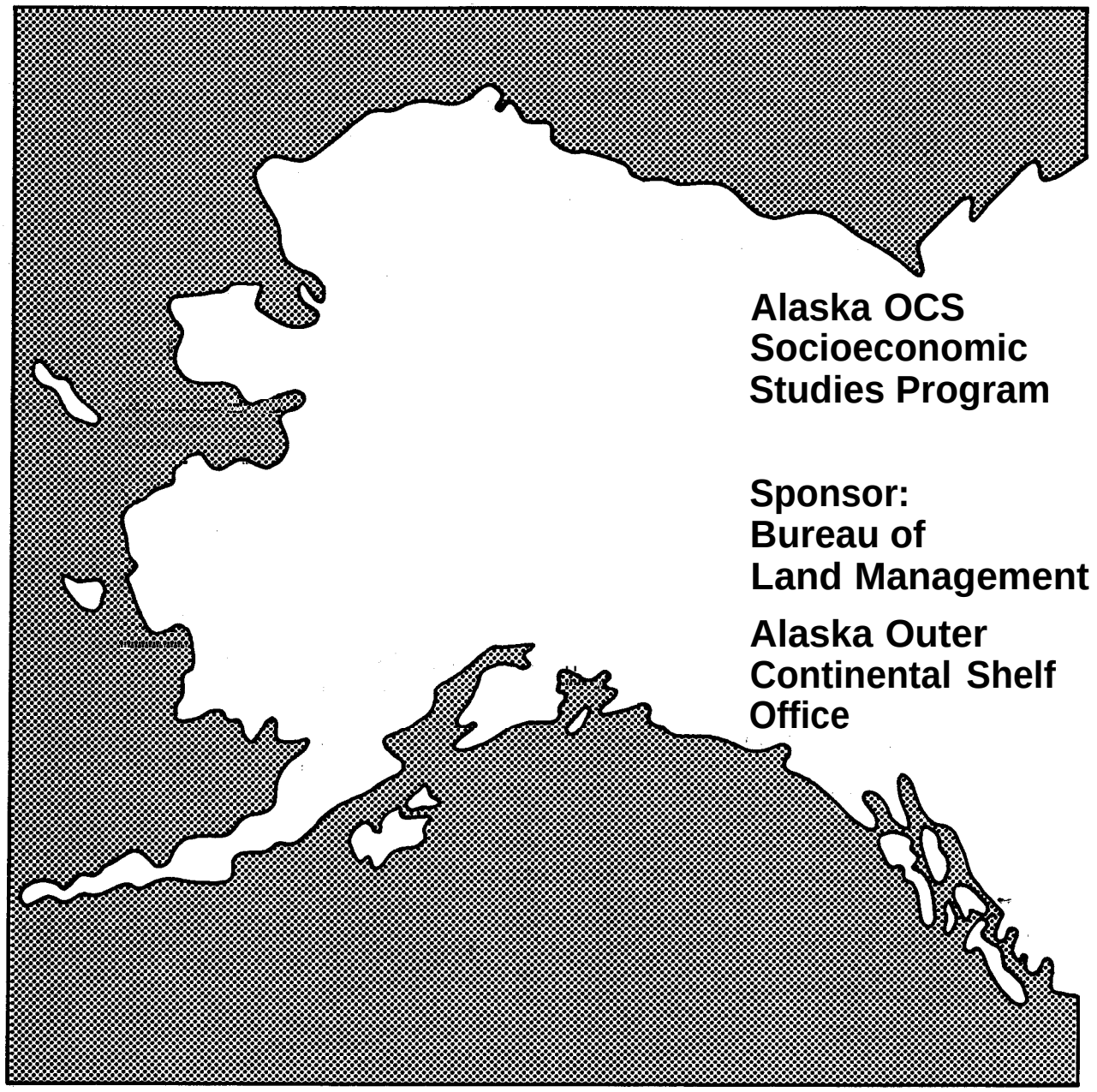
Technical Report
Number 21



Alaska OCS Socioeconomic Studies Program

Sponsor: Bureau of Land Management

Alaska Outer Continental Shelf Office

Beaufort Sea Petroleum Development Scenarios Natural Physical Environment Impacts

FOREWARD

The United States Department of the Interior was designated by the Outer Continental Shelf (OCS) Lands Act of 1953 to carry out the majority of the Act's provisions for administering the mineral leasing and development of offshore areas of the United States under federal jurisdiction. Within the Department, the Bureau of Land Management (BLM) has the responsibility to meet requirements of the National Environmental Policy Act of 1969 (NEPA) as well as other legislation and regulations dealing with the effects of offshore development. In Alaska, unique cultural differences and climatic conditions create a need for developing additional socioeconomic and environmental information to improve OCS decision making at all governmental levels. In fulfillment of its federal responsibilities and with an awareness of these additional information needs, the BLM has initiated several investigative programs, one of which is the Alaska OCS Socioeconomic Studies Program.

