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MODELING THE CUMULATIVE ONSHORE EFFECTS
OF OFFSHORE OIL AND GAS DEVELOPMENT

by

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Modeling the Cumulative Onshore Effects of Offshore Oil and Gas Development

E. T. Smith and L. G. Hecht, Jr.

Introduction

The pattern of offshore oil and gas development over time can cause a series of related events to occur in an adjacent onshore coastal region. An onshore region, composed of one or a number of States, may experience varying levels of impact because of these offshore events. These events include the siting of various onshore facilities, which in turn result in of primary, secondary, and higher order effects. Such effects can, in turn, impact the physical, social, and economic structure of the region.

Modeling Requirements

Modeling Outer Continental Shelf (OCS) oil and gas developments and effects involves the use of a variety of planning and analysis techniques. Because the "OCS process" (Benton and others, 1979) generally covers long periods of time between, say, an initial lease sale, discovery of oil and gas, and the placement of a related onshore facility, an investigator must conduct an analysis using the method(s) that best matches the quantity, quality, and scale of available data.

As the OCS process in a region moves from initial phases (for example, initial lease sale, first discovery, and initial development) to mature phases, data quantity, quality, and scale tend to move from region-specific to site-specific levels of detail. Thus, analysis techniques associated with a site-specific event may be used with increasing certainty as the process of oil and gas development in a region matures over time. The problem here is to select the best set of methods to fit a given situation. Depending on the analysis to be conducted and data quantity, quality, and scale factors, several alternative methods can be employed. These methods are discussed in some detail by Williams and Hom (1979). One point to note is that given the usually large areal extent of OCS oil and gas operations in a region, the process of modeling offshore events and onshore effects for purposes of planning and evaluation is probably best approached from first a regional, and then a State perspective.

This paper concerns onshore aspects of the OCS oil and gas development process; however, planning for onshore activities requires an understanding of the scale, magnitude, and timing of offshore activities that trigger onshore actions. A number of factors usually influence the numbers and kinds of onshore facilities that eventually locate in an area, given marketable discoveries of oil and gas. Generally, these include the discovered recoverable reserves of oil and gas in an offshore basin, the number and size of oil and gas fields discovered over time, production platform requirements, timing of field development and production operations, and the location and means of product transportation and processing.

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The sequence of events that occurs during the oil and gas leasing, exploration, development, and production process has been the subject of this study, with cooperation from the New England River Basins Commission (NERBC) for a 4-year period. Much of the discussion on magnitude and timing of offshore activity and onshore facility impacts leans heavily on work done as part of the effort (New England River Basins Commission, 1978).

Magnitude and Timing of Offshore Activity

Before one can proceed with onshore facility analyses, an investigation into the functions of offshore development should be completed. Data relating to each function of the development process should then be translated into one or a series of offshore scenarios. Building a suitable and relatively certain offshore scenario requires the investigator to review historical trends about the amounts of oil and gas to be discovered over some future time period. In addition, an investigator will also need to compile the following data:

- year-by-year schedules of past oil and gas finds
- the number of past sales and tracts leased at each sale
- exploratory rig activity by lease sale
- platform requirements for discovered oil and gas fields
- platform installation schedules (past and present)
- development drilling schedules for fields presently undergoing development
- production schedules for oil and gas (past, present, and projected)

Much of the data required to construct a scenario may be obtained from Summary Reports and Indexes provided by the U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM) under CFR 30, Part 252 (Federal Register, v. 44, no. 3, part III). A scenario constructed here is based on OCS activities in southern California (see fig. 1). For example, the production function showing magnitude and timing of offshore development for the Pacific OCS from 1966 to 1979 is shown in figure 1. Supporting this graph are tables 1, 2, and 3 which show the history, status, and projections of oil and gas development and production in the Pacific OCS (ref. 4). Note that the driving force for the production function (1968-79) is in terms of more than one variable. Not only is the physical quantity of the resource considered, but also the number of platforms and development wells needed to handle this amount of production, as well as physical factors such as water depth and distance to shore. It is from these technological and physical variables, rather than the physical quantity of the resource itself, estimates of onshore development and their primary and secondary impacts are derived. In the case of the Pacific OCS, production information for figure 1 was derived from those areas that are presently producing (Dos Cuadras and Carpinteria Offshore). Other areas listed on tables 1 and 2 will begin producing at a later period. Projected oil and gas production figures are found in table 3. For purposes of scenario construction covering present and projected events, present and projected amounts of production need to be graphed.

