REGIONAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

# *Onshore impact of offshore oil and natural gas development in the West and Central African Region*

*UNEP Regional Seas Reports and Studies No. 33*

Prepared in co-operation with

UNITED NATIONS DEPARTMENT OF INTERNATIONAL ECONOMIC AND SOCIAL AFFAIRS

UNEP 1984

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## PREFACE

Ten years ago the United Nations Conference on the Human Environment (Stockholm, 5-16 June 1972) adopted the Action Plan for the Human Environment, including the General Principles for Assessment and Control of Marine Pollution. In the light of the results of the Stockholm Conference, the United Nations General Assembly decided to establish the United Nations Environment Programme (UNEP) to "serve as a focal point for environmental action and co-ordination within the United Nations system" (General Assembly resolution (*XVII) of 15 December 1972). The organizations of the United Nations system were invited "to adopt the measures that may be required to undertake concerted and co-ordinated programmes with regard to international environmental problems", and the "intergovernmental and non-governmental organizations that have an interest in the field of the environment" were also invited "to lend their full support and collaboration to the United Nations with a view to achieving the largest possible degree of co-operation and co-ordination". Subsequently, the Governing Council of UNEP chose "Oceans" as one of the priority areas in which it would focus efforts to fulfil its catalytic and co-ordinating role.

The Regional Seas Programme was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes eleven regions [1/] and has over 120 coastal States participating in it. It is conceived as an action-oriented programme having concern not only for the consequences but also for the causes of environmental degradation and encompassing a comprehensive approach to combating environmental problems through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned. It is designed to link assessment of the quality of the marine environment and the causes of its deterioration with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-oriented programme activities[2/].

At the third session of UNEP's Governing Council (1975), a number of West and Central African States requested UNEP to study the problems of marine and coastal pollution of their region. As a result of that request, UNEP's exploratory mission visited fourteen States of the region during 1976. The mission's report identified the major environmental problems of the region and recommended the development of a regional action plan for the protection and development of the marine environment and coastal areas of the region.

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1/ Mediterranean Region, Kuwait Action Plan Region, West and Central African Region, Wider Caribbean Region, East Asian Seas Region, South-East Pacific Region, South Pacific Region, Red Sea and Gulf of Aden Region, East African Region, South-West Atlantic Region and South Asian Region.

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies. UNEP Regional Seas Reports and Studies No. 1. UNEP, 1982.

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After considering the report of the mission, the fifth session of the Governing Council (1977) decided that "steps should be undertaken for the development of an action plan and a regional agreement to prevent and abate pollution" in the West and Central African region.

The preparatory work on the development of the action plan and the regional agreement included several expert group meetings, missions and surveys[3/] leading to the Conference of Plenipotentiaries on Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (UNEP/IG.22/7) convened by UNEP in Abidjan, 16 - 23 March 1981 as the final stage of the preparatory work leading to the adoption of the (a) Action Plan for the protection and development of the marine environment and coastal areas of the West and Central African Region, (b) Convention for the Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, (c) Protocol concerning co-operation in combating pollution in cases of emergency, and (d) a set of conference resolutions.

This document is one of the surveys prepared as a contribution to the development of the Action Plan.

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3/ For details see:

- Report of the Executive Director on preparatory activities for an action plan for the protection and development of the marine and coastal environment in the West African Region. UNEP/IG.22/4. UNEP, 1981.

- UNIDO/UNEP: Survey of marine pollutants from industrial sources in the West and Central African Region. UNEP Regional Seas Reports and Studies No. 2. UNEP, 1982.

- UNESCO/UNEP: River inputs to the West and Central African marine environment. UNEP Regional Seas Reports and Studies No. 3. UNEP, 1982.

- IMCO/UNEP: The status of oil pollution and oil pollution control in the West and Central African Region. UNEP Regional Seas Reports and Studies No. 4. UNEP, 1982.

- UNDIESA/UNEP: Ocean energy potential of the West African Region. UNEP Regional Seas Reports and Studies No. 30. UNEP, 1983.

- UNDIESA/UNEP: Environmental management problems in resource utilization and survey of resources in the West and Central African Region. UNEP Regional Seas Reports and Studies No. 37. UNEP, 1984.

CONTENTS

# I. INTRODUCTION

## 1. Introduction

The present profile of commercial energy production and consumption in the West African Region, is dominated by oil and natural gas liquids. During the period 1971-75, the average annual production of oil and gas accounted for almost ninety-nine per cent of the total production of commercial energy in the region. Production of crude petroleum and natural gas, however, was concentrated in five of the nineteen countries (Angola, Congo, Gabon, Nigeria and Zaire) that constitute the region and is dominated by Nigerian production.1/ Of the five producers during this period, only three were net exporters of oil (Nigeria, Gabon and Angola) while the remaining two producers and fourteen non-producers were part of a large group of oil importing developing countries (OIDC's).

For the group of oil importing developing countries, the sum effect of the oil price increases on their economies since 1973 has been severe. The price rises, world economic recession, and lack of deflationary policies in several of them have led to large increases in their current account deficits. Since imported energy (in this case consisting almost entirely of imported oil) is required for the industrial sectors of their economies, a reduction in energy supply in the short-term, will result in lower economic growth because non-productive uses of oil are minimal. For these countries, the new level of petroleum prices has two principal long-term implications:

(1) In the short-term, given their limited ability to conserve oil or substitute other energy sources for petroleum, they must continue to borrow the foreign funds needed to finance oil imports or else reduce their rate of economic growth;

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1/ See Annex 1 for production, reserves and movements in 1977-78 of petroleum in the region.


Figure 1: The Region

(2) In the longer term most have the opportunity to develop alternative indigenous energy sources. At present crude oil prices, it is now economic for them:

(a) to develop domestic sources of petroleum that were regarded as uneconomic at pre-1973 prices, and to endeavour to expand known reserves;

(b) to expand the provision of energy from alternative sources in order to substitute for petroleum-based energy supplies.

As far as the region is concerned, crude oil production has been fairly recent. Exploration for oil and gas has been sporadic especially in the recent past when data on petroleum bearing provinces were unavailable. Currently available information suggests that the potential for further oil and gas discoveries in the region is fairly good (Fig. 2 ) with the overwhelming proportion of such areas located in the offshore area. Exploration activity in the region is, therefore, expected to be on the upswing, particularly in the offshore areas as more of the countries in the region seek to develop domestic sources of petroleum.

The impact of offshore oil and gas production on the coastal areas is, however, potentially very significant. Petroleum development activities impinge directly on the level of employment, community facilities and coastal and nearshore ecosystems. In the absence of past experience or proven capabilities in planning for such development, the risk of adverse impacts is heightened while potential benefits are not fully realized. In the West Africa region where such experience is fairly limited and capabilities are generally unproven, the need for such planning becomes even more necessary.

This report is, therefore, structured firstly to provide the link from primary offshore development activities to secondary industrial growth and secondly, to indicate the induced effects and impacts of the activities above on the immediate ecosystem -- principally the potential impacts on the fisheries, wildlife and habitat resources of the region. While the report is designed to stand on its own, it is also intended as an information guide for decision-makers and planners in the region to understand the full benefits and the hazards associated with such activities and to offer a broader perspective for environmental assessment by providing more detailed descriptions of various aspects of the recovery of offshore oil and gas.

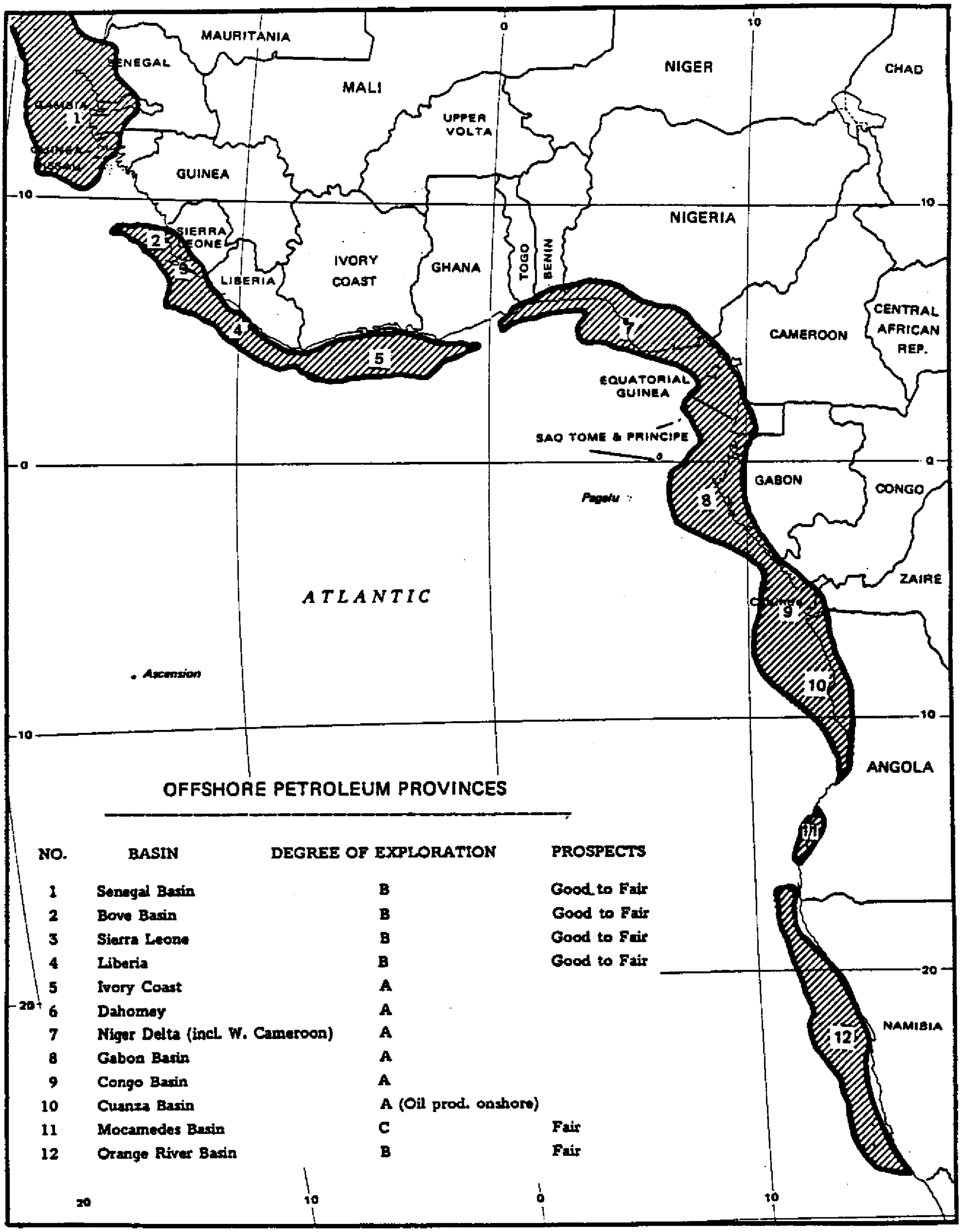
The report, therefore,

1. Identifies offshore areas of past and current activity;
2. Provides a review of the state-of-the-art in impact assessment procedures;
3. Undertakes a review of the range of potential impacts of offshore development activities on both living and non-living resources and coastal communities;
4. Isolates specific areas in the region that can be used for case studies in determining the nature and extent of potential impacts; and
5. Recommends a framework for the protection of the environments affected by offshore development activity, including living resources and their habitats.

A number of working assumptions will be used in the preparation of this report.

