Modeling the Economic Impacts of Offshore Activities in the Alaska Arctic

*By Jonathan Skolnik and Chris D. Holleyman**

Abstract

Production of oil and gas in the offshore Alaskan Arctic relies upon a set of technologies unlike those used anywhere else in the world. Remote locations, temperatures of 60 degrees below zero, and shifting ice flows that rule out traditional platforms, waterborne craft and sea-floor pipelines are just a few of the challenges that must be overcome. The solutions include roads and islands built of ice, man-made gravel islands, pipelines buried below the ocean floor, and cold weather retrofitted vehicles and equipment that are run for years without ever being turned-off.

Economic impact modeling of these activities also requires a set of methods that are unique. Readily available regional economic impact models contain production functions that are based on national averages. These national-level input coefficients cannot accurately reflect the unique arctic production function. These models are also unable to accurately trace the regional distribution of purchases made by the industry or the workers who commute to the site. Finally, these readily available models do not have enough detail to accurately model the differing impact of specific projects.

This paper describes the development of a first step model that can be combined with a readily available regional model to produce more accurate estimates of economic impacts. The first step model utilizes vectors of purchases, disaggregated by both geographic area and activity, to allow a more accurate accounting of the inputs required for a specific project. The vectors are constructed by coding detailed engineering estimates of inputs to the individual activities. These direct inputs can then be used to stimulate the standard regional impact models.

Introduction

The Outer Continental Shelf Lands Act, as amended, established a policy for the management of oil and natural gas in the Outer Continental Shelf (OCS) and for protection of the marine and coastal environments. The Act authorizes the conduct of studies in areas or regions to determine the "environmental impacts on the marine and coastal environments of the OCS and the coastal areas which may be affected by oil and gas development." The U.S. Minerals Management Service (MMS) is the administrative agency responsible for leasing submerged Federal lands.

The National Environmental Policy Act (NEPA) of 1969 requires use of the natural and social sciences in any planning and decision making that may have an effect on the human environment. To this end, the MMS prepares Environment Impact Statements (EIS) and environmental assessments (EA); acquires marine environmental data; analyzes data, literature surveys, socioeconomic studies, and special studies; and holds public conferences. These undertakings often call for assessing the regional economic impacts of a proposal such as a lease or a sale.

In the past, an assortment of models and methods were used to estimate economic impacts, and these typically varied by planning areas. At present, the existing models used to develop direct OCS and secondary employment projections for the Alaska OCS Region are outdated and do not produce results comparable to other OCS regions such as the Gulf of Mexico. As a result, regional comparisons are difficult to make. Section 18 of the OCS Lands Act, however, requires that the U.S. Department of the Interior prepare a 5-year schedule of lease sales that considers "an equitable sharing of developmental benefits and environmental risks among the various regions." For this reason, MMS decided to standardize the approach used to estimate regional economic impacts and has settled on IMPLAN, an economic input-output model, for that purpose.

To facilitate EIS work for Alaska's OCS Arctic subregion and to develop a tool for the "equitable sharing" analysis, a new model was developed. It can estimate industry employment and expenditures, by region, of offshore oil exploration and development (E&D) activities in the Beaufort Sea. The new model is known as the Arctic Impact Model for Petroleum in Alaska (Arctic IMPAK). Unlike the current model, this new model is designed to produce a set of outputs that can be used to stimulate IMPLAN.

The Current Modeling Process

Economic analysis of lease sales in all areas begins with the Exploration and Development (E&D) Scenarios. The first step model refers to any model that translates the E&D Scenario into direct effects. Direct effects are defined as those resulting from the first round of spending by companies working directly on an OCS project(s). The first-step model must estimate the level of industry expenditure (or employment) and how that spending/employment is allocated to onshore geographic areas. The MMS calls the spending allocation to industry a "cost function."

For Alaska, the previous first-step model was the Manpower model. It simply converted OCS activities levels from the E&D scenarios (number of wells drilled, platforms installed, pipeline miles laid, etc.) into estimates of direct employment using ratios, such as employees per mile of pipelines laid. It was developed in the late 1970s and then refined in the early 1980s. No documentation of the model or the sources of the underlying estimates is available.

