/03/85	16:58:59	04.02.02.03.02	VR	60* 39	2340	02	E7TKM	OILTANKERS 3.000-30.000 TON, TONKM	EXTERN SHIPMOD	
74	15/03/85	16:58:59	04.02.02.03.03	VR	60* 39	2340	02	E7TKM	OILTANKERS GT 3.0000 TON, TONKM	EXTERN SHIPMOD	
75	15/03/85	16:58:59	04.02.02.04.01	VR	60* 39	2340	02	E7TKM	REST ROUTEBOUND LT 3.000 TON, TONKM	EXTERN SHIPMOD	
76	15/03/85	16:58:59	04.02.02.04.02	VR	60* 39	2340	02	E7TKM	REST ROUTEBOUND 3.000-30.000 TON, TONKM	EXTERN SHIPMOD	
77	15/03/85	16:58:59	04.02.02.04.03	VR	60* 39	2340	02	E7TKM	REST ROUTEBOUND GT 30.000 TON, TONKM	EXTERN SHIPMOD	
78	29/04/85	TEST W&M	05.03.01.00.00	VR	60* 39	2340	02	6 INT	DUTCHFLEET FISHINGINTENSITY 1980	EXTERN RIVO	
79	23/04/85	TEST W&M	05.03.02.01.00	VR	60* 39	2340	02	6 INT	DUTCHFLEET FISHINGINT. PELAGIC, 1980	EXTERN RIVO	
80	23/04/85	TEST W&M	05.03.02.02.00	VR	60* 39	2340	02	6 INT	DUTCHFLEET FISHINGINT. DEMERSAL, 1980	EXTERN RIVO	
81	23/04/85	TEST W&M	06.01.01.00.00	VI	60* 39	2340	02	(--)	MASK CONT PLAT COARSE GRID	MASK OF 184	
82	29 04 85	TEST W&M	06.01.02.00.00	VI	60*117	7020	02	(--)	MASK CONT PLAT FINE GRID	MASK OF 185	
83	23/04/85	TEST W&M	06.04.02.01.00	VR	60* 39	2340	02	1 INT	MARPOL 12-MILE ZONE	EXTERN	
84	23/04/85	TEST W&M	06.04.02.02.00	VR	60* 39	2340	02	1 INT	MARPOL 50-MILE ZONE	EXTERN	
85	15/03/85	16:58:59	07.04.02.05.01	VR	60* 39	2340	02	TON	OILDISCH. BILGE CASE1	EXTERN SHIPMOD	
86	15/03/85	16:58:59	07.04.02.05.02	VR	60* 39	2340	02	TON	OILDISCH. BILGE CASE2	EXTERN SHIPMOD	
87	15/03/85	16:58:59	07.04.02.05.03	VR	60* 39	2340	02	TON	OILDISCH. BILGE CASE3	EXTERN SHIPMOD	
88	15/03/85	16:58:59	07.04.02.03.01	VR	60* 39	2340	02	TON	OILDISCH. BALLAST/WASH CASE1	EXTERN SHIPMOD	
89	15/03/85	16:58:59	07.04.02.03.02	VR	60* 39	2340	02	TON	OILDISCH. BALLAST/WASH CASE2	EXTERN SHIPMOD	
90	15/03/85	16:58:59	07.04.02.03.03	VR	60* 39	2340	02	TON	OILDISCH. BALLAST/WASH CASE3	EXTERN SHIPMOD	
91	18/03/85	17:42:47	08.01.02.01.01	VR	60*117	7020	1	(--)	RISCINDEX CADMIUM 1980	RISC 12	
92	18/03/85	17:42:47	08.01.02.01.02	VR	60*117	7020	1	(--)	RISCINDEX CADMIUM 1990	RISC 13	
93	18/03/85	17:42:47	08.01.02.02.01	VR	60*117	7020	1	(--)	RISCINDEX MERCURY 1980	RISC 14	
94	18/03/85	17:55:00	08.01.02.02.02	VR	60*117	7020	1	(--)	RISCINDEX MERCURY 1990	RISC 15	
95	18/03/85	17:55:00	08.01.02.03.01	VR	60*117	7020	1	(--)	RISCINDEX COPPER 1980	RISC 16	
96	18/03/85	17:55:00	08.01.02.03.02	VR	60*117	7020	1	(--)	RISCINDEX COPPER 1990	RISC 17	
97	18/03/85	17:55:00	08.01.02.04.01	VR	60*117	7020	1	(--)	RISCINDEX CHROME 1980	RISC 18	
98	18/03/85	17:55:00	08.01.02.04.02	VR	60*117	7020	1	(--)	RISCINDEX CHROME 1990 1)	RISC 19	
99	18/03/85	17:55:00	08.01.02.05.01	VR	60*117	7020	1	(--)	RISCINDEX LEAD 1980	RISC 20	
100	18/03/85	17:55:00	08.01.02.05.02	VR	60*117	7020	1	(--)	RISCINDEX LEAD 1990	RISC 21	
101	18/03/85	17:55:00	08.01.02.06.01	VR	60*117	7020	1	(--)	RISCINDEX ZINC 1980	RISC 22	
102	18/03/85	17:55:00	08.01.02.06.02	VR	60*117	7020	1	(--)	RISCINDEX ZINC 1990	RISC 23	
103	29/04/85	TEST W&M	08.01.02.99.01	VI	60*117	7020	02	(--)	NUMBER METALS RISC-INDEX GT 0.75, 1980	UNTL	
104	29/04/85	TEST W&M	08.01.02.99.02	VI	60*117	7020	2	(--)	NUMBER METALS RISC-INDEX GT 0.75, 1990	UNTL	
105	06/03/85	17:51:45	08.02.01.01.01	VR	60*117	7020	02	(--)	ANTHR.INDEX CADMIUM 1980	EXTERN WQ-MODEL	
106	06/03/85	17:51:45	08.02.02.01.01	VR	60*117	7020	02	(--)	ANTHR.INDEX MERCURY 1980	EXTERN WQ-MODEL	
107	06/03/85	17:51:45	08.02.03.01.01	VR	60*117	7020	02	(--)	ANTHR.INDEX COPPER 1980	EXTERN WQ-MODEL	
108	06/03/85	17:51:45	08.02.04.01.01	VR	60*117	7020	02	(--)	ANTHR.INDEX CHROME 1980	EXTERN WQ-MODEL	
109	06/03/85	17:51:45	08.02.05.01.01	VR	60*117	7020	02	(--)	ANTHR.INDEX LEAD 1980	EXTERN WQ-MODEL	
110	06/03/85	17:58:30	08.02.06.01.01	VR	60*117	7020	02	(--)	ANTHR.INDEX ZINC 1980	EXTERN WQ-MODEL	
111	06/03/85	17:58:30	08.02.07.01.00	VR	60*117	7020	02	(--)	ANTHR.INDEX TOT-N 1980	EXTERN WQ-MODEL	
112	06/03/85	17:58:30	08.02.08.01.00	VR	60*117	7020	02	(--)	ANTHR.INDEX TOT-P 1980	EXTERN WQ-MODEL	
113	29/04/85	TEST W&M	08.02.99.01.01	VI	60*117	7020	02	(--)	MEAN ANTHR.INDEX H.M. 1980	SUML	
114	29/04/85	TEST W&M	08.02.99.01.02	VI	60*117	7020	02	(--)	NUMBER OF METALS ANTHR.-INDEX GT 0.6	UNTL	
....											
....											
....											
181	05/03/85	16:53:45	09.07.02.00.00	VR	60*117	7020	1	--	SUM ANTR.INDEX, TOTAL SUM	SUML	TEMP
182	05/03/85	16:53:45	09.07.02.02.00	VR	60*117	7020	1	--	SUM ANTR.INDEX, MEAN VALUE	SUML	TEMP
183	04/03/85	19:15:00	09.02.00.00.00	VR	60*117	7020	1	--	SUM ANTR.INDEX ALL COMPONENTS	SUML	TEMP
184	23/04/85	TEST W&M	06.01.01.00.00	VR	60* 39	2340	1	(--)	CP COARSE	EXTE	TEMP
185	29/04/85	TEST W&M	06.01.02.00.00	VI	60*117	7020	1	(--)	CP FINE	CGRD 184	TEMP
186	29/04/85	TEST W&M	04.01.99.01.00	VI	60* 39	2340	2	(--)	OIL OR GASRESERVE GT 0.1	UNIT 36 41	TEMP

RECORDNUMBER

1) RISCINDEX represents the ratio between calculated and lethal concentration under laboratory conditions, applying a safety factor 100.

Table A.3 Description file DATDIC.

AT SESSION 29/04/85 TEST W&M AREAS WERE CALCULATED ACCORDING TO MASK 43, EXCL. ECONOMIC ZONE'S COARSE GRID
FOR RECORD 39 CONTAINING NUMBER OF SPAWNING SPECIES (--).

THE TOTAL AREAS -KM**2- FOR EACH INTERVAL ARE:

EXCL. ECONOMIC ZONE	SPAWNERS: INT. NR. / VALUE	1 / 0	2 / 1	3 / 2	4 / 3	5 / 4	6 / 5	7 / 6	8 / 0	9 / 0	TOTAL AREA
1 GREAT BRIT.	AREA	6619.8	20502.3	32841.5	47703.3	77127.8	26586.1	31537.0	0.0	0.0	242904.2
	PERCENT	1.3	4.1	6.5	9.4	15.3	5.3	6.2	0.0	0.0	48.0
2 NORWAY	AREA	34.2	10172.1	43768.5	21492.2	22336.7	9482.0	6114.8	0.0	0.0	113396.6
	PERCENT	0.0	2.0	8.7	4.2	4.4	1.9	1.2	0.0	0.0	22.4
3 DENMARK	AREA	972.3	4186.2	9488.9	3806.0	24475.2	3842.6	0.0	0.0	0.0	46771.3
	PERCENT	0.2	0.8	1.9	0.8	4.8	0.8	0.0	0.0	0.0	9.2
4 GERMANY	AREA	2718.7	3451.0	5168.5	4031.5	23285.5	1556.0	0.0	0.0	0.0	40211.1
	PERCENT	0.5	0.7	1.0	0.8	4.6	0.3	0.0	0.0	0.0	8.0
5 NETHERLANDS	AREA	0.0	0.0	3049.3	13239.9	33480.4	7413.4	0.0	0.0	0.0	57182.9
	PERCENT	0.0	0.0	0.6	2.6	6.6	1.5	0.0	0.0	0.0	11.3
6 BELGIUM	AREA	0.0	545.9	1289.6	857.1	429.3	1707.9	424.6	0.0	0.0	5254.4
	PERCENT	0.0	0.1	0.3	0.2	0.1	0.3	0.1	0.0	0.0	1.0
TOTAL AREAS		10345.0	38857.5	95603.6	91127.9	181126.4	50587.8	38076.4	0.0	0.0	505702.3
PERCENT		2.0	7.7	18.9	18.0	35.8	10.0	7.5	0.0	0.0	

TOTAL AREAS 505702.3

observation: . total number of considered species is 12;
. for spatial distribution see figure A.12.

Table A.4 Areas in exclusive economic zones per total number of spawning species.

AT SESSION 29/04/85 TEST W&M A TOTAL SUM WAS CALCULATED ACCORDING TO
MASK 43, EXCL. ECONOMIC ZONE'S COARSE GRID
FOR RECORD 96 CONTAINING OILDISCHARGE BALLAST/WASH CASE1 (TON)

THE TOTAL VALUES FOR EACH INTERVAL ARE:

EXCL.	ECONOMIC ZONE	VALUE	PERCENTAGE
1	GREAT BRITTAIN	20712.82	30.6
2	NORWAY	3987.66	5.9
3	DENMARK	9968.54	14.7
4	GERMANY	8643.54	12.8
5	NETHERLANDS	21688.43	32.1
6	BELGIUM	2642.22	3.9
TOTAL VALUE		67642.44	

Table A.5 Oil discharged in economic zones due to deballasting and tank cleaning operations.