A. For the region in question, there will be no governmental restrictions on explorable Outer Continental Shelf (OCS) tracts.

B. No major breakthroughs will occur in the near future which could be expected to significantly change the environmental impact potential of Outer Continental Shelf development.




## OFFSHORE PETROLEUM PROVINCES

| NO. | BASIN | DEGREE OF EXPLORATION | PROSPECTS |
|---|---|---|---|
| 1 | Senegal Basin | B | Good to Fair |
| 2 | Bove Basin | B | Good to Fair |
| 3 | Sierra Leone | B | Good to Fair |
| 4 | Liberia | B | Good to Fair |
| 5 | Ivory Coast | A | |
| 6 | Dahomey | A | |
| 7 | Niger Delta (incl. W. Cameroon) | A | |
| 8 | Gabon Basin | A | |
| 9 | Congo Basin | A | |
| 10 | Cuanza Basin | A (Oil prod. onshore) | |
| 11 | Mocamedes Basin | C | Fair |
| 12 | Orange River Basin | B | Fair |

Sources : World Oil, Oil and Gas journal and The World Energy Conference.

Figure 2: Offshore Petroleum Provinces

C. In established onshore refinery and transportation areas, the significant impact on living organisms will come from the release of hydrocarbons during tanker transfers and noxious gases such as the oxides of sulphur during processing.

D. The potential for onshore impacts on living matter generally will increase, at least initially, somewhat in proportion to the level of onshore development activity.

E. Criteria for the protection of environments affected by OCS-related facilities may be broadly applied to equivalent non OCS-related facilities in the coastal zone.

2. Recent Regional Developments

Worldwide offshore oil and gas exploration and production are on the increase due to a number of factors: the shortage of oil in the international market place; the soaring price of oil which makes areas that were considered uneconomic at pre-1973 prices economic; the fact that geologists estimate that between 40 and 45 per cent of undiscovered oil and gas producible reserves will probably be found on the continental shelves and margins (most of which are unexplored); and the interest of developing countries to explore their offshore areas.

In the region, these developments resulted in a significant increase in new production wells during the period 1977-79. Nigeria, Gabon and Cameroon were the countries within which offshore drilling was most pronounced. Among the three countries, Cameroon, with the development of a new petroleum province in the western region recorded the most activity. Nigeria and Gabon were second and third, respectively. This group was followed by Ivory Coast, Angola, Chad and Ghana in that order. 1977 marked the year during which the offshore Laongo field in the Republic of Congo and two smaller fields offshore Zaïre were brought into production. Cameroon became Africa's 10th oil producing country in 1978 when the offshore Kole field was brought into production. During the same year, at least two new discoveries -- one onshore and the other offshore -- were made in Nigeria. During 1979, offshore drilling revealed the existence of fields in Ghana and Ivory Coast. The field in the Ivory Coast is scheduled for production this year. In September of the same year, the Sanaga wildcat field off the coast of Cameroon about 75 miles southwest of Douala was reported by Mobil Oil to be "a potentially significant hydrocarbon bearing zone". In Nigeria, the government-owned Nigerian National Petroleum corporation signed agreements with foreign companies for further exploration.

These activities together with a myriad of others within the region attest to the growing interest on the part of some of the countries in the region and of the continued interest of some of the current producers to develop domestic sources of petroleum. The nature of the development activities taking place in each country is, therefore, considerably varied.

3. The nature of offshore oil and gas development

The difficulty associated with the discovery of profitable accumulations of oil and gas has led to the development of a wide variety of exploratory techniques to seek them out. The choice among the various techniques depends on many factors, including geographical conditions, the expected depth of the reservoir, the expected trap and economic conditions. If an entirely new area must be explored, then the sequential phases previously noted can be distinguished.

In the beginning, general surveys covering vast territories at relatively low cost must be performed (pre-exploration). Such surveys seek to generate a general insight into the area. Photogeology, gravimetry and magnetometry are frequently applied. Photogeology employs air reconnaissance, and is best adapted to onshore problems where the surface of the earth's crust provides insight into the geology of deeper formations. Magnetometric surveys also use aircraft and are applicable offshore as well as onshore. These measurements give information about the broad outlines of geological provinces and the expected sediment thicknesses.

Offshore, as soon as some general knowledge has been obtained about an area, more specific information can be obtained through seismic work (geological and geophysical surveys). Seismic measurements contribute considerably to the discovery of potential structural traps. The last phase of exploration is drilling. The drilling of a new field exploration well (wildcat) is expensive, especially offshore where floating rigs must be used. Only an exploration well can prove conclusively the existence of an oil and/or gas field. Apart from rock samples, new well-logging techniques can add much to existing knowledge about the formations beneath the earth's crust. Most well-logging techniques consist of the continuous measurement of physical characteristics of the well rock of the bore hole - such as resistivity, natural and induced radioactivity, spontaneous potential, etc. Apart from well logging, various other tests are necessary to know the volume of oil or gas which a well can produce after their presence has been established. The most important is the production test.

In the first years of exploration, mainly structural traps are sought. Such traps can be recognized earlier in exploration from detailed geologic and seismic work. The search for such traps follows rapidly upon evidence that such a trap may be present.

As soon as a field has been located by an exploration well, work is begun to delineate it (field development). One well alone gives only partial information about a field; a number of wells are needed to fix the extent of the field. Wells drilled to seek this information are called step-out wells.

Following the conclusion that a field can be profitably produced, sufficient development or production wells are drilled to allow a profitable flow of oil or gas and surface equipment is installed. Surface equipment includes all necessary pipelines and stock tanks and equipment to clean gas or oil and to separate the oil, natural gas liquids, gas and water. Offshore, all these installations may be concentrated on a production platform, a highly technologically developed piece of equipment.

In general, the infrastructural needs of offshore development are organized around the existing or potential source of oil and gas, especially around areas with the largest concentration of producing or potentially producing fields. This way, the associated pipelines and/or refineries are supplied more economically from the local fields.

The steps leading to the development and of a final closing field can be divided into six major sequential phases. These phases are pre-exploration, geological and geo-physical surveys, exploratory drilling, field development, production and shut-in facilities. The development process is planned in this sequential phase not only because the phases are physically and conceptually different, but also because technological decisions dictate that one precede the other. Each phase is usually characterized by the introduction or development of specific industrial projects and activities. The more mature the field, all things being equal, the greater the number of concurrent phases. In the more mature petroleum regions in West Africa, such as those off the Nigerian and Gabonese coasts, all of these activities occur simultaneously.

Offshore, a development programme will, therefore, involve not only the drilling of production wells, but also the installation of platforms, separators to process crude oil and gas offshore, pipelines or vessels to transfer the oil and gas onshore, and onshore tank farms and plants for additional processing. During the production period, additional wells will be drilled, existing wells will be serviced to maintain production, and a variety of techniques will be employed to stimulate lagging output. The oil and gas produced will either be shipped by pipeline and/or vessels to onshore facilities for refining and marketing.

An understanding of the entire offshore development process is necessary if one is to understand the full range of services, materials, and facilities needed to support offshore activities. The impact of offshore activities will fall most heavily upon those onshore communities which become the principal staging areas for offshore operations, and which may become the site of energy transfer and processing facilities. The spectre of potential impacts arising from these activities must be the concern of planners when initiating such development.

Associated with the six phases of development above, a number of specific projects must be anticipated. These projects subdivided by the sector wherein they occur include:

Offshore Zone:

a. Geophysical Survey

b. Exploratory Drilling

c. Production Drilling

d. Pipeline Laying

e. Offshore Mooring and Tanker Operation Facilities

Onshore Zone:

1. General

a. Service Bases

b. Marine Repair and Maintenance Facilities

c. General Shore Support Facilities

d. Platform Fabrication Yards

e. Pipe Coating/Painting Yards

f. Oil Storage Terminals

2. Associated with Processing

a. Refineries

b. Petrochemical Industries

c. Gas Processing Plants

d. Liquefied Natural Gas Processing

The offshore and onshore projects will commence at different times in the development programme, but the bulk of planning for these projects will most likely occur during the final stages of exploratory drilling and early field development phases. This ensures that the basic characteristics of the field are known and exploitation and support requireemnts are well defined. It must again be emphasized that these discrete types of projects are generally not easily recognizable in an area with an established oil-related production industry (such as Nigeria, Gabon).

## II. PLANNING AND DESIGN FOR OFFSHORE DEVELOPMENT

### 1. Introduction

Planning for the development of offshore oil and gas can be a long and complex process. The development process will be discussed here in six major sequential phases where decision making at governmental or industrial level will be required to determine whether to proceed to the next or termination of the entire development effort. (Fig. 3)

The case with which offshore oil and gas fields have been discovered has been found to be related to the degree of geologic knowledge of the area or region involved. More specifically, the knowledge acquired in developing coastal and onshore fields has accelerated the rate of discovery offshore. The majority of offshore fields are believed to be either extensions of existing onshore fields, or to have geologic characteristics similar to that of the onshore producing area. Certainly prior geologic knowledge enhances the potential for an offshore find, although other factors cannot be ignored such as technical capability, physical environment, government or regional policies and availability of investment capital.

### 2. The Process of Offshore Development

The planning process can be conveniently carried out in six sequential phases, namely: (i) pre-exploration; (ii) geological and geophysical exploration; (iii) exploratory drilling; (iv) field development; (v) production; and (vi) shut-in of facilities.

(i) Pre-exploration:

Before actually prospecting for oil and gas, considerable effort is devoted to carefully analyzing available geological and geophysical data on the area. Where data are unavailable, analysis is preceded by generation of the requisite data through surveys. These are performed by seismic companies under contract to oil and gas companies. The analysis identifies sedimentary basins and aids in the subsequent ranking of fields according to their potential for oil and/or gas.

If a field has hydrocarbon potential, it may be necessary, especially in remote areas, to establish survey control networks onshore and to perform hydrographic surveys for updating navigation charts. Increased efforts to establish and update control networks, as well as the operation of hydrographic vessels, are a signal of future offshore oil and gas activities, often followed closely by geophysical vessels searching for petroleum.

(ii) Geological and Geophysical Exploration

From favourable recommendations developed in the pre-exploration phase, extensive geophysical surveys and shallow rock coring programmes are conducted in promising areas to locate and identify geologic structures capable of trapping and holding hydrocarbons.

Where there are large structures, deep test wells may be drilled "off-structure" (away from where hydrocarbons collect) to determine the characteristics of reservoir rocks.

(iii) Exploratory Drilling

Significant development of physical facilities first occurs during the exploratory phase. Exploratory drilling is an operation that begins with relative uncertainty of success, especially in a new region where geologic data are unavailable or incomplete. Each additional exploratory well drilled and each rock core examined rapidly increases the data base and enhances better placement of the next hole.

Teams of geologists carefully examine the records of the seismic, gravity and magnetic surveys to determine a promising location for the first exploratory well. As drilling proceeds, rock cores are removed and periodically the well is "logged". Well logging is a process by which sonic, electric, and radiation characteristics of the sub-surface rocks are measured, in place, for mapping sub-surface structures.

If the exploratory well indicates an encouraging flow rate of oil (or gas) another well will be drilled nearby to confirm the discovery. A more accurate estimate is developed as appraisal ("step-out") wells are drilled to delineate the extent of the field and to determine the number of wells needed to economically drain the field.