The Alaska OCS Socioeconomic Studies Program is a multi-year research effort which attempts to predict and evaluate the effects of Alaska OCS Petroleum Development upon the physical, social, and economic environments within the state. The analysis addresses the differing effects among various geographic units: the State of Alaska as a whole, the several regions within which oil and gas development is likely to take place, and within these regions, the local communities.

The overall research method is multidisciplinary in nature and is based on the preparation of three research components. In the first research component, the internal nature, structure, and essential processes of these various geographic units and interactions among them are documented. In the second research component, alternative sets of assumptions regarding the location, nature and timing of future OCS petroleum development events and related activities are prepared. In the third research component, future oil and gas development events are translated into quantities and forces acting on the various geographic units. The predicted consequences of these events are evaluated in relation to present goals, values, and expectations.

In general, program products are sequentially arranged in accordance with BLM's proposed OCS lease sale schedule, so that information is timely to decision making. In addition to making reports available through the National Technical Information Service, the BLM is providing an information service through the Alaska OCS Office. Inquiries for information should be directed to: Program Director, Socioeconomic Studies Program, Alaska OCS Office, Post Office Box 1159, Anchorage, Alaska, 99510.

TECHNICAL REPORT #21 CONTRACT NO. AA550-CT6-61

ALASKA OCS SOCIOECONOMIC STUDIES PROGRAM
BEAUFORT SEA PETROLEUM DEVELOPMENT SCENARIOS:
NATURAL PHYSICAL ENVIRONMENT IMPACTS

FINAL REPORT

Prepared for

BUREAU OF LAND MANAGEMENT

ALASKA OUTER CONTINENTAL SHELF OFFICE

Prepared by

DAMES & MOORE

June 1978

Job No. 8699-013-20

NOTICES

1. This document is disseminated under the sponsorship of the U.S. Department of the Interior, Bureau of Land Management, in the interest of information exchange. The U.S. Government assumes no liability for its content or use thereof.

2. This is a final report designed to provide preliminary petroleum development data to groups working on the Alaska OCS Socioeconomic Studies Program. The assumptions used to generate offshore petroleum development scenarios are subject to revision.

3. The units presented in this report are metric with American equivalents.

ALASKA OCS SOCIOECONOMIC STUDIES PROGRAM
Projected Impacts of Beaufort Sea OCS Development - Assessment of Natural Physical Environment
Final Report

Prepared by

DAMES & MOORE

June 1978

REPORT DOCUMENTATION PAGE

1. Report No.	2.	3. Recipient's Accession No.
Technical Report #21		

4. Title and Subtitle
Alaska OCS Socioeconomic Studies Program
Beaufort Sea Petroleum Scenarios
Natural Physical Environment Impacts

5. Report Date
June 1978

6.

7. Author(s)

8. Performing Organization Report No.
8699-013-20

9. Performing Organization Name and Address
Dames & Moore
510 L Street, Suite 310
Anchorage, Alaska 99501

10. Project/Task/Work Unit No.

11. Contract or Grant No.
AA550-CT6-61

12. Sponsoring Organization Name and Address
Bureau of Land Management
Alaska Outer Continental Shelf Office
Post Office Box 1159
Anchorage, Alaska 99510

13. Type of Report

14.

15. Supplementary Notes

16. Abstract

This report analyzes the environmental impacts of Beaufort Sea petroleum exploration, development and production. Petroleum development scenarios have been established which provide a reasonable range of technological, economic and geographic options for minimum and maximum impact data.

Using the petroleum scenarios, man's impact on the North Slope of Alaska is analyzed for two situations. First, the impacts of man if OCS development does not occur and secondly, if OCS development does occur. The discussions concern water resources, water quality, sanitation, mineral resources (mainly sand and gravel) and fish and wildlife resources.

17. Originator's Key Words

18. Availability Statement
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

19. U. S. Security Classif. of the Report	20. U. S. Security Classif. of This Page	21. No. of Pages	22. Price
Unclassified	Unclassified		

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.}

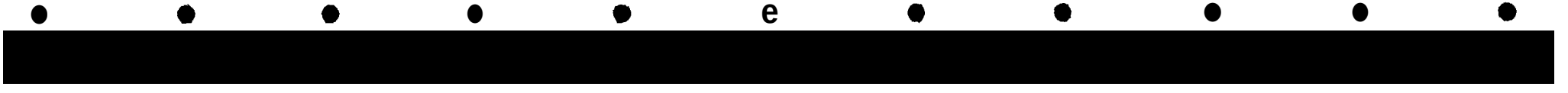
TABLE OF CONTENTS (Cent.)

LIST OF TABLES

LIST OF TABLES (Cont.)