AT SESSION 29/04/85 TEST W&M AREAS WERE CALCULATED ACCORDING TO MASK 44. EXCL. ECONOMIC ZONE'S FINE GRID
FOR RECORD 75 CONTAINING MEAN ANTHR.-INDEX FOR 6 METALS 1980 (--)

THE TOTAL AREAS -KM**2- FOR EACH INTERVAL ARE:

ANTHR.-INDEX	INT. NR. VALUE	1 LT 0.3	2 0.3- 0.5	3 0.5- 0.6	4 0.6- 0.7	5 0.7- 0.8	6 GT 0.8	7	8	9	TOTAL AREA
EXCL. ECONOMIC ZONE											
1 GREAT BRIT.	AREA	4710.5	83126.9	16310.3	808.6	138.9	115.5	0.0	0.0	0.0	105202.5
	PERCENT	2.1	37.4	7.3	0.4	0.1	0.1	0.0	0.0	0.0	47.2
2 NORWAY	AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PERCENT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 DENMARK	AREA	0.0	12646.0	6047.1	0.0	0.0	0.0	0.0	0.0	0.0	18693.0
	PERCENT	0.0	5.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	8.4
4 GERMANY	AREA	0.0	21793.5	16013.4	67.1	0.0	0.0	0.0	0.0	0.0	37873.9
	PERCENT	0.0	9.8	7.2	0.0	0.0	0.0	0.0	0.0	0.0	17.0
5 NETHERLANDS	AREA	0.0	46506.4	6935.4	2604.3	888.5	0.0	0.0	0.0	0.0	56934.4
	PERCENT	0.0	20.9	3.1	1.2	0.4	0.0	0.0	0.0	0.0	25.6
6 BELGIUM	AREA	0.0	3901.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3901.0
	PERCENT	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
TOTAL AREAS		4710.5	167938.6	45305.9	3480.0	1027.4	115.5	0.0	0.0	0.0	222548.7
PERCENT		2.1	75.5	20.4	1.6	0.5	0.1	0.0	0.0	0.0	

TOTAL AREAS 222548.7

Table A.6 Areas where the average anthropogenic fraction for 6 heavy metals falls within the ranges indicated.

AT SESSION 29/04/85 TEST W&M AREAS WERE CALCULATED ACCORDING TO MASK 44. EXCL. ECONOMIC ZONE'S FINE GRID
FOR RECORD 77 CONTAINING NUMBER OF METALS WITH RISC-INDEX GT 0.75 1980

THE TOTAL AREAS -KM**2- FOR EACH INTERVAL ARE:

NUMBER OF METALS	INT. NR. VALUE	1 0	2 1	3 2	4 3	5 4	6 5	7 0	8 0	9 0	TOTAL AREA
EXCL. ECONOMIC ZONE											
1 GREAT BRIT.	AREA	0.0	87981.3	4360.7	11577.7	1174.5	115.5	0.0	0.0	0.0	105202.5
	PERCENT	0.0	39.6	2.0	5.2	0.5	0.1	0.0	0.0	0.0	47.2
2 NORWAY	AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	PERCENT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 DENMARK	AREA	0.0	6644.8	2386.2	9662.1	0.0	0.0	0.0	0.0	0.0	18693.0
	PERCENT	0.0	3.0	1.1	4.3	0.0	0.0	0.0	0.0	0.0	8.4
4 GERMANY	AREA	0.0	4872.8	5995.0	25797.7	1208.6	0.0	0.0	0.0	0.0	37873.9
	PERCENT	0.0	2.2	2.7	11.6	0.5	0.0	0.0	0.0	0.0	17.0
CHANGE '80-'90	AREA	0.0	+ 2039.2	+ 2658.4	- 4194.5	- 503.0	0.0	0.0	0.0	0.0	37873.9
	PERCENT	0.0	+ 0.9	+ 1.2	- 1.9	- 0.2	0.0	0.0	0.0	0.0	17.0
6 NETHERLANDS	AREA	0.0	36211.3	6350.4	12925.9	1362.8	84.4	0.0	0.0	0.0	56934.4
	PERCENT	0.0	16.3	2.9	5.8	0.6	0.0	0.0	0.0	0.0	25.6
CHANGE '80-'90	AREA	0.0	+ 2733.8	+ 819.1	- 2105.7	- 1362.8	- 84.4	0.0	0.0	0.0	56934.4
	PERCENT	0.0	+ 1.2	+ 0.3	- 0.9	- 0.6	- 0.0	0.0	0.0	0.0	25.6
7 BELGIUM	AREA	0.0	3901.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3901.0
	PERCENT	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
TOTAL AREAS		0.0	139588.4	19092.0	59963.2	3745.9	199.8	0.0	0.0	0.0	222548.7
PERCENT		0.0	62.7	8.6	26.9	1.7	0.1	0.0	0.0	0.0	

TOTAL AREAS 222548.7

Table A.7 Areas in which for the indicated number of heavy metals the ratios between calculated and lethal concentration exceeds the value of 0.0075

AT SESSION 29/04/85 TEST W&M AREAS WERE CALCULATED ACCORDING TO MASK 101. NUMBER OF SPAWNING SPECIES
FOR RECORD 77 CONTAINING NUMBER OF METALS WITH RISC-INDEX GT 0.75

THE TOTAL AREAS -KM**2- FOR EACH INTERVAL ARE:

NUMBER OF METALS	INT. NR. VALUE RECI	1 0	2 1	3 2	4 3	5 4	6 5	7 0	8 0	9 0	TOTAL AREA
NUMBER OF SPAWNING SPECIES											
1	AREA	0.0	1237.4	1173.8	3054.2	773.1	0.0	0.0	0.0	0.0	6238.4
	PERCENT	0.0	0.6	0.5	1.4	0.3	0.0	0.0	0.0	0.0	2.8
2	AREA	0.0	6413.8	537.8	10343.0	1161.4	115.5	0.0	0.0	0.0	18571.3
	PERCENT	0.0	2.9	0.2	4.6	0.5	0.1	0.0	0.0	0.0	8.3
3	AREA	0.0	12540.4	899.5	13301.1	1041.9	84.4	0.0	0.0	0.0	27867.0
	PERCENT	0.0	5.6	0.4	6.0	0.5	0.0	0.0	0.0	0.0	12.5
4	AREA	0.0	26275.2	2454.3	11942.3	560.3	0.0	0.0	0.0	0.0	41232.0
	PERCENT	0.0	11.8	1.1	5.4	0.3	0.0	0.0	0.0	0.0	18.5
5	AREA	0.0	74184.7	13187.2	20971.3	209.2	0.0	0.0	0.0	0.0	108537.5
	PERCENT	0.0	33.3	5.9	9.4	0.1	0.0	0.0	0.0	0.0	48.8
6	AREA	0.0	17264.7	839.6	351.7	0.0	0.0	0.0	0.0	0.0	18455.9
	PERCENT	0.0	7.8	0.4	0.2	0.0	0.0	0.0	0.0	0.0	8.3
7	AREA	0.0	1698.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1698.4
	PERCENT	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
TOTAL AREAS		0.0	139588.4	19092.0	59963.2	3745.9	199.8	0.0	0.0	0.0	222548.7
PERCENT		0.0	62.7	8.6	26.9	1.7	0.1	0.0	0.0	0.0	

TOTAL AREAS 222548.7

Table A.8 Areas per number of fish species and per number of heavy metals for which the ratio between calculated and lethal concentration exceeds the value of 0.0075

IN SESSION AT 29/04/85 TEST W&M THIS TABEL WAS GENERATED FOR LOCATION(S):

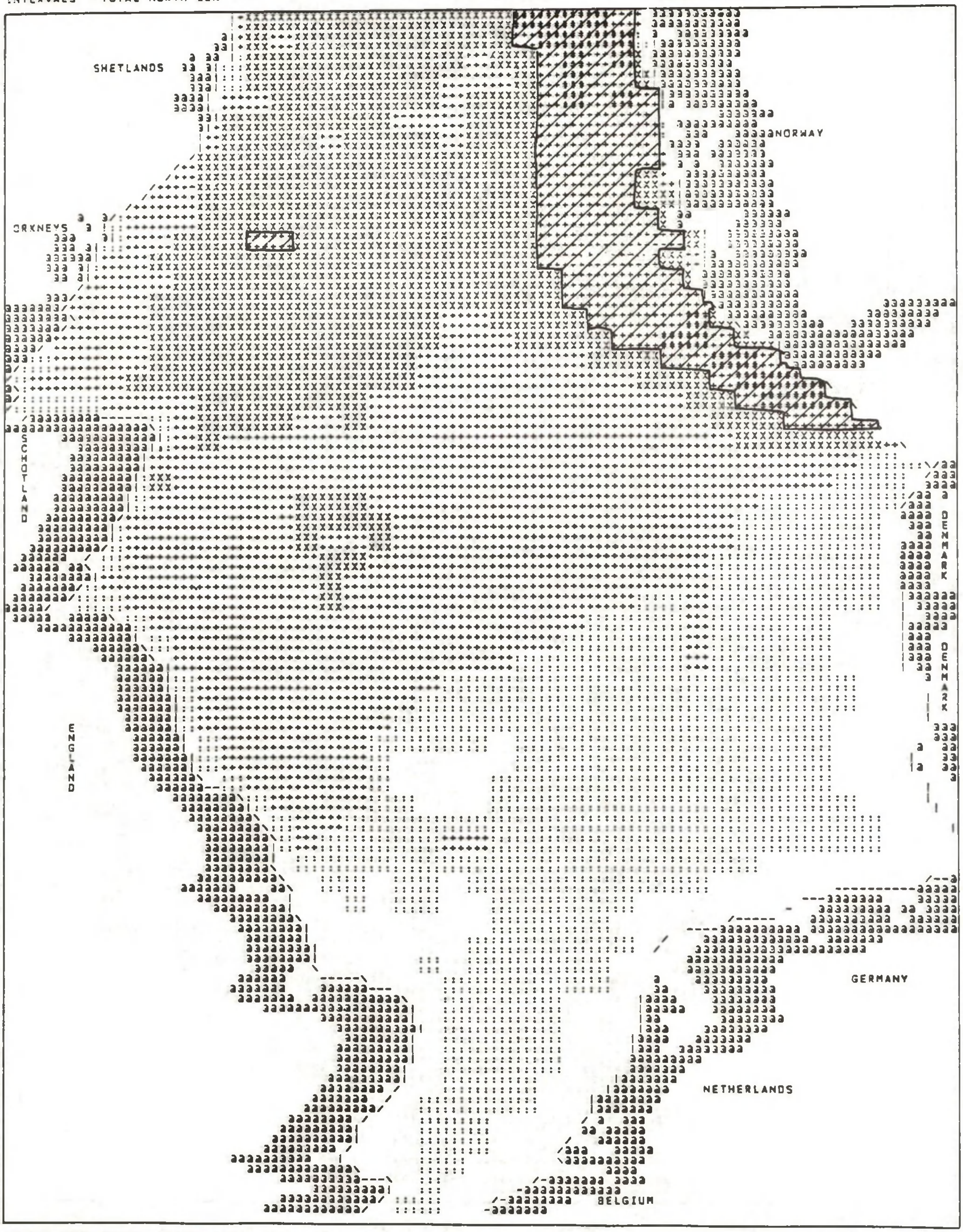
LOCATION NR. 1	Y-COORD. = 72	X-COORD. =	
LOCATION NR. 2	Y-COORD. = 113	X-COORD. =	
LOCATION NR. 3	Y-COORD. = 60	X-COORD. =	