Using the rock cores, well logs and drill stem tests obtained during the exploratory drilling operation, petroleum engineers evaluate the reservoirs to determine the best areas in which to set up permanent oil or gas recovery wells and to establish production platforms. Simultaneously, surface site investigations are commenced to determine foundation characteristics and subsurface geology of the potential platform locations. Platform locations, then are determined by the combined efforts of the reservoir engineers and engineers responsible for designing, fabricating and installing the platform.

(iv) Field Development

Field development combines all the strategies developed during the exploratory drilling and earlier phases. During this phase, the pattern of development is determined, and significant changes will not normally occur over the productive life of the field.

Field development entails the establishment of a number of major onshore and offshore projects. Additional onshore support facility development will also be stimulated. The ratio of gas to oil in the deposit, and the location of the resource, in relation to existing transportation and processing facilities will also affect the decision as to whether to engage in nearby facilities development.

(v) Production

The industrial infrastructure becomes more complex and "mature" during this phase. With little new strategy, the production phase involves a continuing low level of activity. Production will overlap somewhat with exploration, for after the initial platform comes on line, exploratory drilling continues in other portions of the basin.

Though the length of time relates to the size of the field and rate of recovery, the production phase will likely span 20 to 30 years. In addition, the producer is constantly searching for techniques to capture a higher percentage of reservoir hydrocarbons from the fields. If these efforts are successful, the life of the field may be expanded, often through "working over" an existing field by applying new and different recovery techniques.

(vi) Shut-in

As the oil and gas of the specific offshore field approaches exhaustion, it becomes necessary to decommission specific facilities and installations, i.e., to remove production platforms. Pipelines are generally left in place, since the cost of removal is usually more than the salvage value of the pipes.

Tank farms erected for receiving crude oil can obviously be used for storage of oil from other sources, but it is more likely that they will be scrapped. Natural gas processing plants would be salvaged or possibly converted to another use.

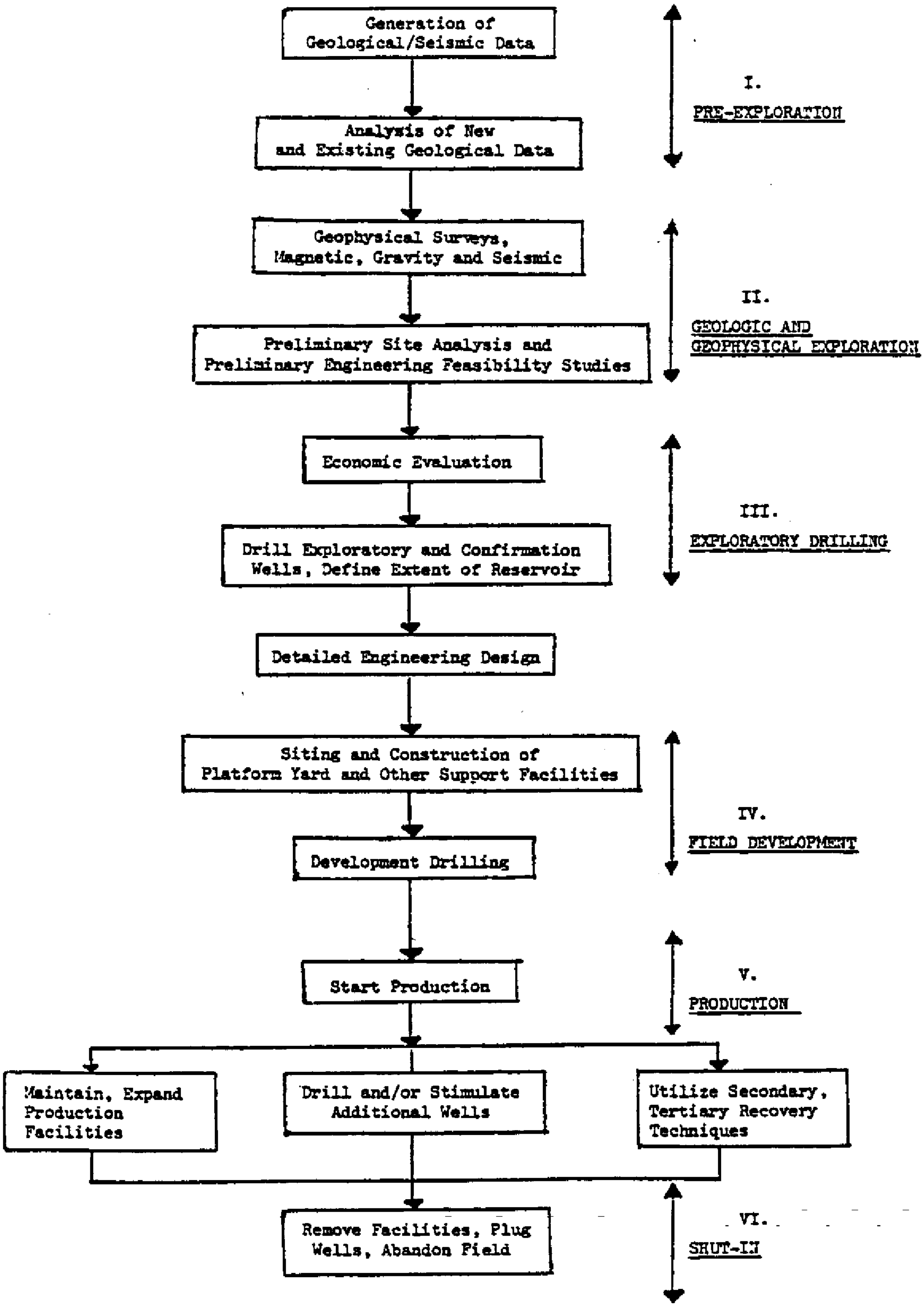



Figure 3: The development process chart

## III. IMPACT ASSESSMENT OF OFFSHORE DEVELOPMENT

### 1. Socio-Economic Impact

The primary factor in assessing the effects of offshore development on coastal communities is employment. The total number of individuals to be employed is the summation of direct employment (the facility project under consideration), indirect employment (working for other companies that support the facility project), and induced employment (employment generated in other sectors of the economy stimulated by the project).

Critical matters to consider in employment are: (1) the different requirements of construction and operational activities; (2) the inter-related training requirements for individual projects; and (3) the percentage of employees who will be new regional residents. Construction and installation of refineries and pipelines require a large labour force, while during their operation, employment labour requirements are much lower. For other facilities, such as platform fabrication yards, the operating force may exceed the construction labour force.

During construction and operation, a percentage of employees will also be new residents of the area. Those who are current residents will not require substantial changes in local services, while new residents will require service from the public and private sectors that had not been demanded previously. The number of secondary and induced employees needed because of new direct employment is difficult to predict. A number of factors affect this relationship. Of these, perhaps the most significant are: the size of the existing community, income of workers, length of construction phase and distance from metropolitan areas. The experience of the offshore oil industry has shown that from 0.3 to 0.9 secondary workers are needed for each new construction worker, and from 1.1 to 2.3 secondary workers for each permanent employee while the induced employment multiplier is projected to be about 1.2 for all direct and indirect workers.

Induced effects are a major consideration. New industrial development options have associated with them plant payrolls and property taxes which result in additional economic benefits to the new or existing community. But the commitment of coastal areas for the siting of heavy industries may engender a wide variety of impacts that extend considerably beyond the direct, localized, impacts of plants. Certainly, new residents employed by an offshore facility will generate increased demand on social services requiring for example, the establishment and/or expansion of public utilities and services (sewage treatment and water supply); employment may also induce the initiation of housing projects, shopping centres, more industry and other community development within the private sector. In addition, costs to the community for streets, police and fire protection, schools and other essential services, may be greater than the direct costs of the plant itself, requiring that planning decisions relating to industry siting must include the development they will induce.

(i) Economic Impact

Employment and Population Forecasting

The myriad of activities both on land and at sea include the construction of giant steel platforms. Construction at sea requires that food, fuel and drilling supplies must be assembled and shipped to the offshore work site, pipelines must come onshore at some point, and storage tanks and pumping stations must be built. These activities require a certain number of workers, who develop into the core of the community providing it with strength and growth. It is possible to forecast this aspect of offshore drilling activity, and a number of established techniques are available in the literature. Most of the forecasting techniques take into consideration the activity proposed, the likelihood of disturbances resulting from it, and finally the effects to be expected from those disturbances. The development process can then be characterized as a network of items, each flowing from the preceding one as follows:

| DIRECT PROJECT | SUB-PROJECT | ACTIVITIES | DISTURBANCES | EFFECTS |
|---|---|---|---|---|
| e.g. | | | | |
| Platform fabrication yard → | Navigation improvement → | Dredging, spoil disposal → | Spoil discharge, dredge spillover → | Turbidity, oxygen depletion |
| ↘ | Site preparation → | Clearing, grading → | Soil erosion, Loss of cover → | Sedimentation runoff pollution |
| ↓ DIRECT OR INDUCED PROJECT | | | | |
| Housing Development → | Site preparation → | Clearing, grading → | Soil erosion, Loss of cover → | Sedimentation, runoff pollution |
| | Solid waste systems → | Filling of wetlands → | Loss of habitat → | Increased BOD (biological oxygen demand) |

A forecasting methodology must answer a number of questions related to the offshore facility and the secondary development it may stimulate. Some steps in the methodology involve non-quantitative analysis of the specific facility and proposed locality. Other steps involve the application of a factor ("multiplier") derived from experience with growth responses in a locality, a region, or perhaps for a whole nation. Any forecasting process, however, is subject to the limitation of imprecision, a situation which is particularly true for major projects such as refineries. Uncertainties are usually unavoidable, so rough approximations are the rule, not the exception.

Some of the forecasting methods, commonly used in assessing the effects of offshore oil and gas development are: Input/output analysis, the Harris Model and development scenarios.

Input/Output Analysis

This model seeks to provide an accounting system to trace the flow of goods, services, and money from one sector of the economy to all other sectors. It does this by describing the interrelationship among all the sectors within a region during a specified time period and expressing these interrelationships as mathematical coefficients. For offshore drilling related forecasting, selection of the region to be considered and use of coefficients appropriate to that specific region may be the most important considerations. Economic structures vary considerably within a region or a country, making the use of regional or national coefficients for industrial classification potentially misleading. For example, coefficients for the offshore petroleum development sector will be significantly different for Nigeria, which has a considerably more developed industrialized base, than for the rest of the region as a whole. The results of an input/output analysis will indicate the impact an industrial activity will exert on other sectors of the economy, but this will not indicate the employment requirements or induced community effects.

The Harris Model

The Harris Model, developed by the U.S. Bureau of Land Management is a sophisticated economic model which examines the need for new industrial facilities in a region. The model uses industrial interrelationships to portray ties among the industries of a defined region. Like the input/output model, it does not directly indicate induced community effects. Among the basic items considered in using the model are population movements, the demand for products, costs of production and transportation, and industrial input/output coefficients. These are used to predict changes in production activities resulting from hypothetical oil finds. Predicted changes are used to forecast such items as employment, earnings, population movements, and overall personal income and expenditures.

Development Scenarios Model

Scenarios are the most popular tool for predicting offshore and onshore related development and their impact.

Scenarios are descriptions of anticipated future situations that would result from assumed changes in specific activities: For example, siting of oil and gas facilities near a community (the assumed change) would probably result in population growth, new political problems, and increased requirements for community services and facilities (the future situation). The accuracy of the scenario (how many people? which political problem? what facilities?) necessarily depends on the accuracy of estimates of the assumed changes.