Onshore Facilities and Their Impacts

Generally, the numbers and kinds of facilities likely to occur in a region, as a result of marketable discoveries, can be estimated from several sources, such as available historical evidence, facility inventory data, analogous development occurring in similar OCS areas, or statistical inferences extrapolated from data concerning magnitude and timing of offshore production coupled with probable energy transportation strategies. Data relating to impacts of each facility type, including land, labor,

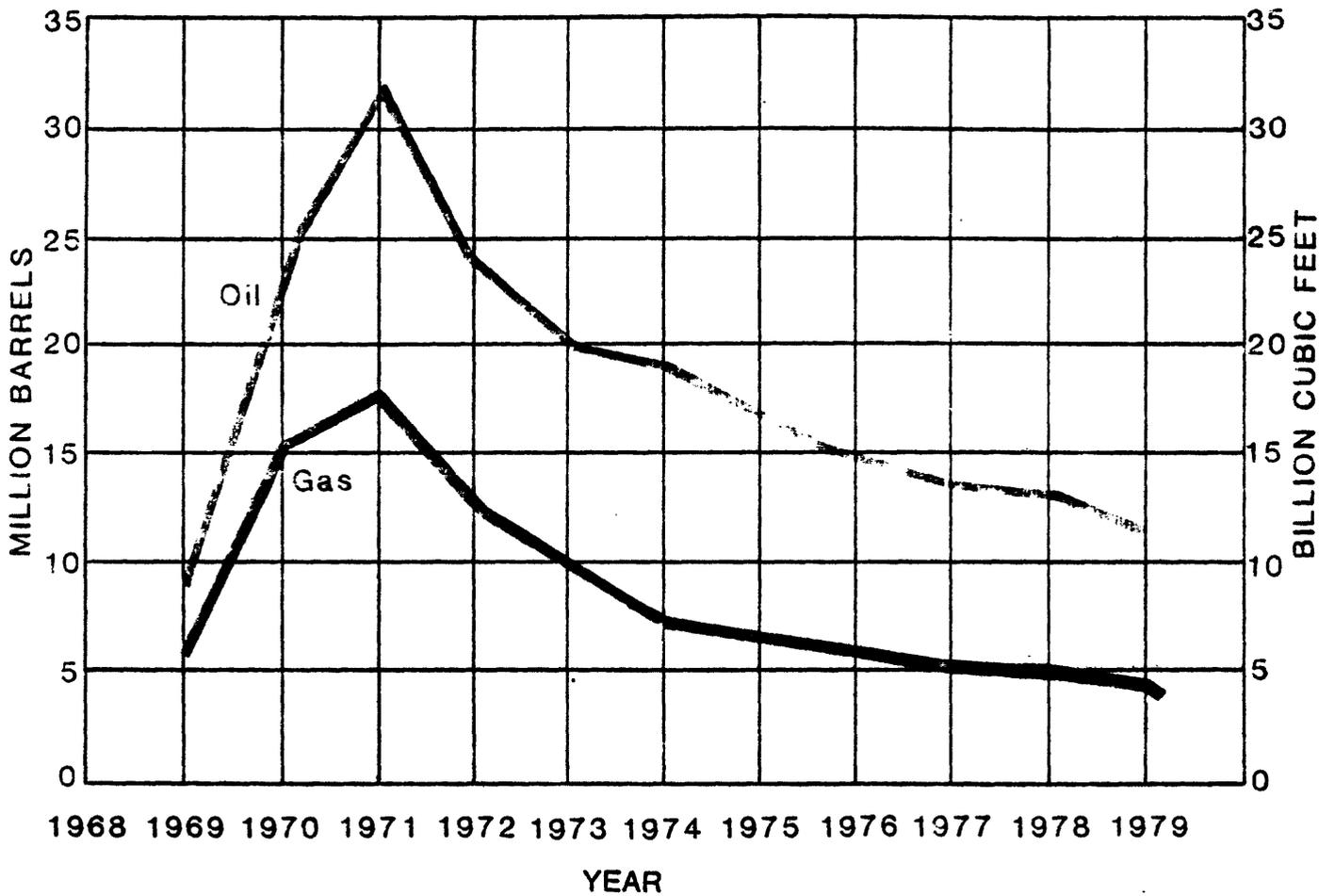


Figure 1. Annual oil and gas production from Southern California OCS, 1968-1979.