ITEMDESCRIPTION	VALUE LOC.1	VALUE LOC.2	VALUE LOC.3
MEAN DEPTH, COARSE GRID	20.510	3.170	44.260
MEAN DEPTH, FINE GRID	19.910	5.000	45.350
VOLUME, COARSE GRID	8.640	1.280	17.880
VOLUME, FINE GRID	1.400	0.340	3.050
VOL. FINE GRID, CALCULATED	1.440	0.213	2.980
SEDIMENTTYPE, COARSE GRID	2.000	7.000	2.000
CADMIUM 1980 *10	0.285	0.181	0.032
CADMIUM 1990 *10	0.158	0.161	0.032
MERCURY 1980 *100	0.0401	0.0611	0.0044
MERCURY 1990 *100	0.0222	0.0580	0.0044
COPPER 1980	2.490	3.530	0.450
COPPER 1990	1.700	3.400	0.450
CHROME 1980	3.060	2.400	0.420
CHROME 1990	1.510	2.140	0.420
LEAD 1980	2.350	2.070	0.320
LEAD 1990	1.380	1.910	0.320
ZINC 1980	14.940	26.650	1.340
ZINC 1990	9.270	25.720	1.340
TOT-N 1980	1.120	2.070	0.150
TOT-N 1990	1.100	2.060	0.150
TOT-P 1980 *10	1.430	1.660	0.200
TOT-P 1990 *10	1.310	1.640	0.200
HERRING, NURSERIES	1.000	1.000	0.000
COD, SPAWNING 1: MINOR, 2: MAIN	1.000	0.000	2.000
COD, ADULTS	1.000	1.000	1.000
MACKEREL, SPAWNING 1: MINOR, 2: MAIN	1.000	0.000	2.000
PLAICE, ADULTS	1.000	1.000	1.000
SOLE, SPAWNING	1.000	0.000	0.000
SOLE, ADULTS 1: MINOR, 2: MAIN	2.000	2.000	2.000
WHITING, ADULTS	1.000	0.000	1.000
NUMBER OF SPAWNING SPECIES	3	0	4
NUMBER OF ADULTS	4	4	7
MASK OF SUM OF ADULTS	5	5	9
CHEMICAL TANKERS, MOVES PER GRID	38.450	0.410	0.000
LPG/LNG TANKERS, MOVES PER GRID	14.020	0.010	0.000
OIL TANKERS, MOVES PER GRID	87.080	1.630	0.000
REST ROUTEBOUND TRAFFIC, MOVES PER GRID	515.040	7.340	0.000
ALL SHIPS, MOVES PER GRID	654.590	9.390	0.000
CHEMICAL TANKERS, TONKM	23.011	0.049	0.000
LPG/LNG TANKERS, TONKM	7.374	0.001	0.000
OILTANKERS LT 3.000 TON, TONKM	8.142	0.090	0.000
OILTANKERS 3.000-30.000 TON, TONKM	96.809	0.065	0.000
OILTANKERS GT 3.0000 TON, TONKM	175.354	0.206	0.000
REST ROUTEBOUND LT 3.000 TON, TONKM	34.983	0.174	0.000
REST ROUTEBOUND 3.000-30.000 TON, TONKM	155.989	0.174	0.000
REST ROUTEBOUND GT 30.000 TON, TONKM	92.553	0.148	0.000
DUTCHFLEET FISHINGINTENSITY, 1980	6.000	1.000	2.000
DUTCHFLEET FISHINGINT. PELAGIC, 1980	6.000	1.000	1.000
DUTCHFLEET FISHINGINT. DEMERSAL, 1980	6.000	1.000	3.000
MASK CONT PLAT COARSE GRID	5	4	1
MASK CONT PLAT FINE GRID	5	4	1
MARPOL 12-MILE ZONE	1.000	1.000	0.000
MARPOL 50-MILE ZONE	1.000	1.000	0.000
OILDISCH. BILGE CASE1	0.526	0.012	0.000
OILDISCH. BILGE CASE2	0.271	0.000	0.000
OILDISCH. BILGE CASE3	13.320	0.661	0.000
OILDISCH. BALLAST/WASH CASE1	936.797	38.167	0.000
OILDISCH. BALLAST/WASH CASE2	55.963	2.283	0.000
RISCINDEX CADMIUM 1980	5.700	3.620	0.640
RISCINDEX CADMIUM 1990	3.160	3.220	0.640
RISCINDEX MERCURY 1980	4.010	6.110	0.440
RISCINDEX MERCURY 1990	2.220	5.800	0.440
RISCINDEX COPPER 1980	17.786	25.214	3.214
RISCINDEX COPPER 1990	12.143	24.286	3.214
RISCINDEX CHROME 1980	1.020	0.800	0.140
RISCINDEX CHROME 1990 1)	0.503	0.713	0.140
RISCINDEX LEAD 1980	0.691	0.609	0.094
RISCINDEX LEAD 1990	0.406	0.562	0.094
RISCINDEX ZINC 1980	0.060	0.107	0.005
RISCINDEX ZINC 1990	0.037	0.103	0.005
NUMBER OF METALS RISC-INDEX GT 0.75, 1980	4	4	1
NUMBER OF METALS RISC-INDEX GT 0.75, 1990	3	3	1
ANTHR.INDEX CADMIUM 1980	0.840	0.730	0.040
ANTHR.INDEX MERCURY 1980	0.720	0.720	0.200
ANTHR.INDEX COPPER 1980	0.610	0.620	0.140
ANTHR.INDEX CHROME 1980	0.590	0.400	0.060
ANTHR.INDEX LEAD 1980	0.610	0.290	0.220
ANTHR.INDEX ZINC 1980	0.740	0.770	0.140
ANTHR.INDEX TOT-N 1980	0.590	0.670	0.020
ANTHR.INDEX TOT-P 1980	0.710	0.690	0.020
MEAN ANTHR.-INDEX METALS, 1980	0.685	0.588	0.133
NUMBER OF METALS ANTHR.-INDEX GT 0.6	5	4	0

1) See note table A.3

Table A.9 Example of retreivables information from COWADAT

INTERVALS TOTAL NORTH SEA RUNDATE AND TIME 29/04/85 TEST W&M

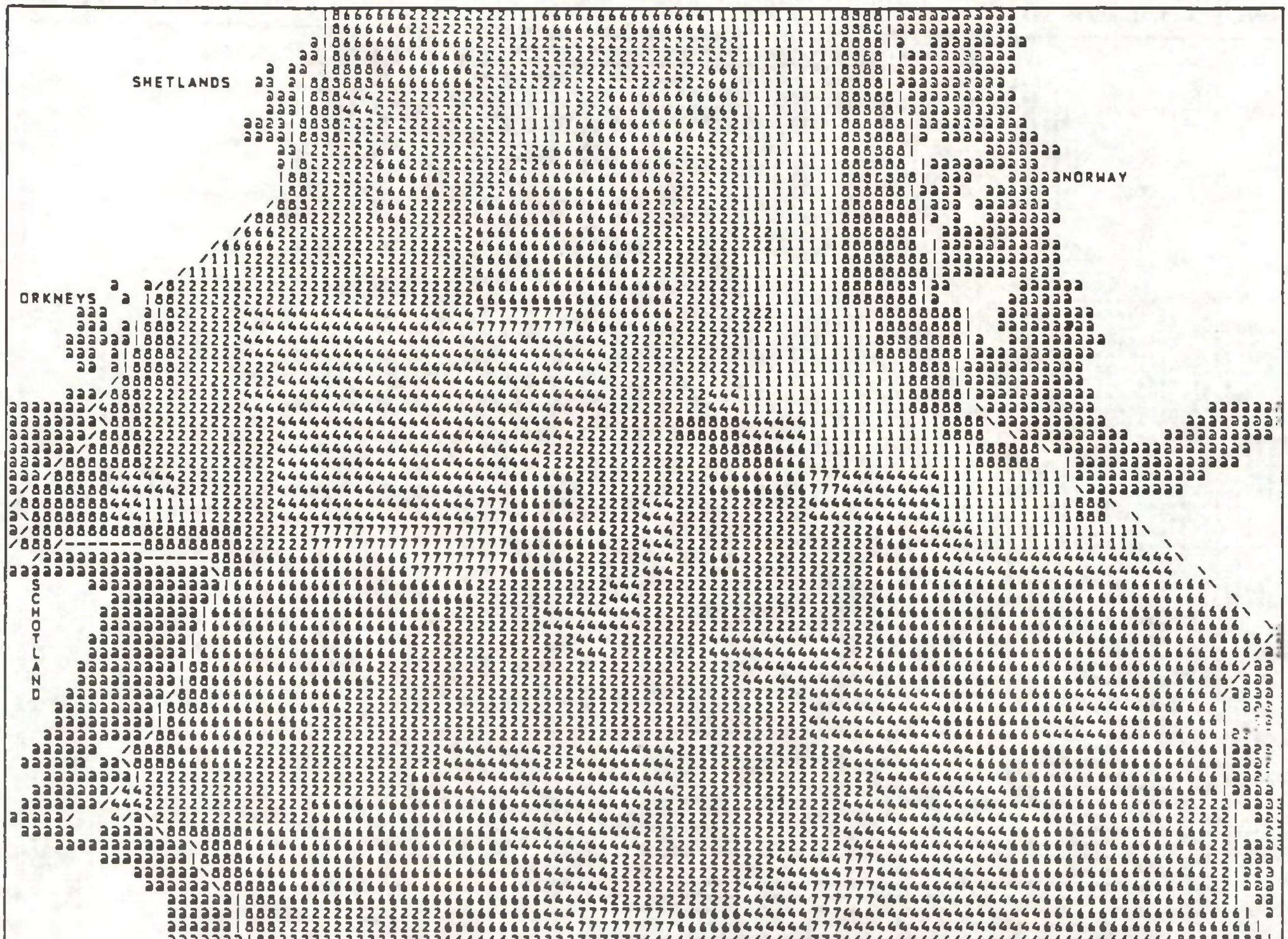


LEGEND MEAN DEPTH, COARSE GRID (M):

LESS THEN 25.00
:::::: 25.00 UP TO 50.00
+++++ 50.00 UP TO 100.00
XXXXX 100.00 UP TO 200.00
200.00 UP TO 300.00
MORE THEN 300.00

Figure A.5 Mean depth, interval representation, coarse grid.

OCCURENCES TOTAL NORTH SEA RUNDATE AND TIME 29/04/85 TEST W



LEGEND SEDIMENTTYPE, COARSE GRID (8 INT)

1: MUD	2: SAND	3: GRAVEL	4: MUD, SAND
5: MUD, GRAVEL	6: SAND, GRAVEL	7: MUD, SAND, GRAVEL	8: ROCK, SAND, GRAVEL

Figure A.6 Sediment type, integer representation, coarse grid.