Scenarios can be formulated at many levels of complexity. In offshore activity studies, they range from verbal descriptions based on a few broad assumptions, to sophisticated computer models where they may be combined with input/output analysis or other economic models, such as the Harris Model.

The need to use scenarios suggests a major problem in planning for offshore related development: it is impossible to precisely predict development patterns and impacts based on a resource of unknown quantity and characteristics. In addition, oil and gas each require different technologies and related onshore support, resulting in different combinations of onshore effects and impacts.

A simplified process flow for developing a forecasting procedure is shown in figure 4. This process first estimates direct employment, then, indirect employment from which the last category, induced employment is predicted. The total employment derived from such an analysis for a given region or country represents invaluable information for planners. Such an exercise as a preliminary activity will require the services of an expert with a strong background in economics and related statistical analysis.

(ii) Community Impact

The total population of the new region under study, after the manner of analysis of the previous section will form the basis for determining the potential demand for public and private community

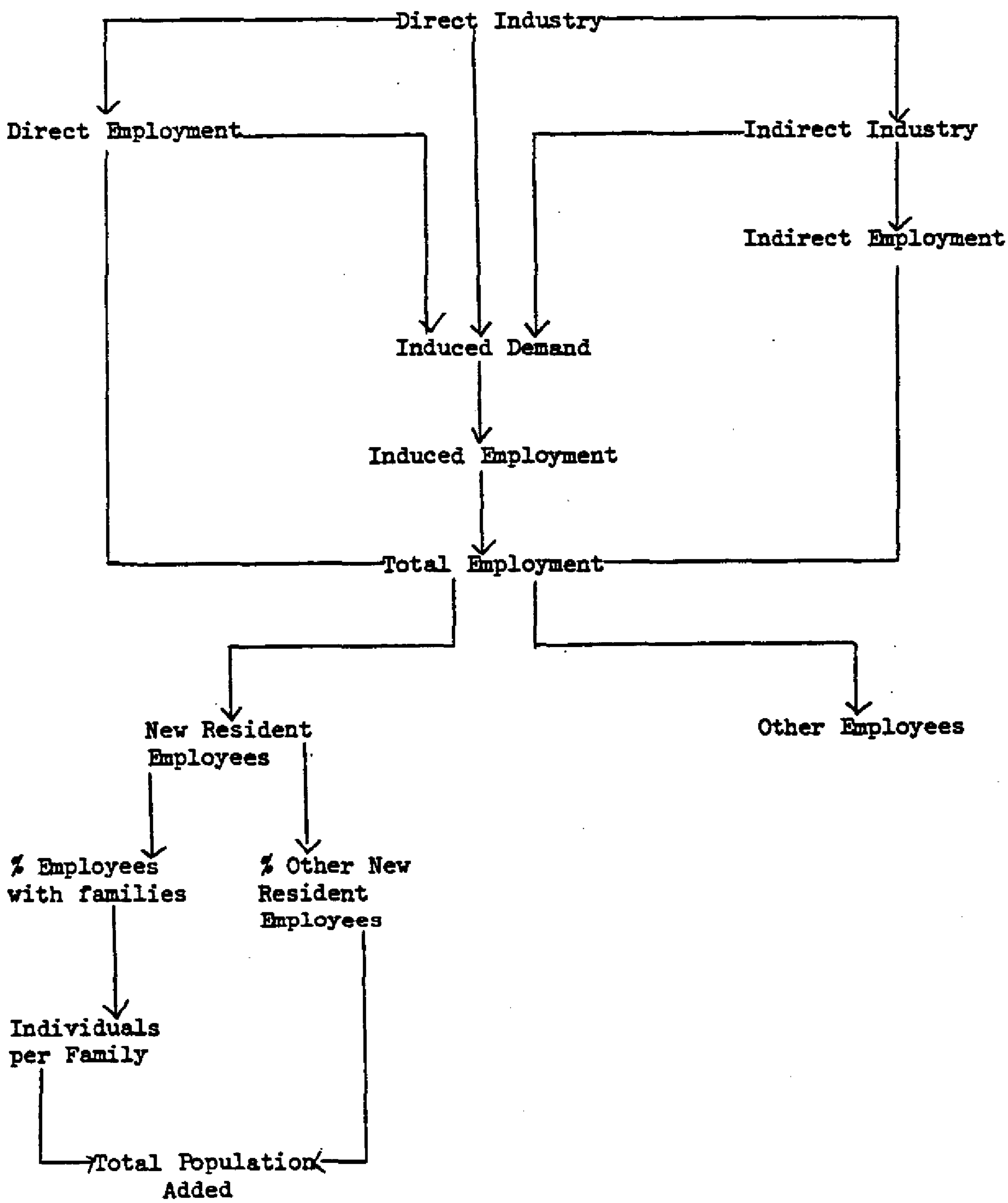



Figure 4: A simplified forecasting process flow diagram

facilities. The siting, design, construction and operation of community facilities can strongly impact on living resources including fish and wildlife and their habitats. Facilities may, for example, require substantial land areas. Their construction may require grading or other land alterations, which may produce significant run-off. Among the facilities which may have such effects are: housing, public utilities and services, transportation, schools, recreation and commercial establishments. Other facilities such as police and fire stations and medical and social services may also cause environmental effects, although they do so on a smaller scale than the former set of facilities.

Housing

It is not easy to assess housing needs because of the interplay between housing demand and supply. Housing demand, is quite simply, a function of the individual household's income (ability to pay for or rent housing), the total number of units demanded by these households, and the price required for each unit of housing. The interplay will further be complicated if a significant sector of the population's housing needs are to be catered for by private or public subsidy. For example, the oil drilling companies may decide to construct and provide all housing requirements of their workers, belonging to the direct employment category while individual entrepreneurs attracted by secondary development will cater for their housing needs individually. There are other variants such as family size, the local vacancy rate where there has been an existing community; the condition and nature of existing housing; and the capabilities of the housing construction industry in the area.

With the prevailing year round warm temperatures over most of the West African region, temporary housing, utilizing prefabricated structures may serve for the initial periods of development, thereby relieving some of the demand for housing. This has to be factored into a thorough analysis. For existing communities, the existing conditions and the vacancy rate of community housing not only indicates the availability of housing, but also lead to initial estimates of the demand for new construction.

The residential space needs of a new population can usually be estimated using residential density standards, depending on the family size -- one-, two- or multi-families.

Public Utilities and Services

In estimating the demand for utility services, the demand for each service -- water, sewers, solid waste, and electricity must be determined. Such estimates can be done using factors established from several selected environmental studies. From several environmental studies performed for different geographical localities in the coastal areas of the United States, domestic water has factors ranging from 100 gallons per day per person to 180 gallons per day per person; domestic sewage has factors ranging from 100 to 120 gallons per person per day; solid waste has a factor ranging from 3 to 6 pounds per person per day; and power has a factor ranging from 6 to 750 kilowatts per person per month (6, 7). In applying these factors to the West African region, there will be considerable variations in demands for water and power due to climatic, income, and cultural differences. These will be established for a given region or locality from similar environmental studies; or as a guide for planning purposes, demand estimates can be based on the above figures and with appropriate adjustments. Power consumption in the United States is much higher than in any of the countries in the region but for estimation purposes power consumption in each of the countries of the region may be thought to vary with respect to Gross National Product, in the same ratio as obtained in the United States.

Transportation

It is extremely difficult to assess the transportation needs (such as roads, highways and railways) without specific information on local road utilization in a particular area. Highway utilization is estimated by determining average daily traffic and peak hour volumes which are then converted to highway capacity. Highway capacity is determined by considering the vehicles traversing a fixed distance in a specified period of time. Increased population and industrial activities spurred on by offshore drilling operations, can cause congestion for an existing highway, as the capacity, a constant, is attained or exceeded.

Highway congestion, more often than not, usually results from two changes in travel patterns. One is congestion around new industrial or commercial facilities where vehicles congregate, and the second is congestion around new supporting development stimulated by highway access.

Transportation projects, therefore, will typically consist of expanding and improving portions of existing facilities. Short sections of highways may be constructed in new locations. Typical projects will include widening of existing roadways, say, a one lane highway to two or more lanes, straightening curves, constructing turning bays, or improving traffic signals. The usual goal of such projects is to improve the smoothness and rate of flow of traffic.

Schools

Determining the impact of added population on school services, requires an estimate of elementary, post primary, high and secondary school age children by area. These estimates can then be applied to local or state standards for school area and classroom size.

Recreational facilities

The need for recreational facilities should be considered both for the community as a whole and for each neighbourhood. The demand for community-wide facilities (such as major natural parks), can be determined by utilizing the expected population increase in the community in developing standards and/or factors such as developed by the Office of Technology Assessment for Delaware and New Jersey.1/ Similarly, estimates of the demand for neighbourhood recreational facilities are based on estimates of the population increase for each neighbourhood. Where growth rates for the population in a particular neighbourhood are unavailable, it can be assumed that the population of each neighbourhood will grow at the same rate as the whole community unless available knowledge suggests otherwise.

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1/ BDM Corporation, December 1975 "Final Report: Study of New Use Demands on the Coastal Zone and Offshore Areas of New Jersey and Delaware, Appendix IV, "Employment and Infrastructure Effects of Offshore Development", A Technical Report submitted to the Office of Technology Assessment, Contract OTA-C-8, Vienna, Virginia.

2. Physical-Ecological Impacts

The potential physical-ecological effects of offshore oil development are differentiated below according to the particular system involved, e.g., production, transmission, utilization, etc. The extent and nature of potential impacts vary significantly enough to require such distinctions when discussing offshore oil development.

(a) Offshore recovery and transmission systems

The major ecological disturbances caused by offshore development are:

(a) Water pollution caused by discharges during drilling.

(b) Water pollution caused by discharges during pumping and preliminary pumping of the oil stream on the platform.

(c) Pollution caused by oil spills from well blowouts and

(d) Disruption of benthic (bottom) organisms.1/

Accidental release of gas could be considered ecologically inconsequential, while exploratory activities (seismic work and exploratory drilling) will likely involve very minor disturbances to marine life and to human uses of the ocean. Other possible disturbances that may occur include chronic discharges of oil formation water (brines) from platforms during production, disposal of drill cuttings and drilling mud during exploration and development and disposal of trash, garbage and sewage. Properly controlled, the combined effect of disposing of these wastes is unlikely to be significant, unless the platform is located in an ecologically vital area. Improperly controlled, the effect can be significant, say, in the release of oil with the discharge of "formation water".2/

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1/ The general nature of these effects and references to current literature can be found in the reports of recent IOC symposia on oil pollution and in the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) Working Group Reports.

2/ Formation water is interstitial water present with petroleum or natural gas in reservoirs.

2. Offshore oil and gas transmission systems

The principal component activities for delivering offshore oil and gas to shore and for transferring and reshipping crude and processed hydrocarbons over or under water are:

(a) Tankers or barges that may receive hydrocarbons directly from offshore wells or from onshore reshipment terminals;

(b) Offshore mooring and transfer stations for tanker loading from wells or for transfer of hydrocarbons at sea and

(c) Pipelines used for direct transmission of hydrocarbons from offshore wells to onshore facilities.

Two ecological problem areas of great concern are benthic (bottom) habitat disruption and oil spills. Benthic habitat disruption occurs in the process of laying pipelines, particularly in the shallower coastal waters where the pipeline is laid under the bottom by a "bury barge" which both digs the trench and lays the pipe.[1/] Oil spills may occur anywhere along the transport route because of pipeline rupture, tanker accidents, and routine tanker operations such as discharge of bilge washings.