Source: Macpherson and Bernstein, 1980, p. 32.

Table 1. -- Status of development and production plans for the Southern California Outer Continental Shelf

Unit/field	Operator	Date of plan submittal	Date of plan approval	Platform(s) (P=Proposed)
Santa Ynez	Exxon	11/11/71 Rev. 8/15/72	8/16/74	Hondo
Santa Rosa	Exxon	None submitted		
Dos Cuadras	Sun	late 1960's	late 1960's	Hillhouse
	Union	5/12/77	6/9/77	A, B, C
Carpinteria Offshore	Sun	6/14/77	11/11/77	Henry
	Phillips	late 1960's	late 1960's	Hogan, Houchin
Pitas Point	Texaco	9/26/79	Pending	Pitas Point (P)
Santa Clara	Chevron	12/30/76	7/14/77	Grace
	Union	12/12/79	Pending	Gilda (P)
Hueneme Offshore	Union	5/7/79	Pending	Gina (P)
Beta	Shell	11/7/79	1/3/80	Ellen, Elly
	Shell	None submitted		Eureka (P)
	Chevron	None submitted		Edith (P)

Source: Macpherson and Bernstein, 1980, p. 26.

**Table 2. -- Current and proposed oil and gas development
off Southern California**

Unit/Field	Platform	Lease	Operator	Number of slots	Water depth (m)	Distance to shore (km)	Status
Santa Ynez	Hondo	OCS P-0188	Exxon	28	259	8	Platform installed, drilling 12th development well, awaiting OS&T installation
Santa Rosa	No development to date						
Dos Cuadras	Hillhouse	OCS P-0240	Sun	60	58	9	Producing
	A	OCS P-0241	Union	56	56	9	Producing
	B	OCS P-0241	Union	61	57	9	Producing
	C	OCS P-0241	Union	59	59	9	Producing
Carpinteria Offshore	Henry	OCS P-0240	Sun	30	53	8	Platform installed, development drilling started 2/8/80
	Hogan	OCS P-0166	Phillips	66	46	6	Producing
	Houchin	OCS P-0166	Phillips	60	49	8	Producing
Pitas Point	Pitas Point	OCS P-0234	Texaco	24	92	18	Plan approval pending
Santa Clara	Grace	OCS P-0217	Chevron	48	97	16	Platform installed, drilling started 2/20/80
	Gilda	OCS P-0216	Union	90	64	16	Plan approval pending
Hueneme Offshore	Gina	OCS P-0202	Union	15	29	6.5	Plan approval pending
Beta	Ellen	OCS P-0300	Shell	80	81	14.5	Jacket installed, platform under construction
	Elly	OCS P-0300	Shell	*	78	14.5	Approved
	Eureka	OCS P-0301	Shell	60	213	14.5	Awaits plan submission
	Edith	OCS P-0296	Chevron	60	46	11	Awaits plan submission

*Platform Elly is a production platform from which no wells will be drilled. Only initial treatment and storage of oil will be done there.

Source: Macpherson and Bernstein, 1980, p. 27.

Table 3. -- Expected oil and gas production off Southern California

(n.a. = Information not available at time of writing. As information becomes available, it will be included in future Pacific Summary Report updates.)

Unit/Field	Platform	First year of production	Peak year	Daily peak oil production (bbl)	Ultimate oil production (million bbl)	Daily peak gas production (mmcf)	Ultimate gas production (bcf)
Santa Ynez	Hondo	1981	1983-86	30,000	94	30	30
Carpinteria Offshore	Henry	1980	1981	6,000	12.7	4	8.65
Pitas Point	Pitas Point	1982	1983	0	0	63	n.a.
Santa Clara	Gilda	1981	1983	18,000	43	19	40
	Grace	1980	1982-1983	16,000	44.6	16	44.6
Hueneme Offshore	Gina	1981	1982	6,450	9.53	1.2	1.72
Beta	Ellen	1982	1983-1985	16,000	150	0	0
	Eureka	1984	1983-1985	10,000		0	0

Source: Macpherson and Bernstein, 1980, p. 33.

economic, demographic, and environmental parameters, should also be collected from source documents such as development and production plans, environmental assessments and reports, summary reports, and indexes.