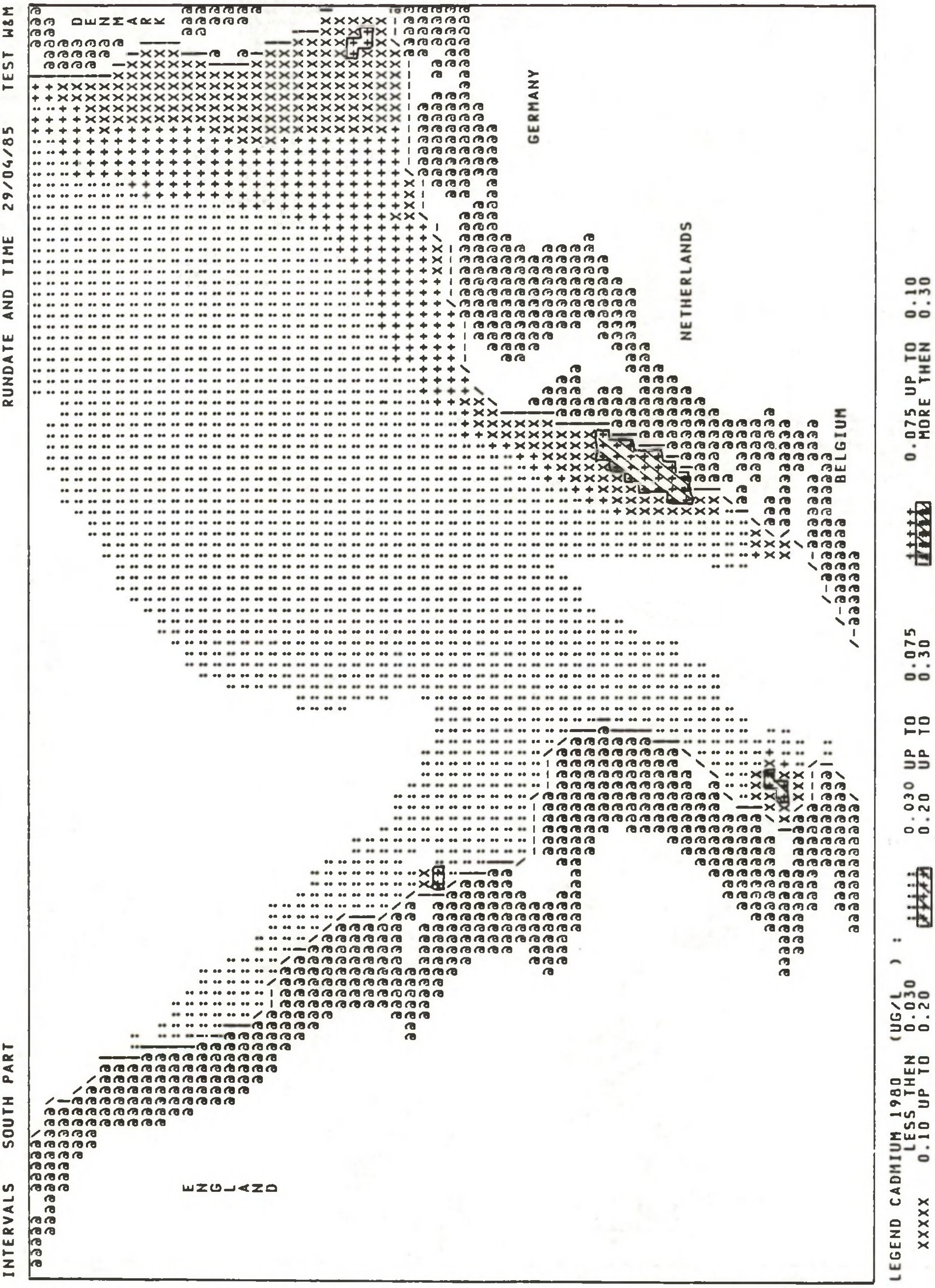


Figure A.7 Cadmium 1980, fine grid.

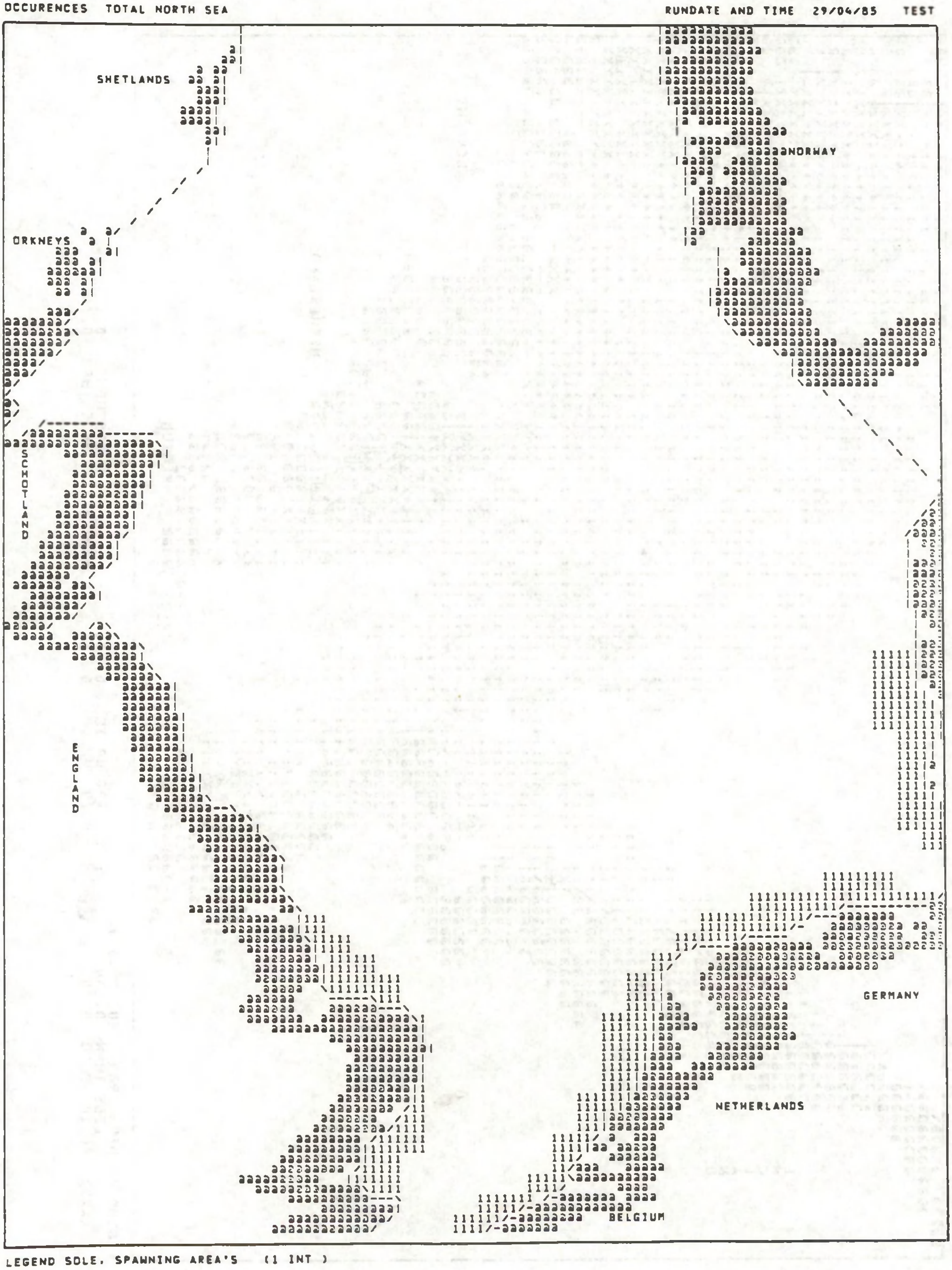
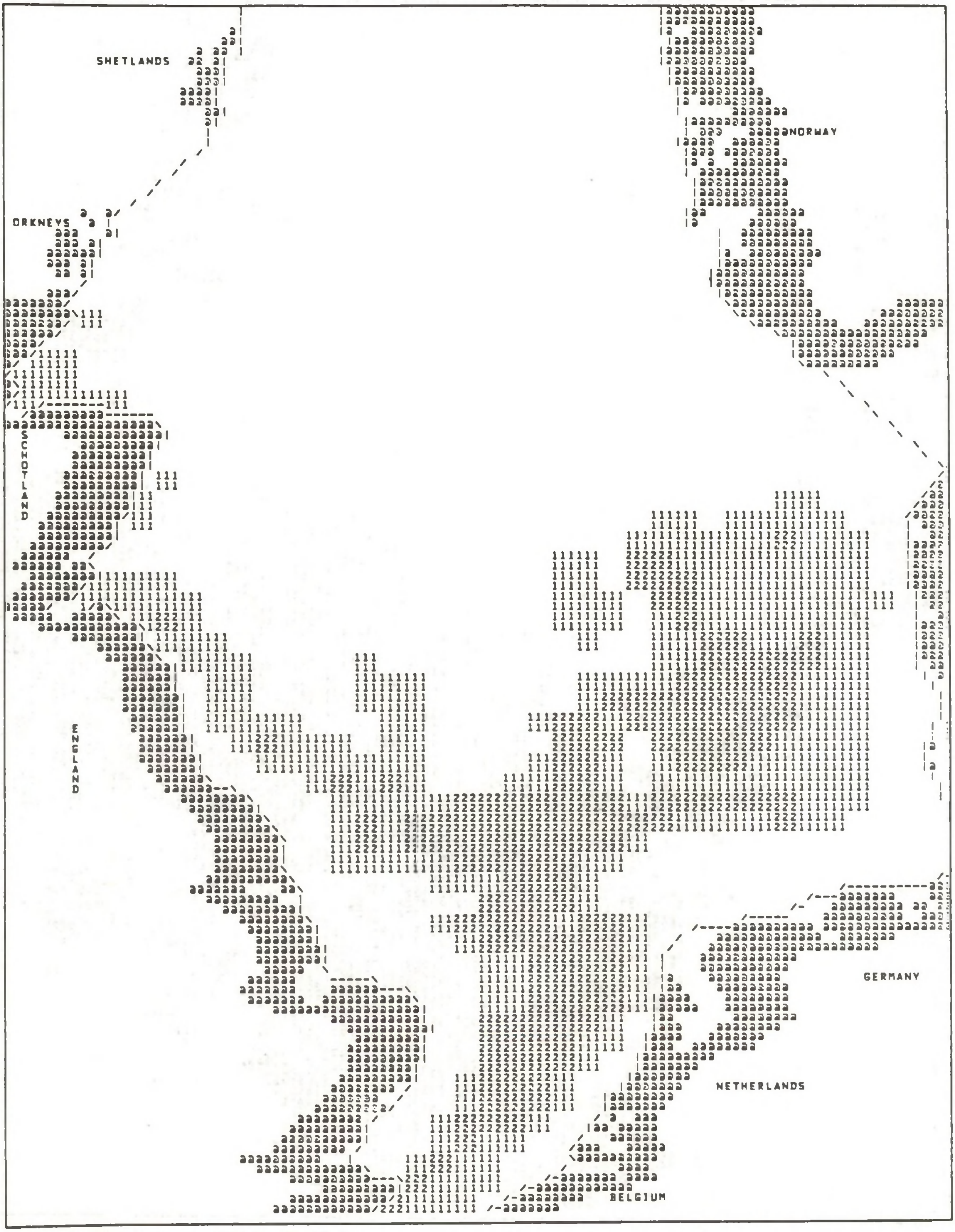