Most tanker accidents from collisions or groundings resulting in large spills occur in heavily travelled or shoal water areas, which are usually near the environmentally sensitive coastline.

The possibility of large oil spills first arises during exploratory drilling. Oil and gas, held under pressure in porous subsea rock layers, may be vented by a well placed drillhole. If not controlled, the well would then become a "gusher", once welcomed, as a sign of success, but now carefully avoided, especially,

1/ A bury barge is a towed barge specifically equipped with underwater boring and pipe-laying equipment.

in offshore development.[1/] Complex blowout preventers incorporating many backup systems and steel well casings firmly cemented in place are now usually employed to reduce the likelihood of a blowout.

More than 70 per cent of all oil discharged or spilled from tankers is during routine operations, particularly bilge washings. Increasingly more tankers have separate ballast systems, as international codes and conventions are more widely adopted but many tankers still load the empty oil tanks with seawater for the return leg of a journey. Oily ballast water is then discharged upon arrival. An additional source of pollution is spillage from tankers during transfer operations. Mechanical failure, faulty design, and human error account for most of these accidents.

Construction disturbance associated with pipeline installations begins with trenching of bottom sediments by sleds during pipe burial. This causes an increase in turbidity and displaces benthic organisms or disrupts their habitat. It is impossible to assess the effects of short-term, episodic increases in turbidity on local ecology, based on current knowledge.

(a) Onshore terminals and transmission system

New marine terminals may disturb fish and wildelife and their habitats, especially when the terminals are located outside of existing harbours. Major impact generating activities include, onshore pipeline installation, channel dredging, pier and dock construction, oil and gas transfer operations, development of water supply and disposal of wastewater. Other potentially important sources of disturbance with adverse effects on fish and wildlife are site clearing and grading activities, new highways, rail

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1/ A gusher is an oil well with an enormous natural and spontaneous flow of oil.

connexions and solid waste disposal.

A new shoreline marine terminal system may require extensive channel, berthing, and turning basin dredging, as well as maintenance dredging, to the depth necessary to accommodate the marine terminal vessels. Therefore, nearshore terminals are often preferred, since they reduce dredging requirements and subsequent alterations to shoreline systems.

A new marine terminal requires the construction of an onshore pipeline to link the loading/unloading facilities with storage tanks. A pipeline corridor from the landfall to the storage and pumping facility and then, perhaps to a distant processing facility can cause significant disturbance if routed, to endangered species habitats or other vital areas. Pipeline installation activities--such as trenching, disposal of excavated material and backfilling--may have to conform to strict environmental standards, especially when crossing wetlands and water courses, to minimize disturbances to fish and wildlife and their habitats.

The major sources of solid waste problems from marine terminal systems are storage tanks and pipeline sludges. Periodically, sediment sludges which have built up in pipelines and tank bottoms are removed to containment facilities to prevent infiltration of toxic compounds into adjacent soils, ground or surface waters. Oil brine separator sludges also contain toxic compounds, including ammonia, sulphur, and ferric chloride, that require special storage and treatment.

Tanker bildge and ballast waters are the major sources of waste water at a marine terminal. Bilge water accumulated by tankers, tug boats and other service boats is usually contaminated by fuel and oil leakage, and by metallic compounds from the machinery. The bilge water requires collection and treatment before it can be discharged to receiving waters.

Both spills and leaks may occur during oil and gas transfer between vessels and storage tanks. Althóugh spills are usually due to human error, they may also result from equipment and structural failures in such components as manifolds, pumps, and valves. Other potential points of structural and equipment failures include storage tank rupture or leak, hose rupture and line or pipe leak. Protection structures for the storage tanks and pipelines, such as dikes and beams, are required to minimize the effects of spills. Gutters and collection basins on the loading pier can prevent leakage into the marine waters. Fire and explosion are also major potential hazards at the transfer terminal and storage tank farm.

(b) Maintenance yards and service bases

Onshore service bases which provide the necessary services and supplies for offshore operations are central to the oil development activity. Marine repair and maintenance yards also play a key support role.

These facilities occupy moderate size tracts of waterfront land, usually in existing developed harbours for new offshore activity where site development and road access systems may involve activities that have adverse effects. Also, the use of the waterfront sites for these facilities may involve alteration of the bay bottom and immediate shoreline.

The potential for small spills of hazardous substances is related to the level of activity in handling supplies and products, and transferring fuels. Storm water systems may require extensive reconditioning of polluted stormwater before release to coastal waters. Where hazardous products are stored, drainage dikes may be needed to collect runoff for treatment and disposal. Channels, berths and turning basins at service bases may have to be dredged to provide adequate navigational access for boats 200 feet or longer, including workboats, crewboats, tugs and drilling rigs. Supply boats equipped with bow thrusters (propellers set in transverse tunnels in the hull near the bow to aid in manoeuvering) may cause scouring and silting of the harbour bottom, and so necessitate redredging within a few years after initial construction. Because service bases and repair yards are often located in developed harbours, they are typified by the accumulation of contaminated bottom sediments. Because heavy metals, hydrocarbons and other toxic compounds may be prevalent in the sediments, dredging existing harbours to improve navigation for offshore craft may require special techniques to reduce the resuspension of pollutants, as well as elaborate precautions in spoil containment and disposal.

(c) <u>Oil refineries</u>

Oil refineries are large, complex and highly visible industrial facilities which handle highly inflammable products, consume large amounts of water, require large tracts of land, and may emit noise and air pollution as well as large amounts of air pollutants. They may have a number of major adverse effects on fish and wildlife and their habitats, resulting from their large freshwater demand; appreciable discharges of polluted wastewater; large amounts of solid waste, and site preparation activities during construction.

The electrical energy requirements for a refining operation depend on the complexity and efficiency of the processing units. The refinery may generate its own electrical power or purchase from commercial sources. In either case, the additional power generated for the oil refinery may also entail production of more thermal effluents and pollutants, with such accompanying problems as entrainment of marine life in cooling water. For instance, a 200,000 barrels per day refinery may use over 25 million gallons of water per day for cooling.

Although air pollution and noise are assumed to have minor effects on fish and wildlife, these disturbances do have major direct impacts on humans and therefore may be critical in siting, design, construction and operation of refineries. Sources of high noise levels are compressors, boilers, furnaces, blowers and cracking unit coolers. A modern refinery, which uses the best available technology for suppressing noise and has an adequate buffer area between its neighbours and processing units, can significantly decrease noise annoyance.

Major emissions to the atmosphere from a refinery may be generated from elements of the processing system, such as cracking and coking units; from machinery, such as boilers and compressors; and from leaks in pipes, valves, seals and storage tanks. The concentrations of these emissions, which include hydrocarbons, oxides of sulphur and particulate matter, depend on the chemical characteristics of the crude oil, the types of processing units and the pollution control equipment installed. Refinery odour emission sources are storage tanks, hydrocarbon contaminated wastewater, pipeline leaks, and leaks of liquids and gases from the process units.

Wastes containing high concentrations of toxic and combustible contaminants such as water treatment, storage tank and separator sludges, require special collection and disposal methods. Fluid bed incineration has replaced ocean dumping, deep well injection, and evaporative lagoons as the preferred disposal technique for contaminated sludges.

(d) Petrochemical industries

Petrochemical plants, in general, have a "refinery look" with their typical mass of piping network plumbing. They are also highly visible industrial complexes that may heavily rely on local land and water resources and cause major noise, odour and pollution problems. Because of the favourable economics of a nearby source of feedstock, the advantage of concentrated services and labour force and the value of local acceptance, most new petrochemical plants are located near refineries, gas processing plants or existing hydrocarbon plants.

Like other major facilities related to petroleum development, petrochemical plants may produce a number of adverse effects on fish and wildlife and their habitats. Major impact generating factors include large fresh water demand, large volumes of waste water effluents, large volumes of solid waste, extensive site preparation, and great runoff potential. Many other sources of disturbance to fish and wildlife may become significant such as electric power requirements and hazardous chemical spills.

Air pollution, noise and odours from petrochemical plants probably have only minor effects on fish and wildlife. However, these disturbances do directly affect human beings and are major considerations in the siting, design, construction, and operation of petrochemical plants.

Quantities of atmospheric emissions from petrochemical plants depend on the volume of material flow through the plant, the types of chemical compounds produced, plant complexity, and the kinds of air pollution abatement equipment used. Major process emissions from a typical plant are toluene, propylene, styrene, and polyethylene. Furnace and cracking operations can release large quantities of carbon monoxide. Machinery and equipment, including heaters and generators, are also major sources of emissions. Evaporative hydrocarbon emissions from fuel storage tanks, and leaks from pipelines, valves, and seals also contribute to air emission problems. Petrochemical plant emissions become more critical when they mix with those from adjacent petrochemical plants, refineries, and gas processing plants.

Major sources of noise at petrochemical plants are air coolers, blowers, compressors and furnaces. Noise levels from these types of equipment can be controlled by the use of mufflers, modifications in design or enclosures. The effects of unpleasant odours can be mitigated by site selection, provision of buffer areas and design techniques.

(d) Gas processing plants

If natural gas is produced from the offshore development in commercial quantities, it is usually passed through processing stages to remove impurities such as carbon dioxide and hydrogen sulphide, and recover valuable hydrocarbons such as methane, butane and propane, before the gas stream enters the commercial distribution system. If the raw gas stream contains a lot of oil or water, these are usually separated from the gas on the production platform. The oil may be pumped ashore; the water is treated to remove hydrocarbons and then discharged into the sea. The separated gas is pumped to shore through a separate pipeline for processing at a gas plant.

Potential sources of adverse effects on fish and wildlife from gas processing plants include fresh water demand, contaminated wastewater and solid wastes, and site development activities. Stormwater runoff and cooling system effluents also may affect fish and wildlife.

Additional potential sources of disturbance are associated with related, dependent facilities. Pipelines are particularly important because a gas processing plant requires a pipeline connection made directly from the production platform or from a marine terminal. It may also be linked by pipeline to partial processing facilities or pressurized gas storage facilities.

Emissions from a gas processing plant may come from processing units, evaporation, flaring, and equipment such as boilers and compressors. Effects from the emissions vary, depending on the composition of the gas stream, the types of processing units, the pollution control equipment, and the regional ambient air conditions. Emissions may include hydrogen sulphide, sulphur oxides, hydrocarbons, particulates, carbon monoxide and nitrogen oxides.

Major sources of noise from gas plants, which operate 24 hours a day, include compressors, boilers, scrubbers and flare stacks. Where gas is stored underground in salt domes, the discharge of brine solution to create storage caverns may also be a pollutant.

(e) Liquefied natural gas systems (LNG)

Where there exists a significant market and use for gas at long distances from the shore, liquefied natural gas (LNG) systems provide a convenient means of transportation in place of pipelines. They are very expensive to build and operate, and are only economically feasible where there is an assured market for gas and the production at the source is abundant.

Liquefaction plants are located as near as possible to the gas field. They receive gas piped from the field, remove impurities, and successively cool and compress the gas until it is below the boiling temperature. This causes a more than 600-fold reduction in volume and converts the gas into a liquid. From the liquefaction plant, the LNG is loaded into a specialized tanker for transport to the regasification site.

An important safety consideration that applies to the entire LNG system is that LNG spills create serious major hazards from fire and explosion.

LNG plants have a moderately high potential for adverse environmental effects involving deepwater marine terminals and associated long piers, site clearing and grading, onshore pipelines necessary to transport the gas to market, and some aspects of pollution control. The use of adjacent surface water or groundwater in heating or cooling the gas and the integrity of pipeline connections are of particular importance.