The second-step model is used to estimate the additional impacts that result as the initial spending reverberates throughout the economy. These secondary impacts are often referred to as indirect and induced effects. Such models must be developed specifically for OCS or must be customized to reflect the unique expenditure and commuting patterns of OCS-related companies and their employees. For Alaska, these problems are exacerbated by the fact that national models like IMPLAN often use national multipliers due to inadequate local data. In order to use IMPLAN as a second step model, the first step model must provide extremely detailed results.

For Alaska, the second-step model that was used in conjunction with Manpower was the Rural Alaska Model (RAM), which was developed by the University of Alaska Anchorage. Like Manpower, RAM is a set of spreadsheets that

* Jonathan Skolnik and Chris D. Holleyman are with Jack Faucett Associates, Bethesda, MD. This is an edited version of their paper presented at the 24th Annual IAEE Conference in Houston, TX, April 25-27, 2001.

uses simple multipliers to estimate results. This model can be used to estimate impacts only at the local level and does not allow for the estimation of impacts at the state or national level.

Purpose and Objective

The purpose of this paper is to describe the development of a model to replace the Manpower Model. Since the early 1980s, when the Manpower model was constructed, there have been significant technological changes in offshore E&D activities. In addition, the production process used in Alaska's arctic regions differs significantly from the process used in the sub-Arctic regions that were modeled in the Manpower model.

In developing the new model, the latest available data were used to develop employment and expenditure factors for the revised E&D activities. With these updated factors, projections of direct and indirect employment impacts in the sub-Arctic region can be forecast more accurately. With more accurate projections, stakeholders will have more confidence in the economic sections of an EIS. More accurate projections may also be used in decisions regarding post-lease mitigation.

The new first-step model converts E&D inputs into direct employment and expenditure impacts for the North Slope Borough (NSB), the state of Alaska, and the rest of the United States. The NSB is the local government for the land area to the south of the Arctic OCS. Shore-based OCS activity would be located in the NSB. Expenditure impacts are itemized by IMPLAN sector. MMS can use the model to estimate the direct impacts of an E&D scenario then enter these impacts into IMPLAN to estimate the indirect and induced effects. Cost functions are used to customize the inputs for IMPLAN. MMS has selected IMPLAN to forecast secondary economic impacts because it is a national level model that will standardize comparison with other MMS OCS regions.

Organization

The economic impact of a particular set of oil and gas activities on the Arctic OCS will depend on both the size of the project and the set of technologies chosen. In the next section of this paper, alternate technologies are first defined and then the most likely set of technologies is chosen.

In the following section, these choices are then compared with the categorization of activities contained in the E&D scenario to assess compatibility. Based on this comparison, the final set of activities is chosen for inclusion in the model. The activities are then defined as either primary or secondary activities. Primary activities include those activities whose levels are determined directly from the E&D scenario. In contrast, secondary or support activities (hotel/camps, personnel transport, ice roads, helicopter support and barge support) are those whose levels are dependent on the levels of several primary activities.

Finally for the chosen set of nineteen activities, a basic unit of activity (mile of pipeline, day of helicopter support, barrel of oil, etc.) is determined.

The next section provides an overview of the methods used to develop the inputs to the nineteen activities that comprise the oil exploration, development and production process in the Alaskan Beaufort Sea. In some sense, this study develops a production function for each activity, where the production function is defined in terms of expenditures for various types of inputs. These inputs can be broadly grouped into the following categories: labor, capital, materials, purchased services and government.

The final section of this paper provides an overview of the inputs and outputs of the completed IMPAK model.

Selection of Technologies

The economic impact of a particular set of oil and gas activities on the North Slope will depend on both the size of the project and the set of technologies chosen. In this section alternate technologies are defined and described and the most reasonable and likely set of technologies is chosen.

Table 1 provides a listing of the technical options for oil and gas activities in the Alaskan Beaufort Sea. This table was developed by combining a variety of tables and materials from the Draft Beaufort Sea/Northstar EIS, supplemented by interviews conducted for this study. For each major activity, the table defines the alternate technologies, their characteristics, advantages and disadvantages. The technologies that were chosen for use in this study are highlighted in bold print.

The analysis clearly indicates that there are a large number of potential technological alternatives. For example, approximately fifteen potential drilling structures were identified. Given the complexity of modeling the technologies, it is crucial to select the most likely technologies and to concentrate on modeling the production functions and the economic impacts of those technologies.