Figure A.8 Sole, spawning areas

OCCURENCES TOTAL NORTH SEA RUNDATE AND TIME 29/04/85 TEST



LEGEND PLAICE, SPAWNING AREA'S (2 INT):
1: MINOR 2: MAIN

Figure A.9 Plaice, spawning areas

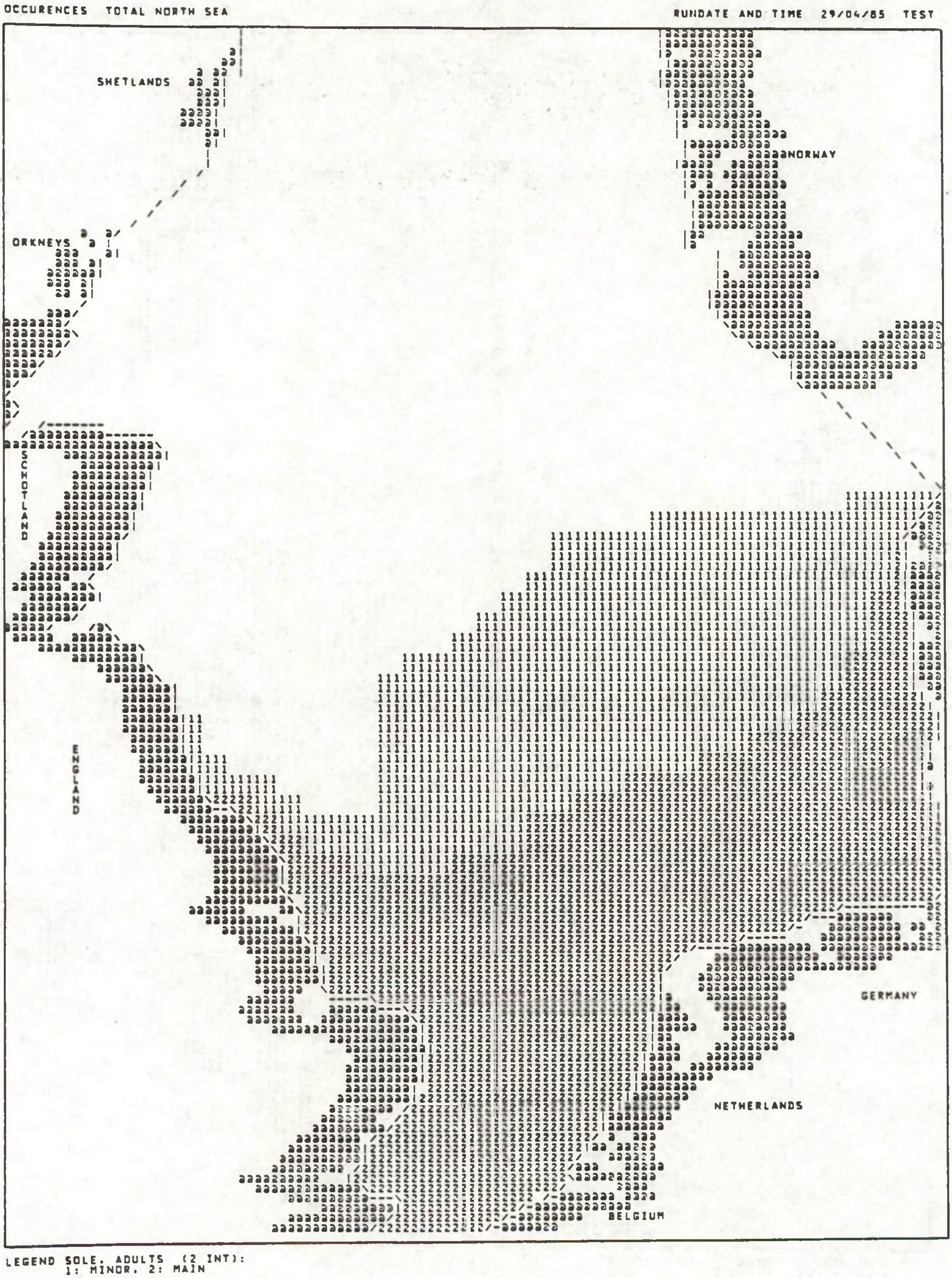


Figure A.10 Sole, fishing areas

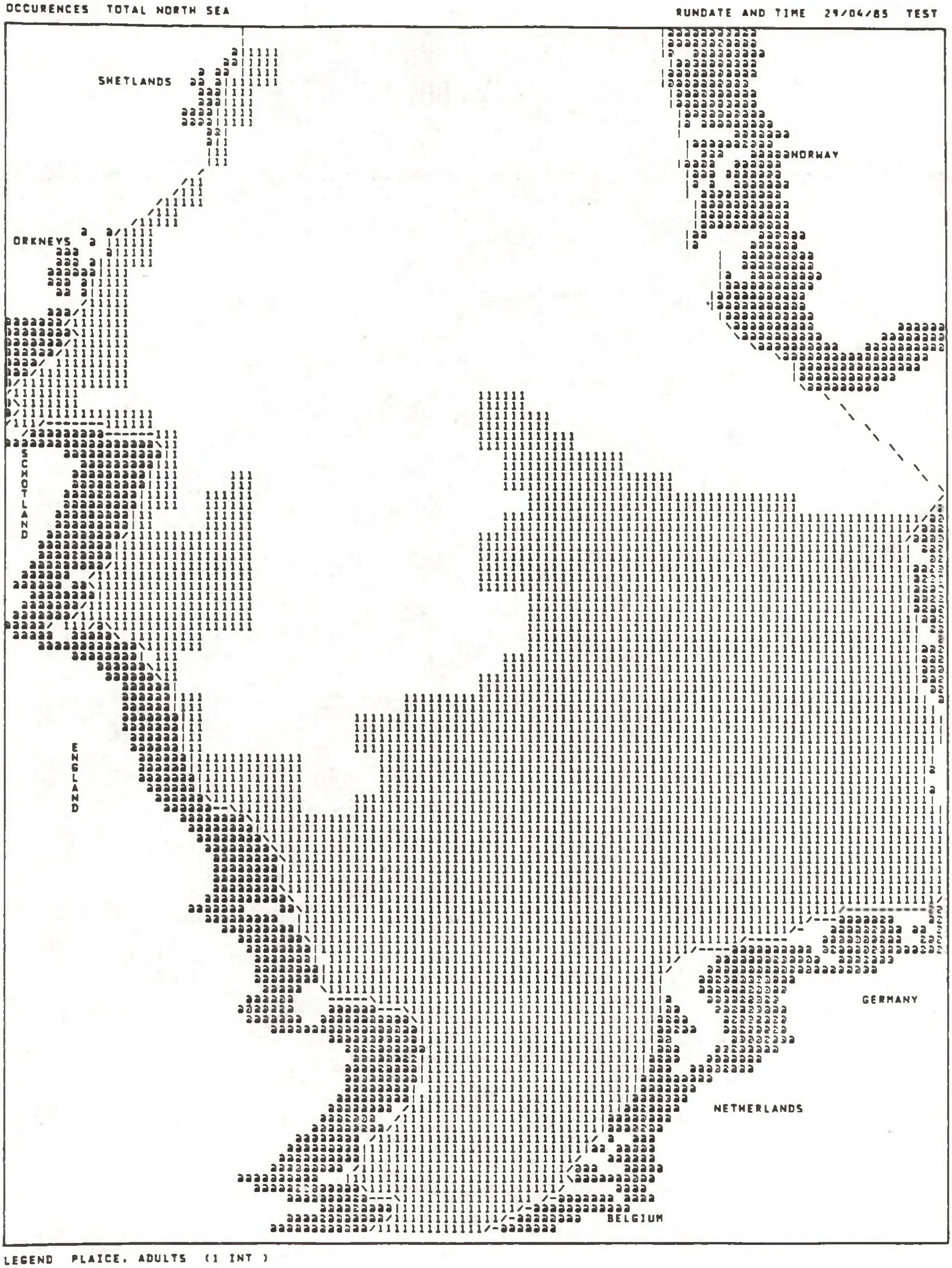
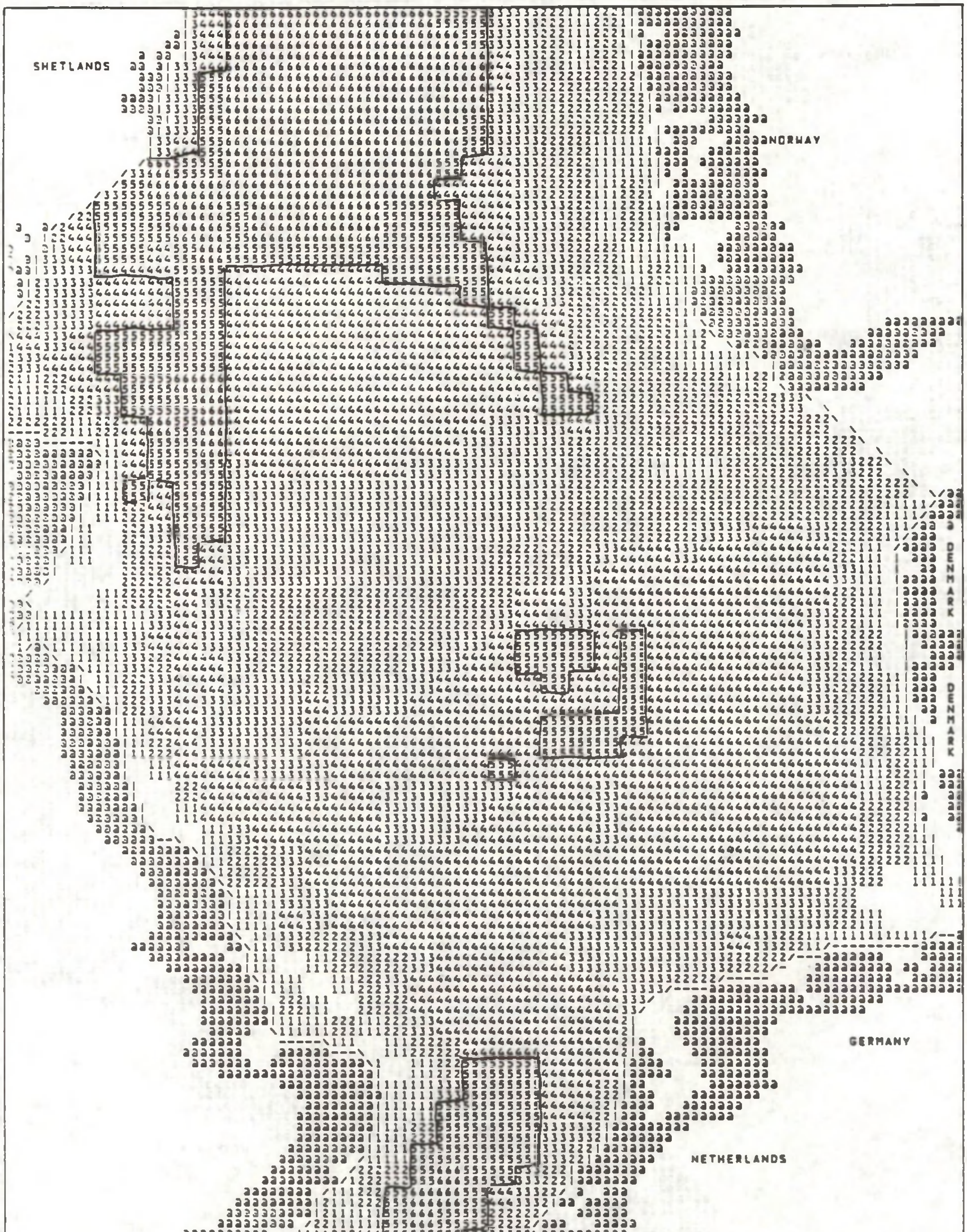