Emissions to the atmosphere may be present in the form of vaporized LNG or natural gas, produced during transfer and from storage tank vents. Natural gas vapor is commonly used to fill the space over the liquid in LNG ship tanks and sotrage tanks. LNG vapors may also be used as fuel for vaporizing LNG, flared or compressed, and sent out through the gas transmission lines. An accident that released LNG to the atmosphere could result in catastrophic explosions and fire.

(f) Disturbance Potential of Standard Onshore Projects

This section will discuss the major construction and operation activities directly related to the offshore programme, but primarily based onshore, and the ecological disturbances that may arise from them. This will be presented here in the form of standard projects which form the basic engineering work units involved in implementing the variety of offshore related projects described in the previous sections. In addition to the effects of primary offshore facility development, a wide range of impacts on coastal communities from secondary development ranging from roadways to mosquito control should be anticipated.

(g) Navigation improvements

Navigation improvement will constitute a major project in the off-shore development activities in the region, and will include navigation channels, turning basins, berthing spaces, harbours, canals and marinas. Because of the relatively low level of technological development in most areas of this region, navigational projects most probably will encompass, in addition, the excavation of waterways in presently non-navigable areas (i.e. canals cut through land) or those dug primarily for real estate development.

The major activities associated with navigational improvement projects are dredge operations and spoil disposal. A variety of ecological disturbances may be associated with these activities within the coastal water basins. Habitat alteration has particularly high potential for generating damage to coastal ecosystems and reducing biotic carrying capacity. Major potential ecological effects include: increased turbidity, sediment buildup, reduction of oxygen content, disruption and alteration of productive estuarine bottoms and their biota, creation of stagnant deepwater areas, disruption of estuarine circulation and increased upstream intrusion of salt water and sediments.

Apart from increased water turbidity, there are other problems associated with dredging such as the release of large quantities of trapped nutrients, organic materials, and toxic pollutants.

The disposal of spoils may cause economic and environmental problems. Polluted spoil with high concentrations of heavy metals, pesticides or other contaminants susceptible to resuspension when dredged, poses a significant threat to estuarine areas. Consequently, bottom materials to be dredged must be analyzed for pollutants type and content. Several methods of treating spoil to remove contaminants and to improve the quality of effluent from dewatering operations at disposal sites are possible. Treatment methods include flocculation, filtration, aeration, incineration, chemical processes, and sewage plant treatment, but these are all expensive.

(h) Piers

Structures that extend into navigable waters for the mooring of watercraft or other purposes, including fixed docks, wharfs, quays, and similar mooring structures are generally categorized as piers. In relation to primary offshore development, piers are built to service a variety of vessels, including those that carry personnel, equipment and materials to offshore oil and gas fields, that bring materials to onshore facilities, and that transport oil or gas. In relation to secondary population growth, piers are built primarily for private recreational craft.

Disturbances to fish and wildlife resources occur when piers are improperly designed and or sited, blocking vital tidal circulation, preempting wetlands, or disrupting the littoral environment. The construction and long-term disturbances from piers may also have adverse effects, such as pollution from miscellaneous discharges and debris and from bottom scour by boat propellers, bow thrusters, and vessel contact with the bottom.

A dense accumulation of individual piers can cause a major obstruction of water flow along the shoreline, as well as significantly litter and pollute the water (e.g. leaks or spills of oil and gasoline) or restrict water area use for fishing and recreational boating.

(i) Bulkheads

Bulkheads referred to here are the structures usually placed in protected waters in the intertidal zone. A bulkhead is a vertical wall of wood, steel or concrete, built parallel to the shoreline and designed to reflect waves and control erosion. In relation to offshore primary development, bulkheads are usually built to provide boat docking capabilities for loading and unloading of heavy materials or to hold fill deposited to convert wetlands and low-lying shoreland to industrial sites. In relation to offshore secondary development, these structures are built to extend land, to protect the shoreline from erosion, provide boat docking convenience, or serve aesthetic purposes.

Bulkheads built in the coastal zone have a high potential for adverse effects on fish and wildlife and their habitats. If not properly located and designed, they eliminate valuable wetlands and vital areas, adversely alter the shoreline through scouring and change in water flow, interfere with runoff, and cause general ecological degradation of the land-water interface.

Major environmental objections to bulkheading arise from the associated loss of coastal marsh and other vital habitat areas, the potential reduction in size of water bodies, the accompanying water pollution, and the interruption of the movement of fresh water into adjacent estuaries. The adverse effect is potentially greatest, when the outer periphery of a coastal marsh is bulkheaded and then covered with dredge spoil from the bay bottom or upland fill material in order to extend property lines.

The proliferation of bulkheads along the shores of an estuary is generally associated with massive ecologic degradation and serious reductions in carrying capacities. Any one of numerous small bulkheads may have a lesser effect when looking at an entire coastline but the accumulation of bulkheads may eliminate a high proportion of the total wetlands and natural shoreline segments.

(j) <u>Beaches</u>

Beaches and dunes shift with changes in the balance between the erosive forces of storm winds and waves, on the one hand, and the restorative powers of tides and currents, on the other. The natural beachfront exists in a state of dynamic tension, continually shifting in response to waves, winds, and tide and continually adjusting towards a point of equilibrium. Protective structures, therefore, must be built to stabilize and safeguard beachfront facilities. Long-term stability is gained by holding the beach's natural repose (slope) or profile intact through balancing the sand reserves held in various storage elements--dune, berm, offshore bar, and so forth. Each component of the beach profile is capable of receiving, storing, and yielding sand, depending on which of several constantly changing forces is dominant at that moment. Stability is fostered by maintaining the storage capacity of each of the components at the highest level..

The potential processes that disturb the equilibrium of a beach can be classified as either natural or man-made. Man-made disturbances are usually the result of construction activities within the coastal zone; however, the equilibrium of some beaches is so delicate that it can be upset just by heavy usage for recreational purposes such as by dune buggies or other vehicles.

All too often, protective measures fail to accomplish their intended purpose, or they necessitate corrective action, elsewhere on the coastline, because of their disruption of the beach equilibrium. The construction disturbances may also cause long-term adverse effects such as elimination of beach area and maintenance dredging of harbour inlets. To prevent such troubles, it is necessary that a thorough study and comprehensive protection plan be developed before structures are authorized. Detrimental structures already in place should be scheduled for removal or replacement at the earliest opportunity.

Waterways

At low-lying sections of coastal communities, the land available and desirable for growth may require drainage before construction. Many communities that would attract onshore facilities in the region are in low-lying eoastal areas with considerable water soaked land. This is particularly true of the adjacent cities of Warri and Port Harcourt and their environs in the oil producing fields of the south-eastern coast of Nigeria. Drainage of these wetlands by constructing canals and ditches may be required (including the use of excavated material as fill for the adjacent land) in these areas. Canals may be dug to provide boat channels back onshore or ditches may be dug to drain land for mosquito control. Whatever the specific reason, canal, ditch and artificial lake excavation can have serious adverse effects. For instance, when the natural flow pattern is disrupted, the water-cleansing function of the surrounding vegetation is reduced and fresh water flow into the estuaries can occur in surges. In addition, drainage may result in the shrinkage of organic soils and subsidence of land, and eliminate the critical ecological functions of wetlands.

Roadways and Bridges

The new population and community outgrowth of offshore activities will necessitate the construction and or improvement of existing roadways. If there is sufficient need for road expansion which requires crossing tidal rivers, bays or wetlands, there is considerably higher potential for adverse ecological effects. A particular problem is associated with solid fill causeways because they block the upper portions of estuaries leading to stagnation which, if unchecked, may result to total deterioration of the estuaries. Roadways may obliterate wetlands due to the need to (a) fill them for roadbeds and approaches; (b) dig channels through them to provide accessways for equipment and (c) use them as spoil disposal sites (a function which may block wetland tidal flows).

Water Supply Systems

Subsurface (groundwater) or surface water sources are generally preferable for the community's water system. In coastal areas, groundwater may be a preferable source either because of a lack of fresh surface water or the presence of easily accessible aquifers. There are problems involving both recharge and withdrawal of ground water. Water diversion caused by paved surfaces and altered water drainage may reduce the amount of natural recharge that would replenish groundwater. At the same time, overpumping of groundwater supplies near the shore can lead to the drying out of wetlands and salt intrusion into aquifers.

Sewage Systems

For a new community, the capability to handle a large sewage load, and hence a great amount of effluents has to be anticipated. Many coastal water basins receive effluents from sewage plants that contain greater concentration of nutrients, organic matter, toxic substances, and pathogenic organisms than the basin can assimilate. In low-lying areas with natural high water tables, liquid waste from septic systems may saturate the soil and cause overflow. This pollution potential from septic tanks is intensified in flood-prone areas, where high tides and storms periodically saturate the soils.

Transmission Systems

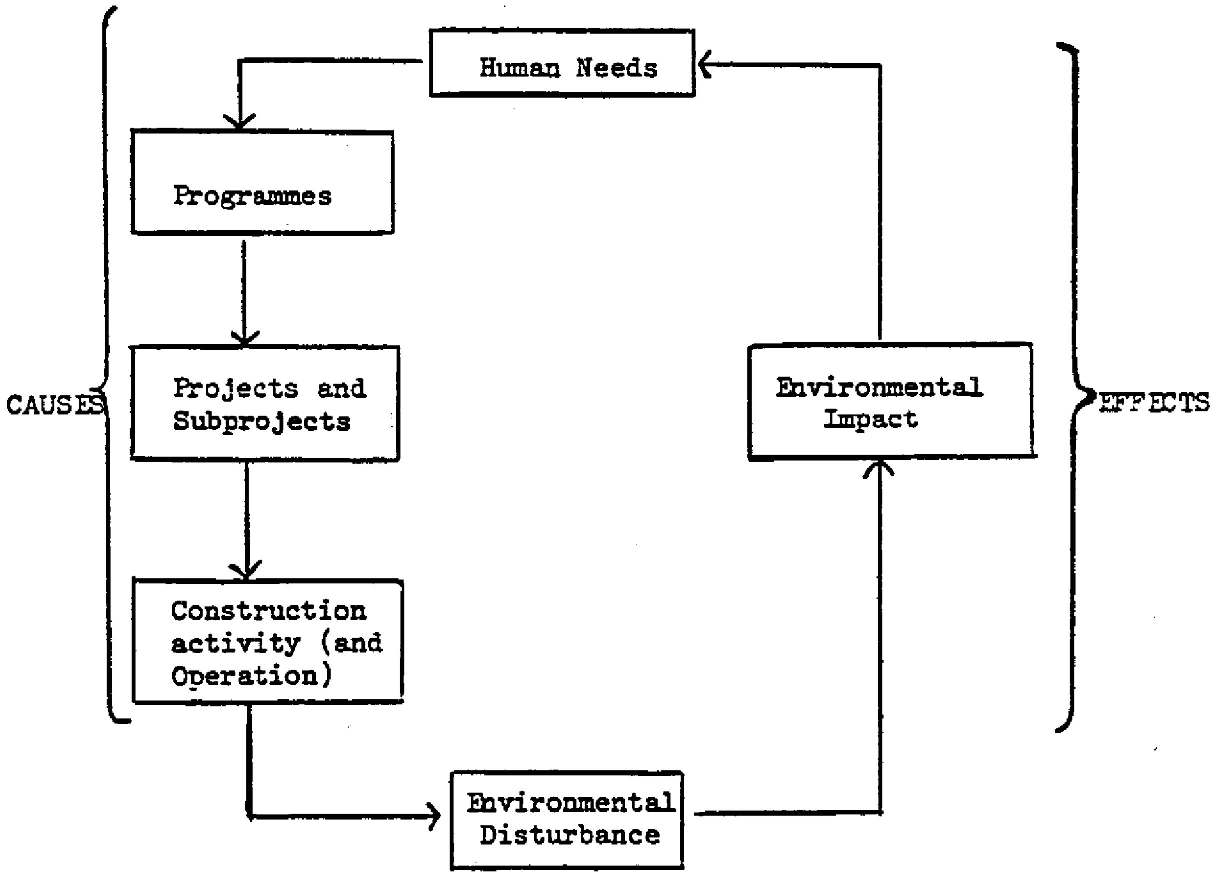
Transmission systems for electricity, water, power, gas and sewage are involved in all aspects of the community's growth. The degree of expansion and extent will depend on the size and capacity of the offshore related activities. Like roadways, these systems may obliterate vital ecological areas or degrade them during clearing, excavation, or installation. For instance, wetlands have been favourite locations for sewage gravity mains and pipe crossings.