The following is a summary listing of the chosen technologies:

- Drilling Method - Directional
- Seismic Surveys - From Ice
- Exploration Structures - Ice Islands
- Development Production Structures - Manmade Gravel Islands
- Oil and Gas Recovery - Gas Cycling
- Oil Processing - Full Offshore Processing
- Product Transportation - Pipeline Buried Beneath Seafloor
- Abandonment - In Place

In each case only a single technology was chosen. For exploration both ice islands and Sinkable Island Drill Ships were considered economical and environmentally friendly options. However, ice islands are the more utilized and proven technology. The estimation of alternative data for seismic surveys on ice and by boat were also considered, but given the relatively small size of this activity it was not deemed worthwhile to do so. While it was recognized that both methods of conducting seismic surveys are likely, the economic differences are not significant. Gravel islands, full offshore processing and pipeline transports were clearly superior both technologically and environmentally when compared with other current options. However, as exploration moves to deeper water, the use of alternative production structures will become more likely. As water depths increase, the cost of gravel islands increases more than proportionately. At 75 to 100 feet these costs probably become prohibitively expensive.

E&D Scenarios, Secondary Activities and Units

Since the level and timing of activities must be derived from the E&D scenario, the level of each activity must be defined in terms of the E&D scenario. Table 2 provides an

Table 1: Technical Options for Oil and Gas Activities in the Arctic OCS		
Phase	**Activities**	**Reason For Consideration or Elimination**
Drilling Methods	• **Directional Drilling Technology** •	• *Can access multiple bottom hole locations for single surface location.*
	• *Vertical Drilling Technology*	• *Only accesses reservoir directly beneath drilling location.* • *Multiple drilling locations increases costs and environmental impacts.*
Seismic Surveys	• *From Boat* •	• *Summer Only*
	• **From Ice**	• *Winter Only* • *Lower environmental impact*
Drilling Structures	• *Onshore Drilling*	• *Too far from reservoir.*
	• *Barrier Islands*	• *Environmental value is too high.*
	• *Bottom-founded Structures* - Caisson Retained Island (CRI) Designs and Tarsiut Island (Concrete CRI)	• *Relocation difficult as caissons ballasted with sand.* • *Redesign and construction of a new caisson structure would be very expensive.* • *Owners proposed to modify to accommodate production facilities (22-35 wells).*
	- Concrete Island Drilling Structure (CIDS)	• *Designed for arctic in water depths of 35 to 55 ft (10.6 to 16.8 m).* • *Demonstrated long-term durability.* • *High cost to convert to production facility.*
	- Mobile Arctic Caisson (Molikpaq)	• *Owners proposed to modify to accommodate production facilities (40 wells).* • *Designed for arctic in water depths of 30 to 130 ft (9 to 39.6 m).* • *Demonstrated durability.* • *High cost to convert to production facility.*
	- Single Steel Drilling Caisson (SSDC)	• *Owners proposed to modify to accommodate production facilities (30-40 wells).* • *Can operate in arctic in water depths of 25 to 100 ft (7.6 to 30 m).* • *Demonstrated durability.* • *High cost to convert to production facility.*
	- **Manmade Gravel Islands**	• *Proven technology, 17 constructed in Beaufort Sea.* • *Useful to approximately 50 ft (15.2 m) water depth.* • *Can withstand high lateral load ice forces.* • *Less expensive to design, construct, and maintain than other structures.*
	- Seafloor Templates	• *Usable in water depths over 200 ft (61 m) where ice gouging does not occur.* • *Water depth too shallow.*
	- Sub-sea Silos	• *Unproven in Beaufort Sea but conceptual design addresses potential hazards.* • *Caisson-protected subsea templates have been used in arctic* • *High cost.*
	• *Floating Structures* - Jack-up Drilling Platforms	• *Not designed to operate in ice or support production.* • *Could support summer exploration.*
	- Semi-Submersible Drilling Vessels	• *Not designed to operate in ice or support production.* • *Could support summer exploration.*
	- Conventional Drill Ships	• *Not designed to operate in ice or support production.* • *Could support summer exploration.*
	- Conical Drilling Unit (Kulluk)	• *Not designed to operate in ice or support production.*
	- **Ice Islands**	• *Melt in summer but low environmental impact and cost.* • *Supports winter exploration.*
	• *Sub-sea Cavern*	• *Unproven concept not yet demonstrated as technically or economically feasible.*
	• *Sinkable Island Drill Ship (SIDS)*	• *Demonstrated technology.* • *Useful to only approximately 50 ft.* • *Suffers occasional ice damage* • *Can be used year round.* • *Extremely low environmental impact and cost* • *Relatively easy to relocate*
Oil and Gas Recovery	• *Natural Blowdown (Primary Recovery)*	• *Recovery rates of 5% to 20% are not economic.* • *Usable on large reservoirs with difficulties implementing pressure enhancement.*
	• *Secondary Recovery*	• *Effective if the reservoir contains heavy, thick oil or has high water content.* • *Not appropriate because of composition of Northstar reservoir.*