Figure A.11 Plaice, fishing areas

ES TOTAL NORTH SEA RUNDATE AND TIME 29/04/85 TEST W&M

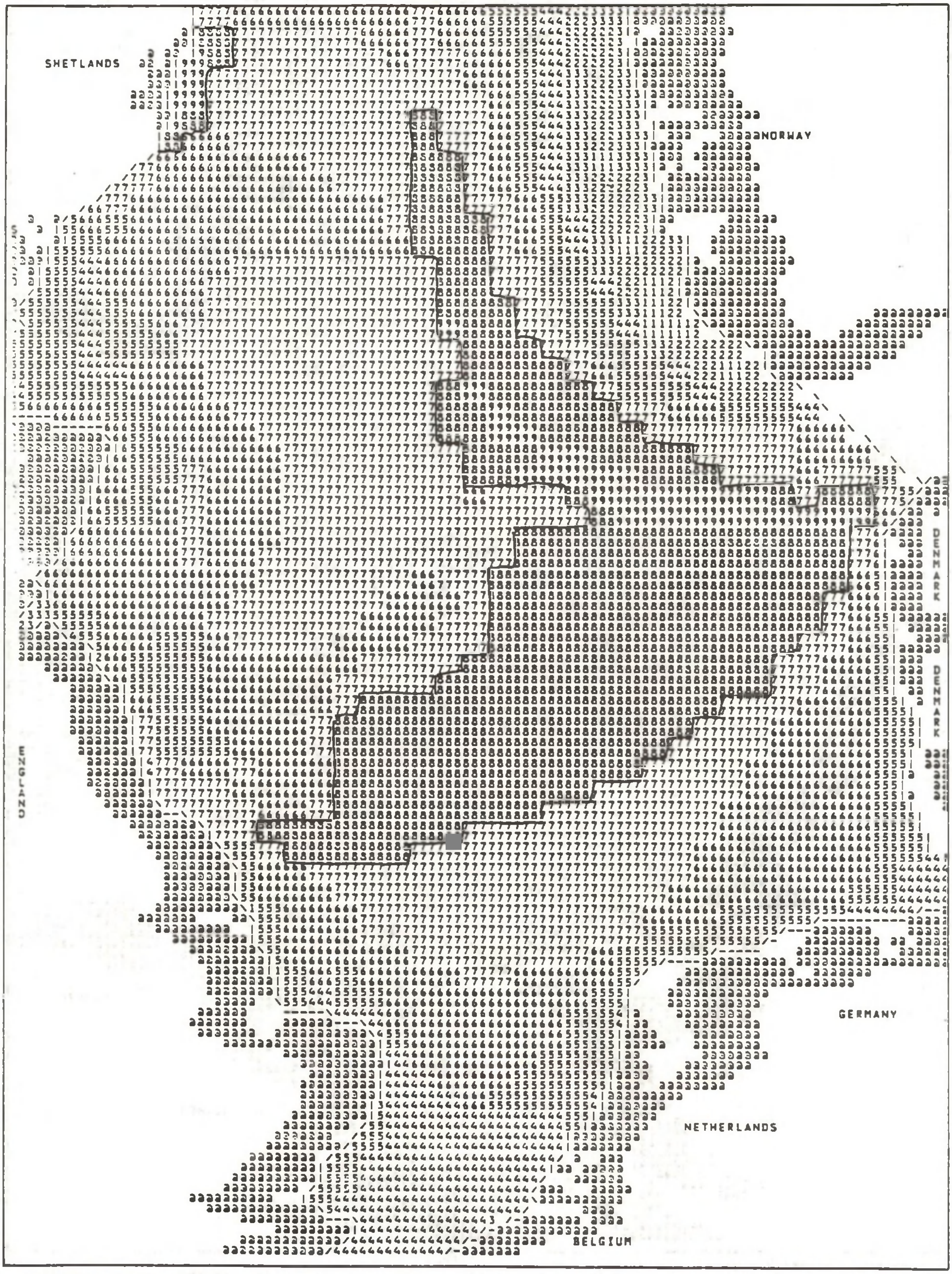


MBER OF SPAWNING SPECIES (--)

Note: Total number of species considered is 12

Figure A.12 Number of spawning species

CES TOTAL NORTH SEA RUNDATE AND TIME 29/04/85 TEST W&M

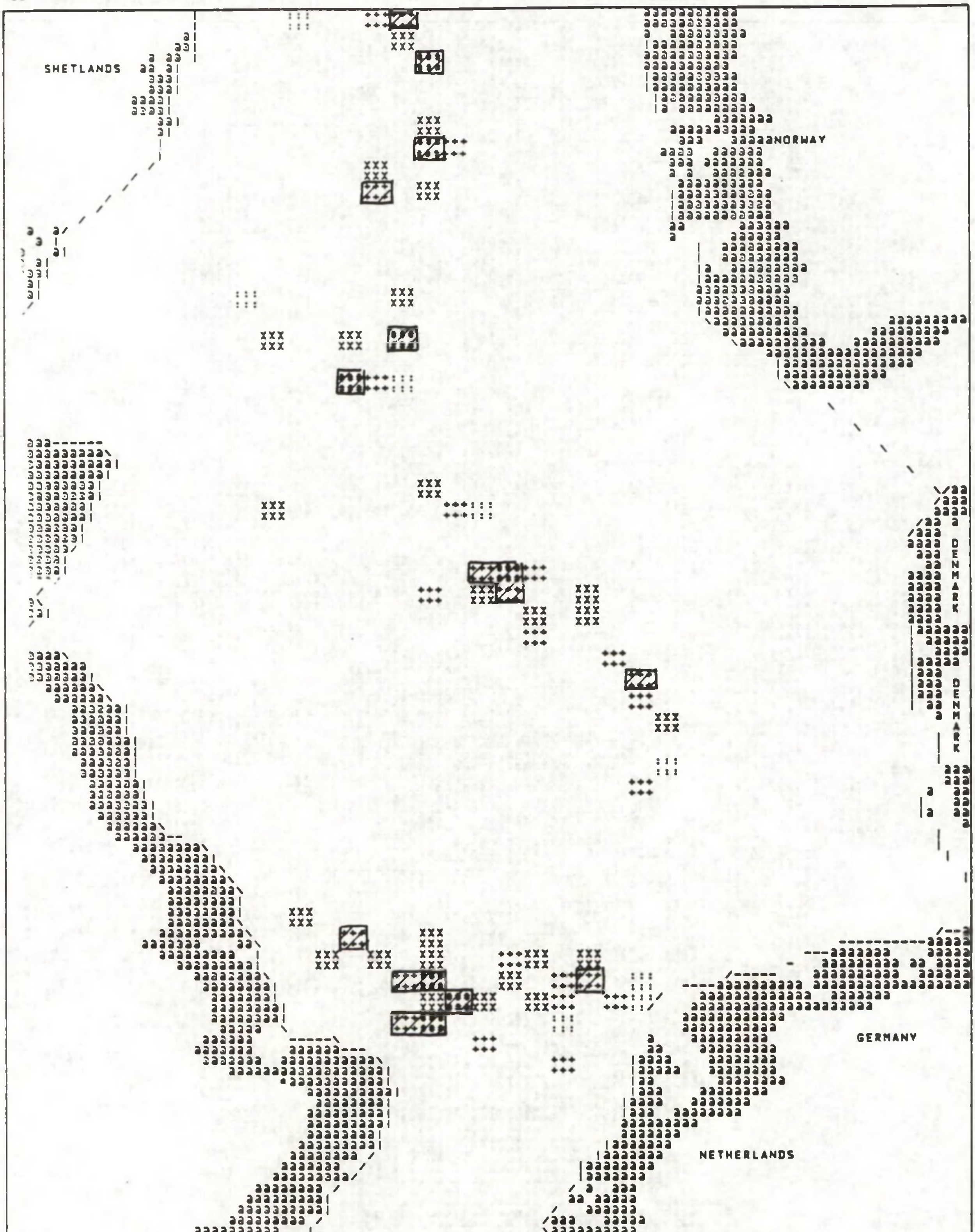


UMBER OF ADULTS SPECIES (--)

Note: Total number of species considered is 12

Figure A.13 Number of fished species

ALS TOTAL NORTH SEA RUNDATE AND TIME 29/04/85 TEST W&M



COVERABLE GASRESERVE 1980 (E9 M3) :
LESS THEN 0.10 | 0.10 UP TO 2.00 | 2.00 UP TO 10.00
10.00 UP TO 50.00 | 50.00 UP TO 100.00 | MORE THEN 100.00