Solid Waste Systems

Solid wastes will be generated from all aspects of the communities life--residential, industrial, commercial, recreational and so on. Solid waste disposal may present problems where, because of community growth, available disposal sites become scarce. The location of sanitary landfills is the major consideration. Solid waste land fills that preempt wetlands or other vital habitats can do considerable ecological damage.

3. Current Impact Assessment Methodologies

Most impact assessment procedures have as components standard elements linked in a chain of causes and effects that start with human needs, and at the end of the cycle, returns to human needs. This is shown thus:




The cycle starts with human needs which result in programmes that lead to the initiation of specific development projects and sub-projects, in the sense used in Sections II and III above. The implementation of projects and subprojects requires a variety of operational activities including construction. Any activity which leads to environmental disturbance sets off a series of ecological effects. If these effects degrade the ecosystem, they cause an adverse impact that detracts from human needs.

One such assessment procedure will be described here. This method, though relatively sophisticated is both simple and useful.

The assessment procedure is broken down into six steps as described below:

Step 1 - Analysis of Proposed Work Plan

Review and analyse the information to determine exact nature and the stages of the work:

- Identify subprojects (primary and secondary) and their relevant design features;
- Identify activities and their relevant construction methods and operating characteristics.

Step 2 - Selection of Activities with Significant Disturbance Potential

Check the activities in step 1 for probable generation of significant (direct) disturbance; select for analysis those with apparent (indirect) disturbance potential:

- Screen identified activities for potential (direct) disturbance to fish and wildlife and habitats.
- Select for analysis those with potential for (indirect) significant disturbance.

Step 3 - Analysis of Disturbance Potential

Consider each activity selected for analysis by the following sequence:

- Activity: Description and sources of disturbance
- Disturbances: Description and sources of adverse (or beneficial).

- Effects and impacts: Description of effects sequence and probable impacts.
- Additive and cummulative effects: Description of probable impacts.

Step 4 - Identify Beneficial Modifications to Work Plan

For each activity verified as having a significant adverse impact potential (in step 3) describe changes which might reduce impacts to acceptable levels by the following sequence (either design or performance specifications).

- Design/layout changes
- Changes in construction or operation
- Mitigation opportunities (enhancement, restoration).
- Substitute projects (location, alternative projects or subprojects).

Step 5 - Make Preliminary Technical Recommendations

Specify technical recommendations such as design criteria for specific engineering solutions or stipulate performance specifications based on comparative costs of measures in step 4.

Step 6 - Make Final Recommendation

Formulate final assessment summaries and recommendations reflecting inputs to step 5 from outside bodies interfacing on proposed project activities.

## IV. SUMMARY AND CONCLUSIONS

The impacts of offshore oil and gas development in the West African region can be segmented into those which affect the natural systems of the region and those which affect man-made systems, i.e., the economies of the region and the general social environment.

It must be remembered that the production history of the region is relatively recent, and that offshore petroleum development is dominated by a few countries, e.g., Nigeria and Gabon. Therefore, there is not much, as compared to some other regions, in the way of data and experience to draw on for planning lessons. The planning approach must look forward and perhaps anticipate potentially adverse effects of the offshore development. It must be remembered, though, that balance of payments pressures will demand that all the nations in the region pursue energy development, including offshore development, with the utmost vigour. It would be unrealistic and impractical to attempt to restrain development of these resources in this region.

The focus for action in this region should be to:

(1) Put into place certain concepts, mechanisms and institutions whereby deleterious effects of offshore energy development on the environment can be identified, assessed and traded off against domestic and international economic benefits of offshore development.

(2) Systematically build up data on environmental baselines in the region, including the human environment, and monitor changes induced by oil and gas production offshore.

In the context of West Africa, it should be mentioned that oil and gas development has already, and will likely, put much more of a strain on the social and economic systems than on the natural environment.

This is particularly true of urban areas and the pressure on services caused by the increased demands induced by oil and gas development. In any assessment of the effects of offshore oil and gas development, emphasis should be placed on the social and economic impacts.

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ANNEX 1: Regional Oil Production

| COUNTRY | Reserves (in $10^6$ barrels)[1/] | PRODUCTION 1 July 1977 No. of Producing Wells | PRODUCTION 1 July 1977 Production in $10^3$ bdp | PRODUCTION 1 July 1978 No. of Producing Wells | PRODUCTION 1 July 1978 Production in $10^3$ bdp | Per cent change in prod. fr. 1977 |
|---|---|---|---|---|---|---|
| Angola | 1,365 | 157 | 195 | 182 | 130 | -33.0 |
| Cameroon | 143[3/] | - | - | 13 | 10 | - |
| Congo | 746 | 97 | 35 | 107 | 28 | -15.2 |
| Gabon | 467 | 240 | 225 | 211 | 170 | -24.4 |
| Ghana | NA[2/] | - | - | - | - | - |
| Ivory Coast | NA[2/] | - | - | - | - | - |
| Liberia | NA | - | - | - | - | - |
| Nigeria | 12,273 | 1,374 | 2,150 | 1,322 | 1,800 | -16.3 |
| Senegal | NA | - | - | - | - | - |
| Sierra Leone | NA | - | - | - | - | - |
| Togo | NA | - | - | - | - | - |
| Zaire | 126 | 12 | 24 | 12 | 20 | -16.7 |
| Regional Totals | 21,792 | 1,860 | 2,629 | 1,847 | 2,158 | -17.9 |

1/ World Oil August 15, 1979

2/ Recently joined the ranks of oil producers

3/ Additional oil discoveries were made in 1979

ANNEX 2: Regional Production by Field

| COUNTRY | Field | Date of Discovery | Depth in Feet | No. of Flows Wells | Avg. bdp. 1st six months 1978 | Location |
|---|---|---|---|---|---|---|
| 1. Angola | Bento | 1972 | 7,500 | 2 | 740 | Onshore |
| | N'Zombo | 1973 | 6100-6300 | 17 | 19,530 | Onshore |
| | Quenguela N. | 1968 | 4900-6200 | - | 2,814 | Onshore |
| | Quinfuqueng | 1975 | 6800-7050 | 5 | 5,974 | Onshore |
| | Quinguila | 1972 | 4700 | 1 | 6,257 | Onshore |
| | Other | | 2100-9900 | 4 | 1,575 | Onshore |
| (Cabinda) | Malongo, N | 1966 | 1500-8500 | 11 | 94,625 (Malongo, N – 121-02) | Offshore |
| | Malongo, S | 1966 | 1300-1600 | 4 | | Offshore |
| | Malongo, W | 1969 | 1800-8750 | 19 | | Offshore |
| | 95-03 | 1969 | 10,650 | 1 | | Offshore |
| | 121-02 | 1971 | 11,100 | - | | Offshore |
| 2. Cameroon | Kole | 1974 | 5,500 | 13 | 10,000 | Offshore |
| 3. Congo | Emeraude | 1969 | 1,000 | - | 27,440 | Offshore |
| | Lioango | 1972 | 3,000 | - | Not avail. | Offshore |
| | Pointe Indienne | 1957 | 5,000 | 2 | 240 | Onshore |
| 4. Gabon | Clairette | 1956 | 8,200 | 130 (Clairette – Anguille, SW) | 878 | Onshore |
| | Tchengue | 1958 | 8,200 | | 2,164 | Onshore |
| | Tchengue Ocean | 1962 | 8,200 | | 750 | Offshore |
| | Anguille | 1962 | 9,514 | | 14,591 | Offshore |
| | Anguille, NE | 1968 | 8,200 | | 5,754 | Offshore |
| | Anguille, SW | 1968 | 7,335 | | 1,147 | Offshore |

| C O U N T R Y | Field | Date of Discovery | Depth in Feet | No. of Flow Wells | Avg. bpd 1st six months 1 9 7 8 | Location |
|---|---|---|---|---|---|---|
| Gabon (cont'd) | Port Genlit Ocean | 1964 | 8,200 | | 2,671 | Offshore |
| | Torpille | 1968 | 10,000 | | 16,087 | Offshore |
| | P.G.S. Marine | | 9,185 | | 2,796 | Offshore |
| | Barbier | 1973 | 7,710 | | 24,431 | Offshore |
| | Mandaros | 1972 | 6,400 | | 19,908 | Offshore |
| | Girelle | 1971 | 11,975 | | 8,894 | Offshore |
| | Gonelle | 1972 | 5,700 | | 9,167 | Offshore |
| | Doree | 1972 | 8,890 | | 8,890 | Offshore |
| | Batanga | 1960 | 529 | | 529 | Offshore |
| | Lucina-Marine | 1971 | - | 6 | | Offshore |
| | Gamba | 1963 | 3,000 | 32 | 12,002 | Onshore |
| | Ivinga | 1967 | 3,100 | 23 | 16,971 | Onshore |
| | Other | | | | 11,830 | Onshore |
| 5. Nigeria | Delta | 1965 | 5600- 9580 | 24 | 17,936 | Offshore |
| | Delta, South | 1965 | 7100-10179 | 21 | 27,669 | Offshore |
| | Isan | 1970 | 5900- 9000 | 8 | 8,735 | Offshore |
| | Malu | 1969 | 4800- 6300 | 12 | 7,135 | Offshore |
| | Mefa | 1965 | 5300- 9300 | 5 | 2,995 | Offshore |
| | Meji | 1965 | 5200-10900 | 19 | 21,565 | Offshore |
| | Meren | 1965 | 5000- 7500 | 41 | 48,205 | Offshore |
| | Okan | 1964 | 5500- 9245 | 45 | 32,820 | Offshore |
| | Parabe/Eko | 1968 | 4500- 8200 | 19 | 11,869 | Offshore |
| | West Isan | 1971 | 7825-10229 | 9 | 1,734 | Offshore |
| | Yorla, South | 1973 | 9980-11400 | 1 | 1,418 | Offshore |
| | Asabo | 1966 | 5,600 | 6 | 19,251 | Offshore |