The Pacific Summary Report (Macpherson and Bernstein, 1980) provides one with a realistic model of the types of information necessary to undertake an analysis of onshore facilities and their effects. This report contains the following planning information:

- current resource and reserve estimates for oil and gas
- past, present, and projected lease sale activity
- past, present, and projected development activities
- past, present, and projected production data
- existing oil and gas related facilities
- new onshore oil and gas facilities

The planner's job of monitoring activities on the OCS is discussed in these reports. Requirements set forth in law insure that updating be undertaken on a timely basis, and reports be revised when a significant event occurs.

The nine major types of OCS oil and gas related onshore facilities are listed below:

- support and service bases (temporary and permanent)
- repair and maintenance yards
- platform fabrication yards
- pipe coating yards
- separation and treatment facilities
- gas processing and treatment plants
- onshore transportation facilities (pipelines, marine terminals)
- refineries
- petrochemical complexes

Depending on the circumstances surrounding actual leasing, exploration, development, and production in a region, some or all of the facility types listed above may become a reality. A geographic depiction of existing and proposed OCS-related onshore facilities in Southern California is shown in figure 2. These facilities are built as a result of lease sales in both Federal and State waters over a 30-year period. (Note that in California's case, offshore oil and gas exploration comes about as an extension of onshore oil and gas discoveries.)

For each type of onshore facility projected for an OCS region, at least four categories of important information need to be collected and kept up to date. These are (1) industry's and government's principle siting criteria, (2) land, labor, water, and capital requirements for each facility, (3) primary environmental effects, and (4) primary and secondary economic and fiscal effects.

The four information needs listed above can be translated into a set of analysis tasks for an agency to undertake when either planning for or evaluating the effects of onshore oil and gas facilities. These tasks include: regional (multi-State) analysis to determine numbers and kinds of onshore facilities, State analysis (siting, environmental, and economic assessments), and cumulative environmental analysis.

Regional Analysis

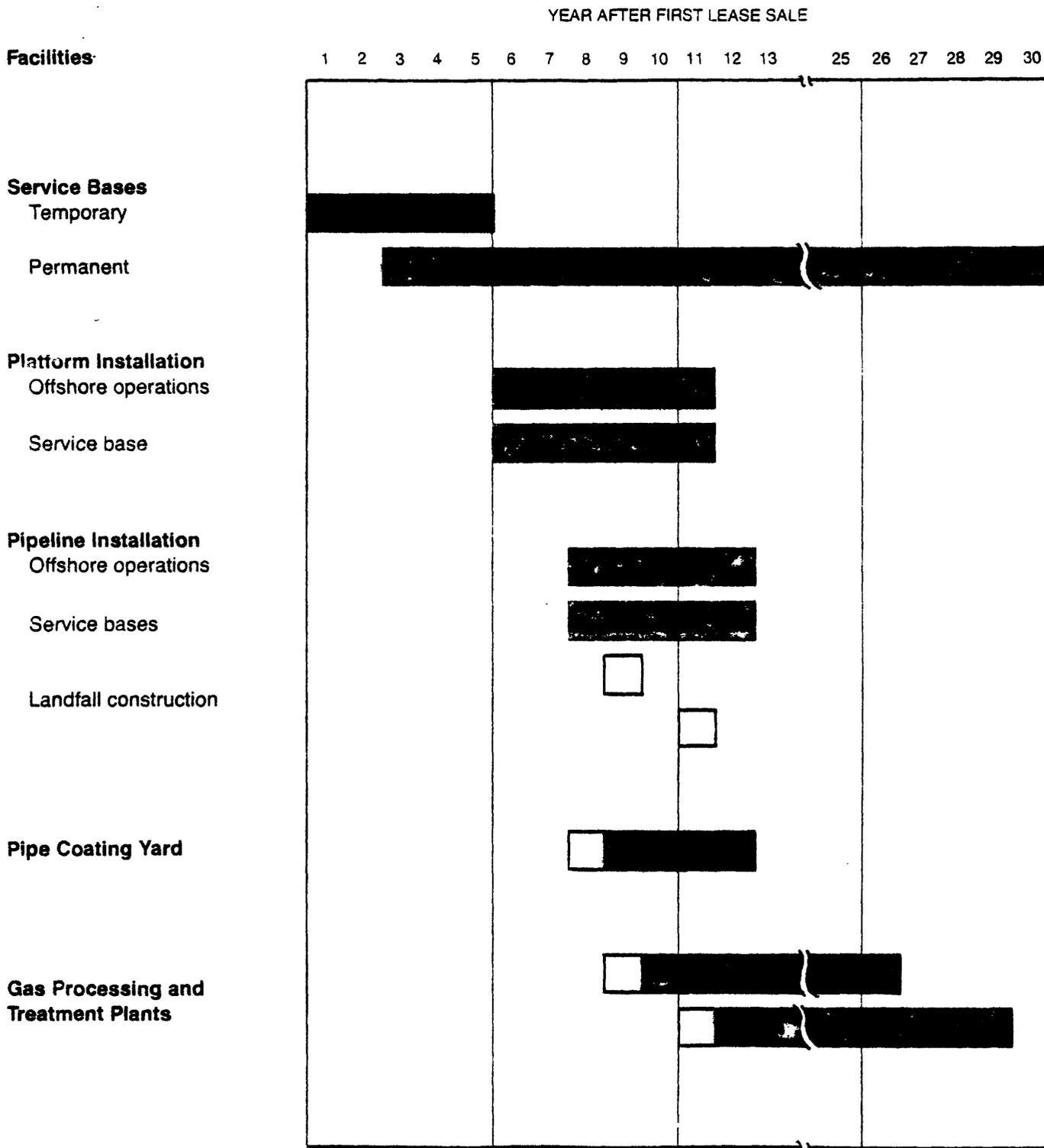
Prior to any analysis, the investigator must account for facility conditions and time and phase differences to determine the "need" for certain facilities. Two distinctions to be accounted for are (1) the possibility of some oil and gas facilities already handling resources with the capability to handle additional amounts, and (2) the possibility that facilities, presently not handling OCS-related activities, will begin handling them with existing capacity (for example, ports). Another distinction to be noted is the relationship between facilities and phases in the OCS process (Benton and others, 1979). Some facilities may closely relate to exploration phases, which means they may need to be sited soon after a lease sale, while others generally occur later in the process once commercial amounts of resources have been discovered, the resource quality is known, and offshore transportation alternatives have been formally proposed or implemented. A theoretical example of the OCS phasing issue discussed above (New England River Basins Commission, 1978) is shown in figure 3.