Table 1 continued next page

Table 1: Technical Options for Oil and Gas Activities in the Arctic OCS		
Phase	**Activities**	**Reason For Consideration or Elimination**
Oil and Gas Recovery	• *Natural Blowdown (Primary Recovery)*	• *Recovery rates of 5% to 20% are not economic.* • *Usable on large reservoirs with difficulties implementing pressure enhancement.*
	• *Secondary Recovery* - Gas Lift	• *Effective if the reservoir contains heavy, thick oil or has high water content.* • *Not appropriate because of composition of Northstar reservoir.* • *Gas supply available in the Alaskan Beaufort Sea.* • *Can be integrated with other recovery methods.*
	- **Gas Cycling**	• *Highest recovery rates of 45% to 65%.* • *Can be integrated with other recovery methods.* • *Useful for light oils that flow easily.*
	- Water Injection	• *Recovery rates of 35% to 45% are not economical.* • *Can be integrated with other recovery methods.*
	- Waterflood	• *Recovery rates of 40% to 50%.* • *Can be integrated with other recovery methods* • *Best backup method.*
	• *Enhanced (Tertiary) Recovery*	• *Not considered because options are unknown.*
Oil Processing	• **Full Offshore Processing**	• *Secondary oil recovery techniques can be incorporated.* • *Transport sales quality oil directly from production facility.* • *Lowest environmental impact.*
	• *Partial Offshore and Onshore Processing*	• *Difficult transportation of three-phase fluids by pipeline.* • *Multiple locations increases environmental impact.*
	• *Full Onshore Processing*	• *Offshore production structures can be smaller.* • *Difficult transportation of three-phase fluids by pipeline.* • *Environmental impacts too high onshore.*
Product Transportation	• *Tankers and Barges*	• *Greater spill risk.* • *High cost for facilities and dredging.*
	• *Pipeline on a Gravel Causeway*	• *Provides protection of pipeline and access for maintenance.* • *Negative environmental impacts* • *High cost for bridges.*
	• **Pipeline Buried Beneath Seafloor**	• *Avoids damaging effects from ice.* • *Safest option with lowest impact*
	• *Pipeline Installed on Seafloor*	• *Risk of damage or rupture from ice.* • *Can be used only in water depths over 200 ft (61 m).*
	• *Elevated Pile-supported Structure*	• *Would be exposed to winds, wave action, and ice forces.* • *Structure could impede passage of vessels/barges.*
Spoil Disposal	• *Onshore*	• *Saline material kills terrestrial vegetation.*
	• *Shallow water*	• *Sediments block water circulation and navigation.*
	• ***Outside Barrier Islands***	• *Achieves good dispersion of waste material.* • *Does not impede water circulation or navigation.*
Abandonment	• **In Place**	• *Preserves key facilities for reuse and shelter.*
	• *Removal*	• *Returns environment closer to original state.*

Notes: ft = Foot or Feet
Km = Kilometer(s)
m = Meter(s)
% = Percent
TAPS= Trans Alaska Pipeline System

example of the format and content of an E&D scenario for arctic Alaska. The types of activities included in the E&D scenarios and their definitions were an important consideration in developing the activities to be included in the IMPAK model.