| COUNTRY | Field | Date of Discovery | Depth in Feet | No. of Flow Wells | Avg. bpd. First 6 months 1978 | Location |
|---|---|---|---|---|---|---|
| Nigeria (Cont'd) | Adua | 1968 | 4,500 | 8 | 12,730 | Offshore |
| | Ekpe | 1966 | 7,650 | 10 | 19,178 | Offshore |
| | Eku | 1966 | 5,420 | 5 | 3,558 | Offshore |
| | Ehang | 1968 | 5,600 | 21 | 22,618 | Offshore |
| | Etim | 1968 | 6,200 | 6 | 14,380 | Offshore |
| | Idoho | 1966 | 8,536 | 3 | 2,373 | Offshore |
| | Inim | 1966 | 6,650 | 7 | 16,339 | Offshore |
| | Mfem | 1968 | 5,175 | 3 | 6,436 | Offshore |
| | Ubit | 1968 | 4,842 | 34 | 23,345 | Offshore |
| | Unam | 1968 | 5,150 | 3 | 7,450 | Offshore |
| | Utue | 1966 | 5,700 | 4 | 8,269 | Offshore |
| | Pennington | 1965 | 5,000-7,000 | 4 | 3,867 | Offshore |
| | Middleton | 1972 | 5,000-7,000 | 2 | 3,639 | Offshore |
| | North Apoi | 1973 | 4,000-7,500 | 12 | 33,857 | Offshore |
| | Aghigho | 1972 | 6,000-8,500 | 1 | 4,600 | Onshore |
| | Okpoko | 1967 | 6,000-7,500 | 2 | 4,660 | Onshore |
| | Obodo-Jatumi | 1966 | 6,000-11,000 | 10 | 14,050 | Onshore |
| | Upomami | 1965 | 6,000-7,000 | - | 3,720 | Onshore |
| | Obagi | 1964 | 6,000-7,000 | 25 | 51,640 | Onshore |
| | Erema | 1972 | 9,800 | 1 | 1,030 | Onshore |
| | Abiteye | 1970 | 5,750-9,400 | 7 | 5,939 | Onshore |
| | Makaraba | 1973 | 7,100-12,005 | 13 | 11,194 | Onshore |
| | Utonana | 1971 | 7,400-9,165 | 2 | 2,943 | Onshore |

| COUNTRY | Field | Date of Discovery | Depth in Feet | No. of Flow Wells | Avg. bpd. First 6 Months 1978 | Location |
|---|---|---|---|---|---|---|
| Nigeria (Cont'd) | Ogharefe | 1973 | 9,900 | 13 | 10,310 | Onshore |
| | Izombe | 1974 | 9,500 | 9 | 7,900 | Onshore |
| | Ossu | 1974 | 9,000 | 2 | 845 | Onshore |
| | Ebocha | 1965 | 8,000-10,900 | 12 | 19,466 | Onshore |
| | Mbede | 1966 | 7,300-9,400 | 13 | 26,910 | Onshore |
| | Akri | 1973 | 9,600-10,600 | 7 | 18,970 | Onshore |
| | Odugri | 1972 | 12,500 | 2 | 2,437 | Onshore |
| | Obiafu | 1973 | 9,300-12,200 | 11 | 23,546 | Onshore |
| | Obrikom | 1973 | 8,000-10,000 | 8 | 13,060 | Onshore |
| | Idu | 1973 | 7,750-10,700 | 3 | 5,889 | Onshore |
| | Oshi | 1974 | 9,600-11,300 | 7 | 13,535 | Onshore |
| | Obama | 1975 | 11,600-14,300 | 7 | 26,815 | Onshore |
| | Tebidada | 1975 | 10,300-13,300 | 8 | 38,926 | Onshore |
| | Omoku West | 1975 | 11,500 | 1 | 2,412 | Onshore |
| | Akri West | 1975 | 9,900-10,200 | 1 | 847 | Onshore |
| | Ogbogene | 1976 | 11,500-12,500 | 2 | 1,912 | Onshore |
| | Ebegoro | 1976 | 11,500-12,000 | 8 | 25,425 | Onshore |
| | Ugh-Ogini | 1964 | 5,560 | 7 | 4,463 | Onshore |
| | Ugh-Uzere, E | 1960 | 8,500 | 13 | 12,333 | Onshore |
| | Ugh-Uzere, W | 1960 | 8,500 | 11 | 10,457 | Onshore |
| | Ugh-Olomoro | 1963 | 7,000-10,000 | 25 | 19,043 | Onshore |
| | Ugh-Uweh | 1964 | 12,300 | 10 | 5,769 | Onshore |
| | Ugh-Kokori | 1961 | 8,000-9,800 | 17 | 35,332 | Onshore |

| COUNTRY | Field | Date of Discovery | Depth in Feet | No. of Flow Wells | Avg. bpd. First 6 months 1978 | Location |
|---|---|---|---|---|---|---|
| Nigeria (Cont'd) | Ugh-Afiesere | 1966 | 8,000-9,000 | 31 | 33,837 | Onshore |
| | Ugh-Eriemu | 1961 | 12,500 | 12 | 9,451 | Onshore |
| | Ugh-Ughelli,E | 1959 | 11,800 | 8 | 8,882 | Onshore |
| | Ugh-Ughelli,W | 1959 | 7,400-10,200 | 6 | 3,842 | Onshore |
| | Ugh-Utorogu | 1964 | 9,000 | 18 | 15,405 | Onshore |
| | Ugh-Oroni | 1964 | 12,000 | 5 | 4,777 | Onshore |
| | Ugh-Warri R | 1961 | 12,264 | 3 | 3,500 | Onshore |
| | Ugh-Evwreni R | 1967 | 10,900 | 4 | 3,378 | Onshore |
| | Ugh-Rapele | 1965 | 12,934 | 3 | 3,893 | Onshore |
| | Ugh-Osioka | 1967 | 12,885 | 2 | 1,167 | Onshore |
| | Forc-Odidi | 1967 | 10,980 | 18 | 32,971 | Onshore |
| | Forc-Jones Cr | 1967 | 7,000-9,000 | 26 | 68,912 | Onshore |
| | Forc-Egwa | 1967 | 9,350 | 17 | 24,818 | Onshore |
| | Forc-Forc/ Yorkri | 1971 | 10,359 | 70 | 95,744 | Onshore |
| | Forc-Batan | 1968 | 11,000 | 7 | 13,109 | Onshore |
| | Forc-Escravos Beach | 1969 | 9,931 | 7 | 12,825 | Onshore |
| | Forc-Otumara | 1970 | 8,176 | 20 | 21,842 | Onshore |
| | Forc-Saghara | 1970 | 8,590 | 3 | 6,434 | Onshore |
| | Forc-Ajuju | 1970 | 13,324 | 1 | 2,127 | Onshore |
| | Node-Sapele | 1970 | 12,788 | 11 | 20,834 | Onshore |
| | Node-Amukpe | 1970 | 12,378 | 2 | 1,406 | Onshore |
| | Ugh-Isoko | 1960 | - | 2 | 2,395 | Onshore |

| COUNTRY | Field | Date of Discovery | Depth in Feet | No. of Flow Wells | Avg. bpd. First 6 Months 1978 | Location |
|---|---|---|---|---|---|---|
| Nigeria (Cont'd.) | Forc-Opukushi | 1963 | - | 9 | 15,177 | Onshore |
| | Ilode-Oben | 1972 | 12,036 | 15 | 18,680 | Onshore |
| | Forc-Opuama | 1973 | - | 4 | 7,307 | Onshore |
| | Forc-Benisede | 1973 | - | 10 | 10,499 | Onshore |
| | Fnl-Boma | 1968 | 6,700-7,500 | 19 | 23,954 | Onshore |
| | Fnl-Imo R | 1968 | 5,800-10,000 | 36 | 45,132 | Onshore |
| | Fnl-Onne | 1965 | 10,384 | 3 | 1,420 | Onshore |
| | Fnl-Nkali | 1963 | 12,000 | 3 | 2,807 | Onshore |
| | Fnl-Obigbo, N. | 1963 | - | 18 | 19,832 | Onshore |
| | Fnl-Ajokpori | - | - | 2 | 1,114 | Onshore |
| | Fnl-Elelenwa | 1959 | 11,000 | 5 | 4,420 | Onshore |
| | Fnl-Agbada | 1960 | 8,000-12,000 | 27 | 15,127 | Onshore |
| | Fnl-Otamini | 1973 | - | 3 | 2,434 | Onshore |
| | Fnl-Umuechem | 1959 | 5,800-10,700 | 11 | 11,598 | Onshore |
| | Fnl-Tai | 1965 | - | 2 | 986 | Onshore |
| | Fnl-Apara | 1960 | 9,000 | 5 | 4,900 | Onshore |
| | Fnl-Akuba | 1967 | - | 1 | 619 | Onshore |
| | Fnl-Afam | 1956 | 6,000 | 13 | 11,336 | Onshore |
| | Fnl-Korokorc | 1969 | 8,000-9,800 | 7 | 6,389 | Onshore |
| | Fnl-Yorla | 1970 | 11,917 | 10 | 7,842 | Onshore |
| | Fns-Bonny | 1959 | 12,254 | 13 | 12,118 | Onshore |
| | Fns-Alakiri | 1962 | 10,000 | 8 | 2,718 | Onshore |
| | Fns-Cawth, Channel | 1963 | 11,000 | 13 | 14,201 | Onshore |

| COUNTRY | Field | Date of Discovery | Depth in Feet | No. of Flow Wells | Avg. bpd First 6 Months 1978 | Location |
|---|---|---|---|---|---|---|
| Nigeria (Contd.) | Phs-Krakama | 1958 | 11,530 | 5 | 3,666 | Onshore |
| | Phs-Soku | 1958 | 11,500 | 19 | 14,086 | Onshore |
| | Egb-Oguta | 1965 | 10,300 | 12 | 22,189 | Onshore |
| | Egb-Ahia | 1965 | 11,500 | 9 | 11,690 | Onshore |
| | Cesw-Nun R | 1974 | - | 5 | 7,893 | Onshore |
| | Cesw-Enwhe | - | - | 2 | 837 | Onshore |
| | Cesw-Adibawa | 1966 | 11,950 | 17 | 7,873 | Onshore |
| | Cesw-Adibawa NE | - | - | 3 | 2,824 | Onshore |
| | Cesw-Efelebou | 1971 | 12,000 | 8 | 28,203 | Onshore |
| | Cesw-Kolo Cr. | 1974 | 12,000 | 18 | 11,257 | Onshore |
| | Cesw-Diebu Cr. | 1974 | - | 12 | 25,453 | Onshore |
| | Cesw-Ubie | 1961 | 14,380 | 4 | 4,805 | Onshore |
| | Phl-Isimiri | 1964 | 5,900-11,000 | 6 | 5,412 | Onshore |
| | Phl-Ebubu | 1958 | 8,200 | 4 | 1,245 | Onshore |
| | Phl-Obele | 1964 | 10,000 | 4 | 986 | Onshore |
| | Phl-Bodo W | 1962 | 9,700 | 9 | 8,448 | Onshore |
| | Phs-Ekulama | 1958 | 10,483 | 27 | 29,035 | Onshore |
| | Phs-Obeakpu | 1975 | - | 2 | 6,072 | Onshore |
| | Egb-Assa | 1961 | 11,300 | 2 | 1,266 | Onshore |
| | Egb-Egbema | 1960 | 10,470 | 4 | 7,725 | Onshore |
| | Egb-Egbema, W | - | - | 14 | 25,207 | Onshore |
| | Phs-Okubiri | 1971 | - | 3 | 1,841 | Onshore |
| | Other | - | - | 7 | 997 | Onshore |
| 6. Zaire | GCO- | 1970 | 7,000-9,000 | 5 | 2,480 | Offshore |
| | Mibale | 1973 | 5,000-6,000 | - | 17,363 | Offshore |

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