As any given facility moves from the hypothetical to the proposed and finally to the approved stage for construction, site characteristics and impacts can be more easily tabulated. Data relating to the effects of such facilities will generally be available from State and local impact statements and assessments, industry project proposals, regional environmental studies, and summary reports.

The starting point for a regional analysis is a tabulation of the existing facilities, if any, by type. The best information source for these data are summary reports and inventories conducted by regional and State economic and planning agencies and industry sources. The important point to note here is that the data will usually show pronounced clustering. That is, those facilities that service the OCS function will be concentrated near ports and harbors. This is by no means an unfailing rule, especially for those facilities that are not bound exclusively to the OCS function. The usual example is the oil refinery, which is located so as to maximize profits that may depend only in part on the OCS (this is the case in California, for example). Other facilities, such as service bases, are much more dependent on access to ports and harbors and hence will show a good correlation with the rule.

Given some production function that shows the magnitude and timing of the oil and/or gas produced in a source region, the curve must next be disaggregated into process functions, or separate curves, for one or more multi-State regions to which the products of offshore operations will be transported. This step can be accomplished in several ways, although they are not of equal reliability. The best approach, of course, would be based on exact knowledge of where the product is to be shipped; otherwise a firm plan that is in existence for transportation can be used, such as output from the Interior Department's "Intergovernmental Planning Program for OCS Oil and Gas Leasing, Transportation, and Related Facilities" (Bureau of Land Management, 1979).

TIMING OF FACILITIES AND ACTIVITIES MEDIUM FIND SCENARIO



Key: Construction
 Operation

Figure 3. Theoretical timing of construction and operation of facilities following a lease sale.

Source: New England River Basins Commission, 1978, p. 2.39.

In the absence of real data or a plan, one needs to simulate transportation through use of a mathematical approach like a gravity model (Isard and others, 1970). A typical model formulation is shown as

$$P_{i,t} = \frac{W_{i,t}}{d_i} P_{o,t}$$

Where

$P_{i,t}$ = production allocated to region i at time t

$W_{i,t}$ = variable weight

d_i = distance from offshore source to region i

$P_{o,t}$ = platform(s) production.

To use this approach, the weights of factors that act, along with distance, must be established to determine the pattern for disaggregation of the basic function. One logical approach is to establish weights in proportion to existing facilities. This approach would be viable in a region with an existing economic complex capable of processing oil and gas along with existing port and harbor facilities.