In addition, while the E&D scenario only specifies a relatively few activities, many of these E&D activities share common support type activities. These include ice road construction, spoils disposal, headquarters support, personnel transport, helicopter and barge support and camp support (room and board). Since the labor, material and equipment inputs to these secondary or support activities are similar across the more primary activities, it is advantageous to separate these components from the primary activities and have the levels of these activities depend on the levels of the primary activities.

Table 3 provides a listing of what were considered primary activities. Fourteen activities are listed in roughly chronological order. Note that the construction and operation of facilities are separated, as operation often continues several years. Also included in Table 3 is a listing of the secondary or support activities. Five of these activities have

Table 2: Example of an E&D Scenario for Arctic Alaska									
Year	Exploration Wells	Delineation Wells	Exploration/ Delineation Rigs	Production Platforms	Production and Service Wells	Production Rigs	Landbase Operations	Oil Production	Pipeline Miles
1998	Lease Sale								
1999	1		1						
2000	1	2	2						
2001	1		1						
2002	1	2	2						
2003	1		1				0.1		
2004	1	2	2	1	4	1	0.2		
2005					10	2	0.2		15
2006				1	18	3	0.2	9	10
2997					16	2		13	5
2008				1	18	3	0.1	18	
2009					16	2		26	10
2010					5	1	0.1	31	
2011								39	
2012								35	
2013								32	
2014								27	
2015 . :								23 . :	

been identified including:

- North Slope Support
- General Personnel Transport
- Ice Roads
- Helicopter support
- Barge support

It was important to rigorously define each activity to insure that there was no double counting. It was also important to ascertain the extent to which the secondary activity varies depending on the primary activity it is associated with. For example, there are differences in the thickness and width of ice roads used during different activities.

The primary and secondary activities are structured so that if a primary activity occurs, predetermined amounts of the required secondary activities are stimulated. For example, if a production island is in operation, a certain amount of helicopter support flights will occur. The number of helicopter flights will vary based on certain aspects of the scenario, such as the distance of the project from shore and the number of islands in operation.

In order to model the impacts of a particular oil and gas development it is necessary to have estimates of the size of the development. These estimates, as provided in the E&D scenario reproduced in Table 2, define the development in terms of number of wells, miles or kilometers of pipelines, etc.

Finally, activities must be defined in terms of a unit of time or size. Table 3 provides a unit for each of the activities

Table 3: Primary and Secondary Activities - Drivers and Default Factors						
		Secondary Activities				
Primary Activities		**15. North Slope Support**	**16. General Personnel Transport**	**17. Ice Roads**	**18. Helicopter Support**	**19. Barge Support**
	Units	Per 300 Person Camp Per Year	Per Day	Per 10 Miles	Per Day	Per Day
1. Survey on Ice	Per Month				**X**	
2. Ice Exploration Island	Per Island	**X**	**X**	**X**	**X**	
3. Exploration Wells	Per Well	**X**	**X**		**X**	
4. Place Gravel Island	Per Island	**X**	**X**	**X**		
5. Gravel Island Protection	Per Island	**X**	**X**	**X**		**X**
6. Equip Production Island	Per Island	**X**	**X**	**X**	**X**	**X**
7. Production Wells	Per Well		**X**		**X**	
8. Operate Production Island	Per Island Per Year	**X**	**X**	**X**	**X**	**X**
9. Construct Offshore Pipeline	Per Ten Miles	**X**	**X**	**X**	**X**	
10. Construct Onshore Pipeline	Per Ten Miles	**X**	**X**	**X**	**X**	
11. Landbase Operations	Per Year	**X**				
12. Well Workover	Per Well Per Workover	**X**	**X**		**X**	**X**
13. Spill Contingency	Per Year Per Ten Islands	**X**	**X**		**X**	**X**
14. Abandonment in Place	Per Island	**X**	**X**		**X**	**X**

used in the IMPAK model. These units were designed to be as compatible as possible with the E&D scenarios. At the same time they needed to match with the engineering and cost data that were collected for the study.

Data Development Methodology

In some sense, this study is developing a production function for each activity, where the production function is defined in terms of expenditures for various types of inputs. These inputs can be broadly grouped into the following categories: labor, capital, materials, purchased services and government.

The estimates developed in this study were based on information collected in the years 1999 and 2000 and published reports providing data for various years, but mostly for the years 1997 to 1999. As such, the authors consider the estimates provided in this paper to be reported in 1999 dollars.