Figure A.14 Recoverable gas reserves 1980

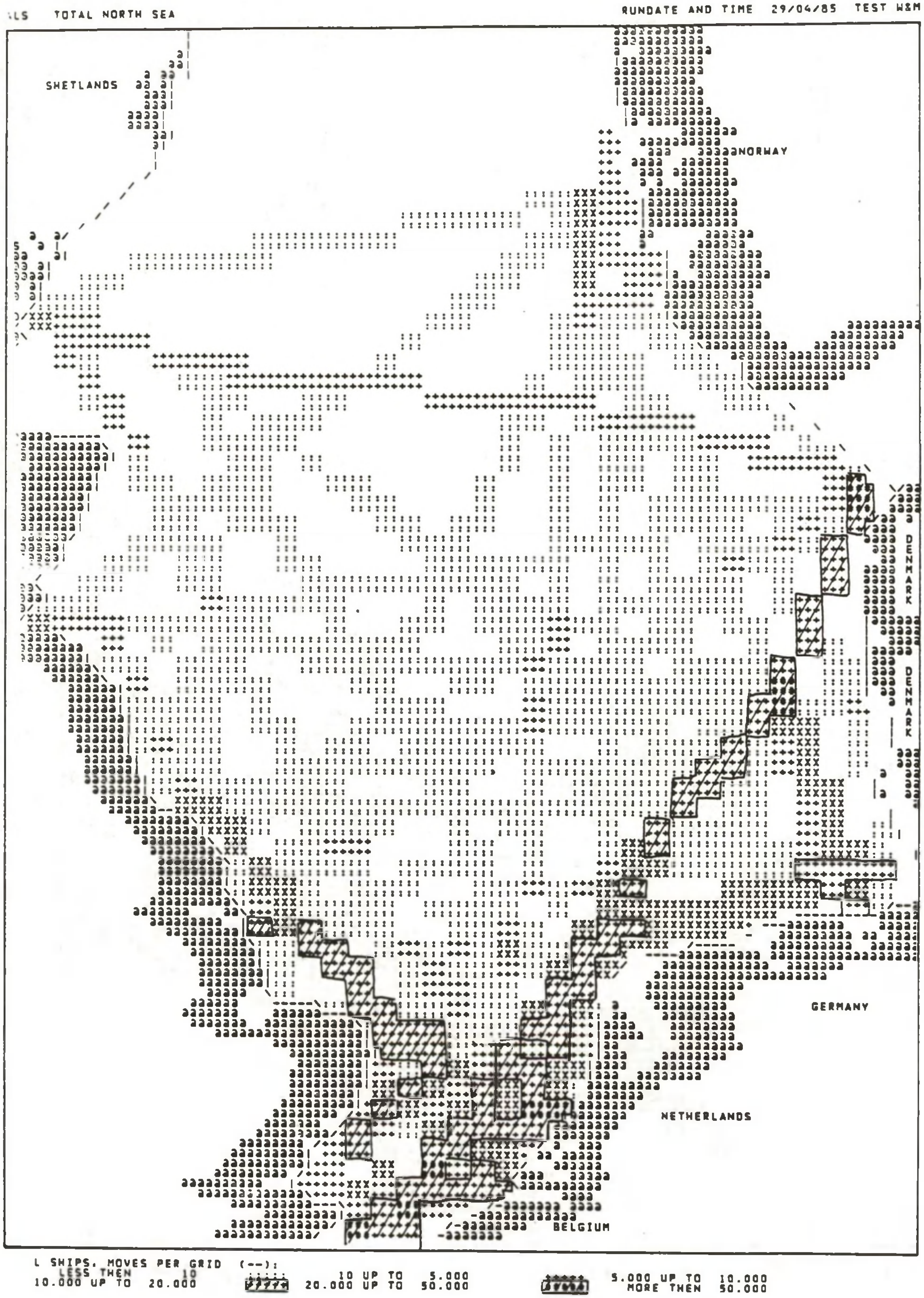


Figure A.15 Route bound shipping traffic, moves per gridcell

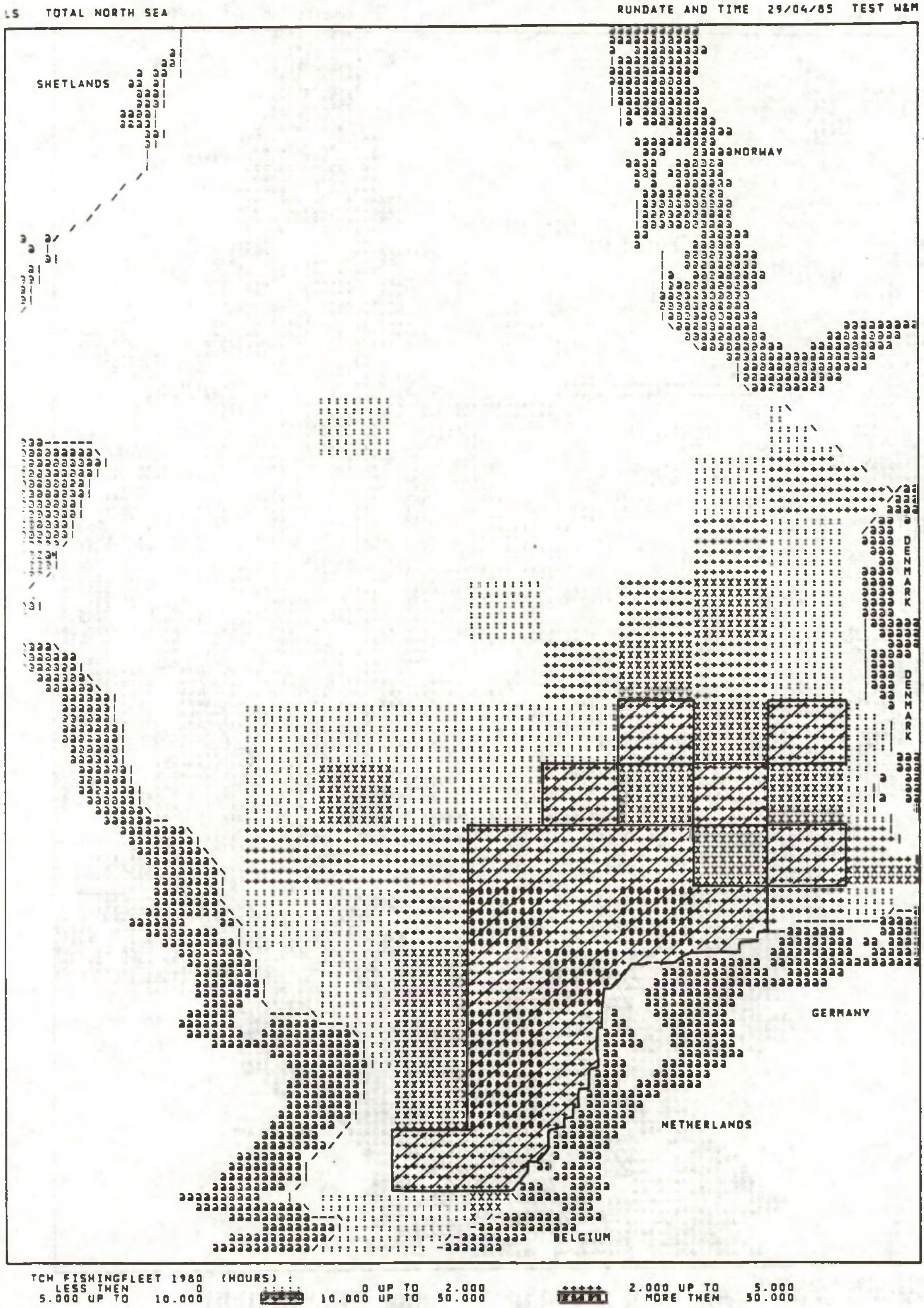


Figure A.16 Dutch fishing activity 1980

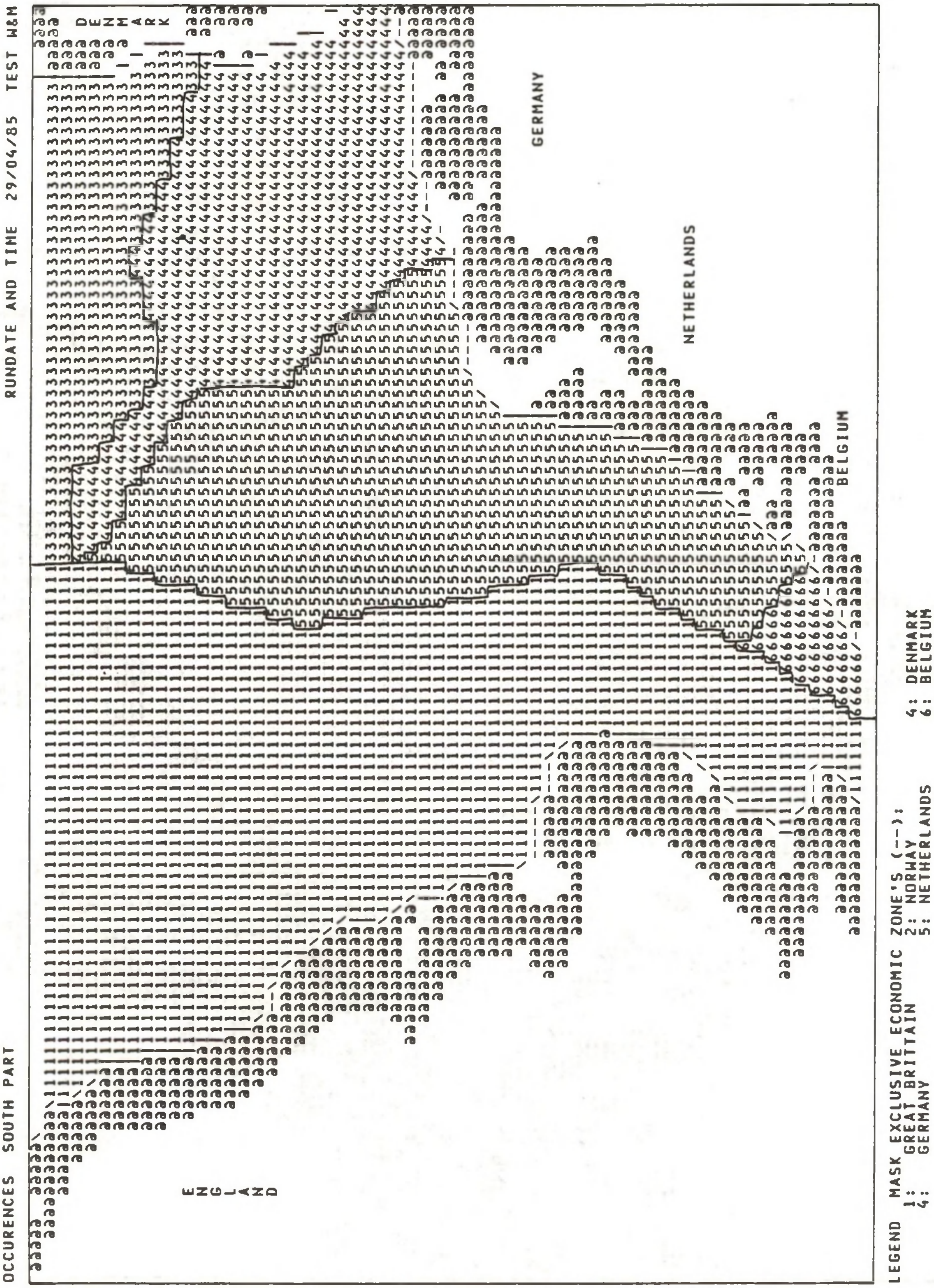


Figure A.17 Exclusive economic zones, fine grid

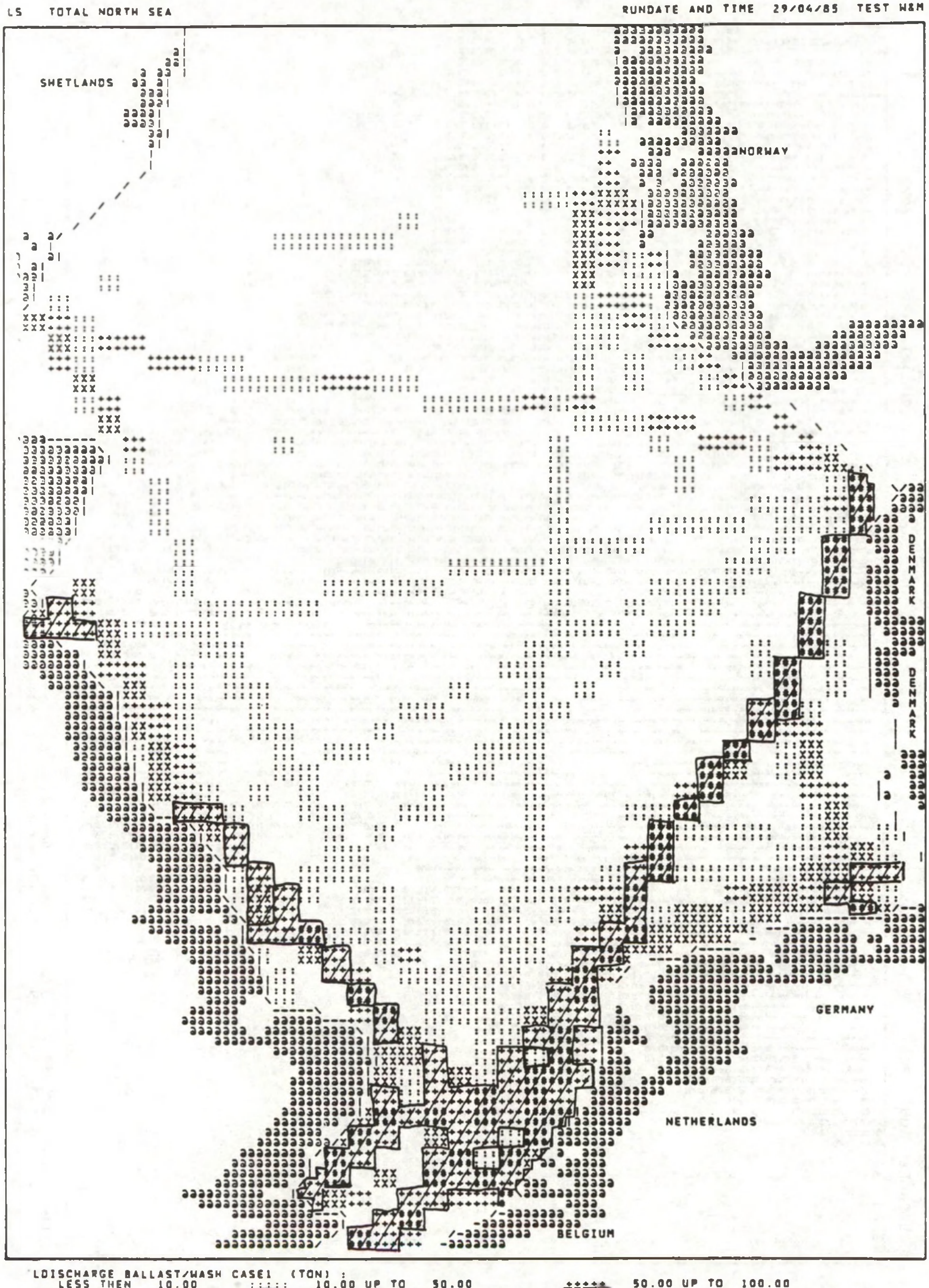


Figure A.18 Oil discharges by deballasting and tank cleaning operations

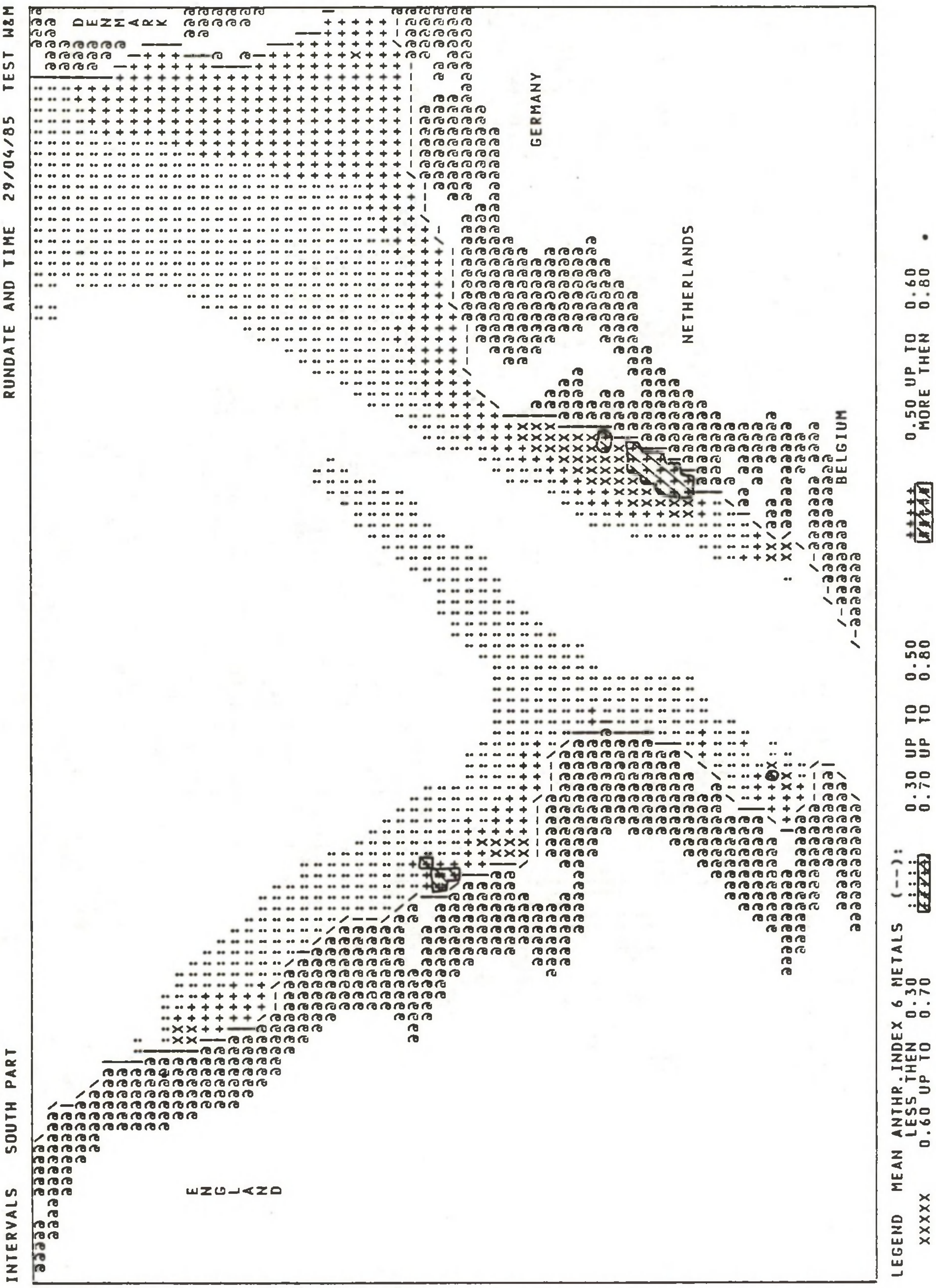
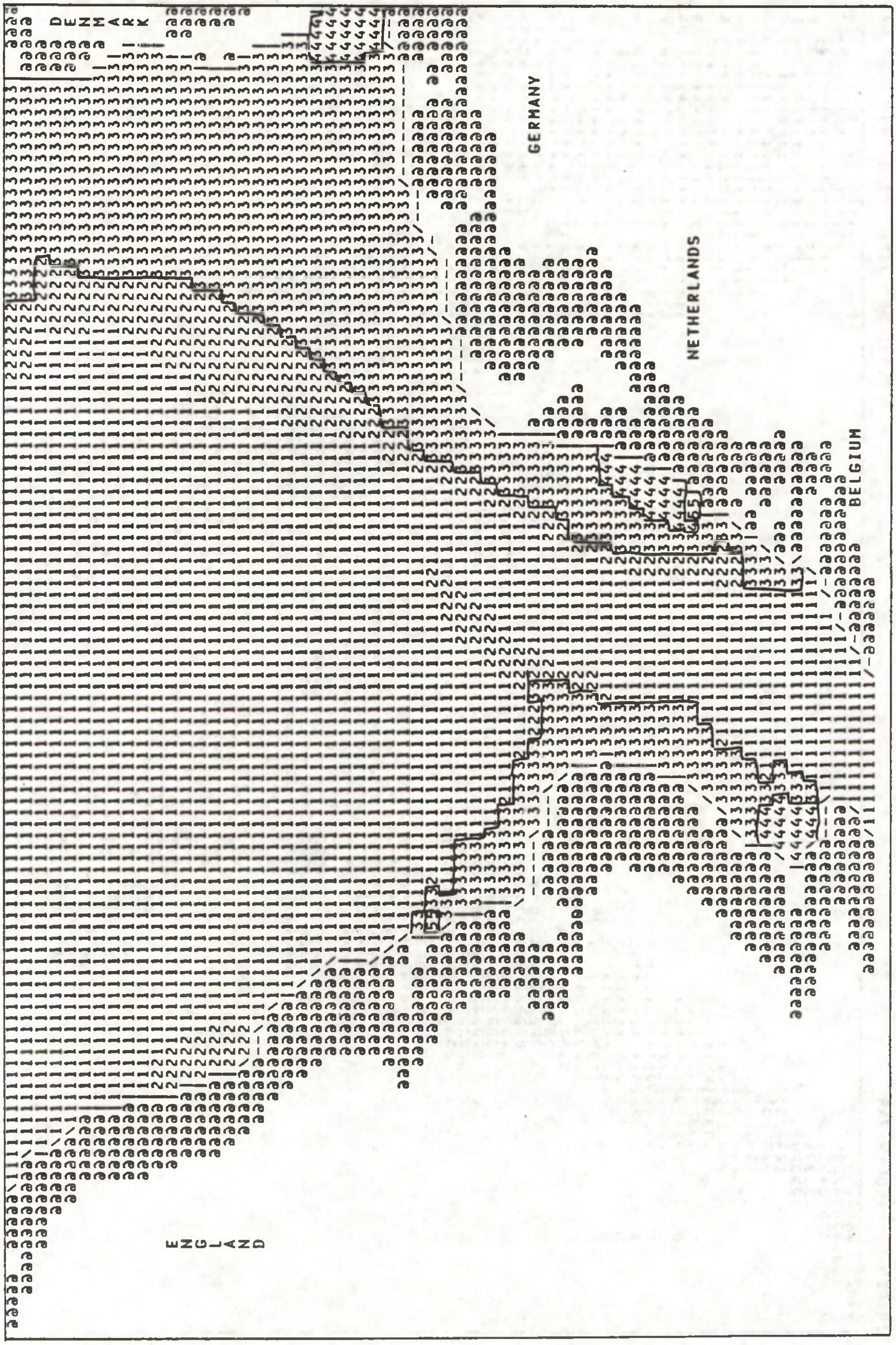


Figure A.19 Mean anthropogenic fraction for 6 metals, 1980

OCCURENCES SOUTH PART   RUNDATE AND TIME 29/04/85 TEST W&M