The situation is far different in a frontier region with no OCS and no onshore facility experience to date. One approach in this case is to derive a regional market demand for a given facility, based upon demand for services in a large market area within the region. This approach relies heavily on such variables as energy consumption as measured in any one of several ways. Data of this kind are usually available from economic sources. The danger of this approach is that demand may be a poor simulator of where the OCS products may be actually transported. For example, competing sources of energy products within the region may destroy the validity of the weights. On other hand, we are dealing with multi-State regions that can have many counterbalancing forces at work within them. As in many such modeling exercises, the inaccuracies tend to "wash out" over large regions and long expanses of time.

As a next step the effect of the facilities already in existence must be determined. The goal is to subtract out their effect so as to isolate the effect of any new facilities that may be constructed. If some of the allocated amounts of oil and gas are handled by existing facilities, then that total amount of oil or gas handled is usefully represented by a surrogate variable, such as the number of platforms needed to produce that amount of oil or gas. This results in a measure of production in terms of the amount of oil not yet handled. Then by employing a multiplier to express the processing capacity of a new facility, the effect of the existing facilities in reducing the demand for new facilities can be calculated, and the demand determined as

$$P'_{i,t} = P_{i,t} - N_{j,t} X_{j,t}$$

Where

$P'_{i,t}$ = the amount of oil not yet handled in region i at time t

$N_{j,t}$ = the number of facilities of type j in existence at t

$X_{j,t}$ = the processing capacity of facility type j

Furthermore, the number of new facilities necessary can be computed as

$$N'_{j,t} = \frac{P'_{i,t}}{X_{j,t}}$$

Where

$N'_{j,t}$ = the number of new facilities of type j

In all cases, P is measured in terms of productive capacity of platform wells.

This method has, in fact, been used in the computer model DEROCES (Marcus and others, 1977), which models the effects of oil and gas finds by use of a series of simple multipliers. The complexity of the situation becomes evident only when these calculations must be repeated for each type of facility, for each region, and for each time period in an analysis.

The next step is to extrapolate the impacts for each selected impact variable using another series of multipliers for each variable, which are specific for each facility type. An equation of the following sort results

$$I_{i,j,k,t} = N'_{j,t} M_{i,j,k,t}$$

Where

$I_{i,j,k,t}$ = new impact k of facility type j in region i at time t

$M_{i,j,k,t}$ = the multiplier for impact k of facility j in region i at time t

State Analysis

Up to this point, the discussion has centered on analysis concerning numbers and kinds of facilities in a multi-State region along a coastline. At this level of aggregation many of the inaccuracies of estimation are less important than at more detailed scales. The estimation issue becomes vital when any attempt is made to drive the models to the more detailed State level. It is of course possible to carry out such a formulation mathematically. The computer program DEROCES begins with source areas on the OCS and disaggregates results down to the individual port level. The question, of course, is how good are such estimates?

Assuming that the sensitivity of regional estimates are low, the simplest approach is to use the knowledge of what activity already exists. If the pattern of existing facilities within the multi-State region (by State) is known, then that pattern can be used as a guide for locating the simulated facilities and their impacts. In many cases this could be a simple proportion. Other information can enter into the estimation of how to disaggregate the overall totals. For example, any firm industry proposal to locate in an area will be just as useful at this stage of analysis as when used to simulate gravity model weights.

Just as in the case of the gravity model, the approach breaks down in new or frontier areas when there may be no activity in a State. In such cases it becomes necessary again to turn to a surrogate variable, such as market demand in a State. The uncertainties associated with this approach are far larger than in the regional case, since at this stage of analysis we are dealing with much smaller areas which vary in size, geometry, and many other characteristics.

An overall methodological approach that does not necessarily require the use of rigorous models has been developed by the New England River Basins Commission (1978). The third of three planning procedures or methodologies establishes a series of seven modules that planners can use to determine site-specific suitability for OCS facilities. The modules first attempt to identify potential sites by using industry criteria. These sites are next screened by applying public policy suitability criteria, which presumably would result in the deletion of some sites. The institutional adequacy of the State's siting authority is also assessed and applied as a criterion. Candidate sites result from these steps. The legal authorities that the State has available to assure that it defines and can gain its public objectives are reviewed next. The final two components are applied only after specific proposals are made by industry: they involve a detailed impact assessment of all environmental, economic, fiscal, and social variables, and a ranking of alternative sites for suitability.