Labor Inputs

Labor inputs include the direct labor used in the construction and operation of the oil and gas facilities as well the overhead or headquarter salaried non-production staff that provide support functions over a range of operations. The direct construction labor inputs were estimated through interviews with representatives of construction contractors and oil companies that have experience in constructing or operating the structures under consideration. In most cases, data were collected, by activity, on the number of employees by trade, wages for employees by trade, task crew size, duration of task, number of shifts, shift duration, rotation pattern and percent native hire. The numbers of headquarters and support staff were estimated based on published Census data on the ratio of total workers to production workers. Non-production employment within Alaska was then divided between the NSB and the remainder of Alaska based on data provided by industry sources. Wages for salaried employees were estimated separately for the various geographical regions based on the State of Alaska's Employment and Earnings Summary Report except for U.S. wages which were based on data from the 1997 Census of Mineral Industries. Wages for all workers in all geographic areas were then adjusted to include an estimate of the value of fringe benefits based on Census data.

In calculating estimates of economic impact in cases where workers are commuting, it is necessary to consider both where the employees work and where they spend their disposable income. Therefore, while data were initially developed based on the location of the workplace of the individual, these estimates were then converted to estimates of the location in which the expenditures of wages and taxes are made. Once employees are paid wages, they will pay taxes, save a small part of these wages and then spend the rest on goods and services, generating induced impacts.

Where an employee spends his/her income depends, to a large extent, on whether the employee is a resident of the NSB. Since food, lodging and transportation are part of an employee's total compensation package, it is unlikely that non-residents spend much of their disposable income in the NSB. Study team members with experience working in the area, estimated that workers in the NSB spent approximately $5 per day at informal lobby shops or on local crafts. Since most employees make in the range of $500 per day, it was assumed that one percent of disposable income is spent on NSB goods. Full time NSB residents, on the other hand, are inclined to spend relatively more of their disposable income in the NSB. Those natives who still live in the NSB, estimated at 25 percent of all natives, were estimated to spend the majority (80 percent) of their income there, with the remainder spent on the occasional trip to Anchorage or other destinations. NSB natives who had left their native village were estimated to spend none of their disposable income in the NSB, other than the one-percent spent while working. In addition, it was assumed that all employees in Alaska spent all of their disposable income within Alaska and that all non-Alaska employees spent all of their income in the rest of the U.S. not including Alaska.

In addition to direct compensation, several contractors provided estimates of additional employee related costs for airfare to and from the NSB, local transportation, clothing, and housing and meal costs. While these costs are theoretically not part of employee compensation, but rather part of overhead costs, their levels are dependent upon the numbers and of employees and are, therefore, most accurately estimated along with employee compensation. They were assumed to not be included in Bureau of the Census estimates of fringe benefits and were coded directly to the appropriate IMPLAN sectors. As described below, they were subtracted from estimates of total overhead prior to distributing remaining overhead expenses to IMPLAN sectors.

Capital Inputs

Unlike most labor and material inputs, which are entirely and immediately consumed in the production process, capital inputs are used up gradually over time. This defining aspect of capital requires special attention when utilizing an input-output (I-O) framework to estimate economic impacts. Capital expenditures are not included in the use coefficients of an industry, which only account for inputs that are immediately consumed for current production. In an I-O model, annualized capital expenditures are included with value added. Unfortunately, these expenses are frequently aggregated and, without a capital flow matrix, it is not possible to isolate specific types of investments or trace the secondary impacts associated with such investments. For this reason, exogenous estimates of capital investment are often developed outside of the I-O model, and then used as model catalysts along with other direct expenditures.

Capital investments represent a substantial portion of mineral exploration and development (E&D) expenditures. Due to the harsh environment, this is especially true in Alaska's Arctic environment, where many of the machines only last four years and are often operated for long periods of time without even being turned off. E&D activities require transportation and earth moving equipment, drilling equipment, etc.

The first step in the process was to identify the capital assets used in each E&D activity. It should be noted that much of the equipment has to be retrofitted with special accessories before it can be used in the harsh conditions found in the Alaskan Arctic. These accessories include insulation, special engine lubricants, and hardware attachments. The accessories associated with each primary piece of capital were also identified in this first step. The numbers of assets required to carry out one unit of the activity were then estimated. This information was compiled through surveys of construction and mining contractors and supplemented with engineering and economic judgment.