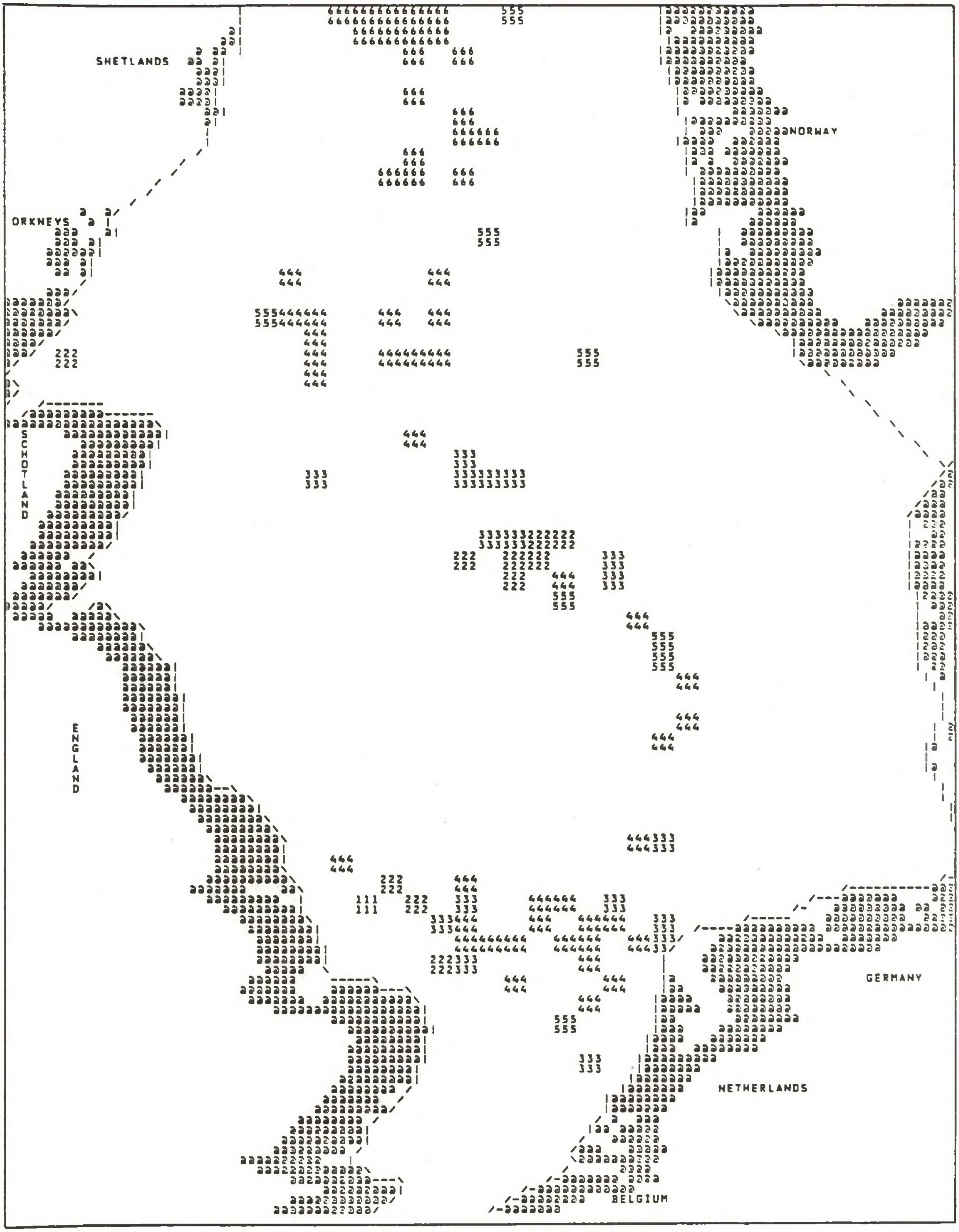


LEGEND NUMBER OF HEAVY METALS WITH RISC-INDEX OVER 0.75 (--)

Note: The RISC-index represents the relation between the calculated and lethal concentration under laboratory conditions, applying safety factor of 100.

Figure A.20 Number of metals with risc-index greather than 0.75

OCCURENCES TOTAL NORTH SEA RUNDATE AND TIME 29/04/85 TEST W



LEGEND NUMBER OF SPAWNING SPECIES AT PRESENT OR POTENTIAL OIL AND GAS MINING SITES

Note: Total number of species considered is 12.

Figure A.21 Number of spawning species at present or potential oil and gas mining sites