Since most of the steps in the NERBC method must be done for each facility and for each site, the process can be time-consuming. Perhaps even more important for planning, some aspects cannot be done at all until an industry proposal has been received. Thus many State-level analyses, if they wish to look far enough ahead, must make use of the admittedly inaccurate, but readily available, mathematical forecasting approaches.

On the other hand, some States have alternatively concentrated their resources on developing and perfecting analytical tools for siting and evaluating OCS-related onshore facilities. State-specific studies make it possible to allocate activities at the State level more realistically. In addition, the State would be the primary determinant of activity within its bounds, since this is where the major governmental responsibility lies. Maryland's experience with development of analytical tools is discussed below because this effort represents a comprehensive package for use in planning and evaluation.

The Maryland Major Facilities Study (Maryland Department of Natural Resources, 1978) provides a transferable process for site selection by areas and sites, resolving site conflicts, and assessing the economic, fiscal, social, and environmental effects from specific facilities. All of these elements are crucial to both economic and environmental objectives for all coastal States.

The Maryland Regional Screening Process (Maryland Department of Natural Resources, 1978, v. 1) contemplates allocating activities according to a series of geographic screening criteria--threshold criteria, exclusion criteria, and potential restriction criteria. The regional screening process operates to identify threshold areas by eliminating areas that are clearly not suitable for facility development, then by determining the most suitable candidate areas by applying the exclusion and potential restriction criteria. By applying finer level data at the candidate area level, a number of "best" alternative sites are identified.

A major strength of this regional screening process is that it is open and invites scrutiny. The process allows anyone to review how the results were achieved, and to reapply the methods if different criteria are chosen or new data becomes available. Another strength is that the process reserves the introduction of subjective values until the last set of steps, after candidate areas have been suitably characterized by objective data. Thus, Maryland was able to select suitable candidate areas without imposing on restricted areas (for example, wetlands). Having a set of alternative sites that meet minimum economic, environmental, and social criteria for industry use at

some point in time provides the stimulus for both industry and the State to use this information for more detailed planning when and if a given facility becomes a necessity. Through such cooperative efforts industry can site and government can regulate in a cost effective manner while protecting valuable coastal resources.

The Economic, Fiscal, and Social Assessment Handbook (Maryland Department of Natural Resources, 1978, v. 3) contains three major elements: an economic element, a population and housing element, and a fiscal element. The economic element forecasts the levels of income and employment generated with a county, or adjacent county, as a result of a major facility. It is based on a variation in the multiplier approach with the principle distinction being that a series of steps were taken to separate those economic effects that remain with the county from those that are lost to the county and go elsewhere. This approach is significant because a good deal of attention is given in relevant literature to massive multipliers for certain industries such as offshore oil and gas activities, without recognizing that most of the activity will not benefit or harm the county in which a facility locates (v. 2). Most of the indirect economic activity generated by such facilities deals with the provision of specialized goods and services and does not exist in local economies outside the Gulf of Mexico and highly urbanized areas. The same is true for personal consumption.

If substantial immigration of workers occurs, rural areas generally do not have the retail establishments and infrastructure to absorb most of the spending of new worker households. Thus, spending goes elsewhere.

The population and housing element deals first with the movement of workers hired outside the county into the county. Second, the number of workers is correlated with numbers of households and school children. The number of households is then used to assess housing demand.

The fiscal element deals with both revenues (to various jurisdictions and levels of government) generated as a result of the facility and the service demands and costs generated thereby. Service demands are distinguished by two types of costs: (1) demands reflected in specific increments that may be required for existing services, and (2) facilities (for example, police protection and sewer and water systems) and government costs, which represent the fiscal effect of increased service demands on the budget. Service demands are very sensitive to policy choices by government. Thus, the handbook leaves the choice of inputs for service demands to the investigator. This procedure, originally developed to be used manually by local planners, is now computerized. Table 4 depicts the kinds of output an investigator may calculate with this component of the study.

The Environmental Assessment Handbook (Maryland Department of Natural Resources, 1978, v. 4) provides planners with readily useable methods for identifying, measuring, and evaluating effects of onshore facilities on the natural environment. The handbook is divided into three major parts to aid in an orderly assessment procedure. Part one provides the investigator with information on effects of development from each major facility. These effects result from a variety of activities carried out during site preparation, facility construction, and facility operation and maintenance. A discussion follows of pertinent activities and environmental factors for each facility. A matrix for each facility was developed relating activities and environmental effects.