The cost for each asset was then annualized (based upon the average life of the machine), converted into a "per unit" basis, and then divided into its various cost components: i.e., manufacturing, transportation and wholesale trade, and retrofitting. Regional purchase coefficients (RPC) were then used to allocate expenditures to impacted geographic regions. This allocation was performed for each cost component. For example, the manufacturing cost of a particular asset may have been assigned to the rest of the United States (not including Alaska) whereas part of the cost of delivering it to the North Slope may have been assigned to the NSB. Finally each cost component was assigned to an associated IMPLAN sector and annual expenditures were summed across assets. RPC is a term which briefly is defined as the percentage of purchases of a particular good or service obtained from within the study area.

Material Inputs

Most major material inputs such as fuel were estimated based on information on cost and quantity gathered in the industry interviews or based on the expert engineering knowledge of project staff. However, in order to determine what materials and purchased services are utilized in quantities that are significant enough to warrant estimation, data from the latest national-level input-output table of the U.S. economy was tabulated and analyzed. In summary, material inputs to the oil and gas production process are made up of four main types of commodities including:

- Chemicals
- Products of petroleum refining such as gasoline as well as lubricating oils and greases
- Various paving and building compounds such as asphalt, concrete and cement
- Specialty minerals used in well drilling operations.

The types of products for each of these sectors and their associated SIC code were a useful input to the interviewing process. Estimates were solicited on the usage of these various inputs for the particular activity under consideration. These estimates were often based on usage rates for particular pieces of equipment that were then multiplied by the number of units in use, the hours or days of use per piece of equipment and the cost per unit of the input. An example would be the gallons of fuel used per day for a pickup truck. The number of pickup trucks and the number of days they were employed in the task would then be multiplied by this estimate. Total usage would then be multiplied by the cost of fuel. Since the products were already defined by SIC code and input-output sector it was a simple matter to code them to IMPLAN sector. As the estimates were in purchasers' prices, rough estimates of shipping costs by mode and wholesale and retail margins (if applicable) had to be made prior to assignment to sectors. Finally, the area of production was specified, so that the resulting values could be divided among the NSB, the remainder of Alaska and the other 49 states.

Purchased Services (Overhead)

The national-level input-output table was also analyzed for purchased services and overhead sectors for which estimates of purchases were not compiled within the labor, capital or materials procedures. These include sectors such as telephone services, banking, insurance, hotels, data processing, advertising, legal, engineering and architectural, accounting, eating and drinking places, and business associations.

The purchases from these sectors, which represent overhead types of services, are usually not separately specified in engineering cost estimates. If they are considered, they are generally lumped together in a common overhead category. Moreover, while these purchases are part of the real costs of doing business they are not easily allocated directly to the different activities that comprise the oil and gas industry. That is to say, they are common overhead components. The amount of advertising that is purchased by a large oil company, for example, is probably fairly independent of the miles of ice roads constructed, but is probably somewhat related to gallons of oil produced. On the other hand, a smaller company specializing in ice road construction, although likely to have a small advertising budget, is also likely to have spending that is fairly related to the miles of roads it constructs in a year.

The assignment of these costs by area is also extremely complicated. The oil and gas industry is an amalgamation of a large number of companies, not just the big oil companies. For example, the 1992 Census of Mineral Industries estimates that almost 17,000 companies were involved in the Crude Petroleum and Natural Gas and Oil and Gas Field Services industries. Therefore, one can not simply ask the large oil companies where they spend their overhead dollar, even assuming they would be willing to provide an answer. Instead, estimates must be made of where the aggregate of all companies makes their expenditures.

As a result, the estimates of spending for each purchased service were based on the following methods. First, estimates of overhead expenses, developed for each activity based on interviews and expert engineering judgments, were allocated to the 18 purchased services sectors based on the relative value of consumption provided in the national-level Bureau of Economic Analysis (BEA) Input-Output (I-O) table. Data for the oil and gas industry were used for all activities except camp support, general transport, and helicopter and barge support. Data for these sectors were based on the BEA I-O data for hotels, local transport, air transport and water transport, respectively. The resulting estimates were then split among the NSB, Alaska and the other 49 states using percentage distributions developed by study staff based on their familiarity with the area and the production process.