Table 4. Summary of major outputs from economic and fiscal assessment model.

ECONOMIC EFFECTS (Chapter 1)	POPULATION EFFECTS (Chapter 2)	REVENUE EFFECTS (Chapter 3)	SERVICE & COST EFFECTS (Chapters 4 & 5)
Income from purchase of goods and services by facility (indirect income) by sector	Immigration of workers and households to county and to subareas within each county	Personal income tax from workers in added jobs	Specific service increments for the following service areas: police, fire, sewer, water, solid waste disposal, health, education (keyed to decision inputs by user)(marginal costs)
Income from personal consumption of workers at facility (induced income) by sector	Households, single individuals, and school children immigrating to county and subareas	Sales tax from purchases of goods and services	Fiscal impact (costs) by year for major services and for total county costs, school and non-school (based on average costing method)
Employment generated by indirect and induced income by sector	Demand for housing in county by type of structure (house, apartment, mobile home) and form of tenure (own, rent)	Personal and corporate income taxes from firms producing goods and services	
Matching of local labor supply to demand from facility	Effect of housing demand on availability of housing in county	Property taxes from house value increment (immigrants)	
Number of outside hires resulting from facility labor demand		Recordation and transfer taxes	
Classification of labor force by wage and consumption level		Taxes paid by major facilities	
Effect of labor demand on county economic sectors		Miscellaneous taxes	

Source: Economic, Fiscal, and Social Assessment Handbook, V. III, Ref. 8.

The second part of the handbook covers measurement of effects. Twenty-six environmental factors are considered. The factors considered are, for the most part, either scarce resources that are threatened by facility development or natural hazards that affect development or are intensified by development activities.

The third part of the handbook pertains to evaluation of effects. A project evaluation worksheet was developed as a means of comparing results of environmental factor assessments and arranging them in a comprehensive format.

Cumulative Effects

The impacts discussed to this point are the so-called facility-specific effects; that is, effects occurring as a result of one facility locating in a region or a State. However, a series of higher order effects also exists which when taken together constitute a set of cumulative effects in a region. In general, these cumulative effects are repercussions of primary and secondary economic and fiscal effects and primary environmental effects.

A number of approaches are available for handling this kind of effect, not all of which rely on mathematical or computer techniques (Schlesinger and Daltz, 1975). However, the approach we developed for problems of this kind does utilize a relatively simple mathematical scheme based on matrix algebra.

The general impact analysis model, EIAMAT, is a matrix approach combining concepts from cross-impact analysis and related matrix algebra methods. The methodology entails combining a schedule of primary effects expected as a result of future activities with a matrix of interrelationships. Each term in the cross-impact matrix relates a change in one variable in 1 year to a change in another variable in the following year, by a linear multiplier. These multipliers are the most important data input necessary to utilize the methodology. The resulting environmental impact forecasts account not only for the direct effect of future activities, but also for higher order interactions that occur in later time periods. This approach makes it possible to provide more complete forecasts in each time interval of the effect of implementing a project, especially as it interacts with higher order effects over time.

The general model can be represented in matrix notation as follows:

$$V(t) = A V(t-1) + B(t)$$

Where

$V(t)$ = The vector of the changes in primary plus secondary values of each impact variable for a given year.

A = The square matrix of multiplier coefficients that show cross impacts between pairs of variables for a 1-year period.

$B(t)$ = The vector of the changes in primary values of each impact variable for a given year (these values can be input from the DEROCS program).

This forecasting or probabilistic process is far more important than the particular values used for the coefficients in the model. Even with the most exacting procedures to validate or verify the model against reality, no model can predict the future. The possibility always exists that the conditions under which model validation is carried out may change in some unexpected way. Instead, the strength of the forecasting technique lies in the ease with which it can be used to examine the results of a wide range of alternatives. Furthermore, this process should not be done only once, but rather should become an integral component of a continuous planning process. In this context, the need for continually analyzing large volumes of numerical information emphasizes the requirement for an automated approach.

This model was originally developed and tested on a coal strip-mining operation in Campbell County, Wyoming. As of March 1981, work is underway to expand the variable base and "fine tune" the model so that a test can be made for a series of onshore facilities. Testing with an OCS case should be completed by December 1981.

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