Government

The model also calculates government expenditures, which are set equal to government revenues in the prior year. Government revenues were generated from IMPAK outputs for that prior year and a series of local, state and federal tax rates. Revenue sources include taxes on employee earnings, employee spending, Permanent Fund (PF) dividends, 8(g) funds, gravel royalties, oil and gas royalties, lease revenues and bonus bids. Government revenues were distributed to a number of IMPLAN sectors based on separate input-output vectors developed for local, state and federal governments. Each cell in the vectors represents a percentage of the respective total government expenditures. For the most part, it was assumed that all expenditures will take place in the region in which the government is located.

In addition, the model includes data for Trans-Alaska

Pipeline system (TAPS) expenditures, which are assigned to the IMPLAN pipeline sector. It was assumed that TAPS expenditures in a given year are equal to TAPS revenues generated in the previous year. These revenues were estimated by multiplying total oil production by a TAPS surcharge, which is defined in terms of dollars per barrel. The user inputs both variables. It was assumed that all oil produced on the North Slope is transported via TAPS to Valdez.

Model Overview

The Arctic IMPAK model forecasts the input requirements needed to carry out oil exploration and development on Alaska's Arctic OCS. In the previous section, the methods used to develop vectors of commodity and labor input requirements on a per unit basis were described. Multiplying these vectors by projected annual activity levels developed from an E&D scenario generates estimates of the total input requirements for each year in the forecast horizon.

The Arctic IMPAK model is contained in a Microsoft Excel platform and is driven by data from the E&D report, as well as other data, which are manually input into the model. Since the activities listed in the E&D reports are not identical to those used in IMPAK, the model has to convert the E&D data into the corresponding IMPAK activity levels. Table 4 details the conversion of E&D scenarios to IMPAK activity levels.

The model inputs are then transposed into a matrix compatible with the regional input-output matrices. An Excel array function is used to accomplish the task. The transposed input is then multiplied by each region's input-output matrix to yield the total direct impacts by region and IMPLAN sector. Again, an Excel array function is used to accomplish the matrix multiplication. Note that each year in the forecast horizon requires a separate formula.

The final output is a matrix that provides total input requirements by IMPLAN sector separately for each year and geographic area. This output then becomes the input for the Microsoft-Access model developed by the MMS. The MMS model estimates the ripple effects in each corresponding, proximate onshore area.

Table 4: Conversion of E&D Scenarios to IMPAK Activity Levels

Activity	Conversion Procedure
1. Geological Survey	Not currently in E&D report, must be manually entered.
2. Construct Ice Island	Equal to number of exploration and delineation rigs in year from E&D report.
3. Drill Exploration Well	Equal to number of exploration and delineation wells in year from E&D report.
4. Place Gravel Island	Equal to number of production platforms in year from E&D report. User can adjust island size and shape.
5. Protect Gravel Island	Equal to number of production platforms in year from E&D report.
6. Equip Production Island	Equal to number of production platforms in previous year from E&D report.
7. Drill Production Well	Equal to number of production wells in year from E&D report.
8. Operate Production Island	Equal to number of production platforms since inception date from E&D report.
9. Lay Offshore Pipeline	Equal to number of offshore pipeline miles divided by ten in year from E&D report.
10. Lay Onshore Pipeline	Equal to number of onshore pipeline miles divided by ten in year from E&D report.
11. Perform Well Workover	Equal to number of production wells in six-year previous increments from E&D report.
12. Landbase Operations	Equal to percentage of landbase operations in year from E&D report.
13. Spill Contingency Operations	Equal to one-tenth of the number of production platforms since inception date from E&D report.
14. Abandonment	In year after E&D activities cease, equal to number of production platforms since inception date.
15. Construct Ice Roads	Based on pipeline miles from E&D reports with factors for depth and width to support specific activities.
16. Helicopter Support	Based on trip per activity ratios, activity levels and trip per day factor based on user specified distance.
17. Barge Support	Based on trip per activity ratios, activity levels, 60 miles per day and user specified distance.
18. General Personnel Transport	Stimulated based on dollar per activity ratios and activity levels.
19. Camp Support	Stimulated based on dollar per activity ratios and activity levels.