LIST OF FIGURES

(FIGURES FOUND IN APPENDIX)


e

I. PROJECTED IMPACTS OF OCS DEVELOPMENT: PETROLEUM DEVELOPMENT SCENARIOS

Objectives of OCS Development Scenarios

In order to analyze the socioeconomic and environmental impacts of Beaufort Sea petroleum exploration, development, and production, it is necessary to make reasonable predictions of the nature of that development. The primary purpose of these petroleum development scenarios is to provide a reasonable range of technological, economic and geographic options so that both minimum and maximum development impacts can be estimated. The scenarios are formulated for the proposed joint State-Federal lease sale area and subsequent Federal OCS lease sale area in the Beaufort Sea.

The salient features of all the detailed petroleum development scenarios and existing North Slope infrastructure [Prudhoe Bay field, Alyeska pipeline, Distant Early Warning line sites (DEW line) etc.] are shown in Figure 1 and Figure 2 in the Appendix. Pipeline corridors and staging area locations were identified by a multi-disciplinary team which attempted to balance developmental, environmental and socioeconomic considerations. The facility locations that should be considered as hypothetical are the oil and gas discovery sites. The purpose of the petroleum development scenarios maps (Appendix) is to provide the geographic perspective to the assessment of environmental and socioeconomic impacts.

This report looks at the impact of man on the North Slope of Alaska in two situations. First, the impacts of man if OCS development does not occur and secondly, if OCS development does occur. The, discussions concern water resources, waste discharges, mineral resources (mainly sand and gravel), and fish and wildlife.

Characteristics and Definition of Each OCS Petroleum Development Scenario

Although the variability of the parameters characterizing potential oil field development permits a nearly unlimited selection of possible outcomes, there are two parameters that outweigh all others with respect to potential impacts on the Alaskan environment and economy: the amount of resource and its location. Consequently, a 'selection of scenarios that covers the range of locations and of reasonably expected resource deposit sizes should provide a sufficient basis for impact consideration.

A range of U.S.G.S. resource values allocated according to a geologic assessment provided 24 skeletal scenarios. Of these, four were selected for detailed analysis. These provided a range of location and developmental magnitudes that allowed the most realistic prediction of baseline conditions (project description) for subsequent socioeconomic impact assessment. With the exception of the Prudhoe Bay scenarios, only one of which may occur, the selected scenarios, although individually analyzed, represent the cumulative petroleum development as anticipated in the Beaufort Sea within the confines of the U.S.G.S. estimates and lease sale areas.

The scenario selection also covers a range of resource discovery probabilities (ranging from 1 to 95 percent). The discovery probabilities indicate that development of the central and eastern areas will be more likely than the western areas. (See Figure 1 in Appendix.)

The western area (Smith-Dease) has been selected as an exploration-only scenario. However, a higher probability of resource discovery has been selected to justify a reasonable level of exploration activity. In the Cape Halkett area, a resource discovery probability of 5 percent has been selected. In the Prudhoe sector, scenarios at the modal value and a high value (one percent) have been selected. In the eastern area (Camden-Canning), a high probability has been selected, but it has been split into two fields to provide detailing of that contingency.

The scenarios selected for detailed study are therefore:

Scenario	Production	Lease Sale
Camden-Canning	1.3 Bbbl for two fields; 3.25 tcf	Joint State-Federal
Prudhoe-Small*	0.8 Bbbl; 1.6 tcf	Joint State-Federal
Prudhoe-Large*	1.9 Bbbl; 4.75 tcf	Joint State-Federal
Cape Halkett	0.8 Bbbl; gas not developed	Federal OCS
Smith-Dease	0.4 Bbbl; exploration only.	Federal OCS

Note: Bbbl means billion barrels
tcf means trillion cubic feet
*For cumulative impact analysis, only one scenario can be used.

This selection of scenarios provides an adequate variation, contrast, and coverage for assessment and review of socioeconomic and environmental impacts. In addition to constructing each of these scenarios with a structural set of cost parameters, producing a range of economic outcomes, small shifts in the location of the large scenario fields were reviewed -- offshore Prudhoe and in the eastern Beaufort to deeper waters. Economic effects of such shifts remain within the envelope of cost parameters considered, even with revision of the assumed mix of platform types. Although an effort has been made to select scenario areas compatible with geologic characteristics known at present about the areas, the locations selected should not be construed as other than hypothetical.

SUPPORT FACILITIES -- EXPLORATION PHASE

During the exploration phase of Beaufort Sea petroleum operations, very limited, if any, new construction of onshore camps, airstrips, staging areas, communication sites, or other facilities will be required, Permits for new construction outside the vicinity of the Deadhorse industrial area will probably be difficult to obtain from state and federal agencies. In any case, it is doubtful that exploration will require shore-based support from facilities other than those available

at Prudhoe Bay with the possible exception of Lonely, which is currently serving as the staging area for exploration in the northeastern sector of NPR-A. Lonely could continue to be a staging area for exploration activities west of Harrison Bay. The facilities of existing or abandoned DEW line stations, principally airstrips, may be used for offshore exploration if fortuitously located with respect to the well site. A significant increase in the North Slope/Beaufort Sea exploration following the State lease sale will undoubtedly produce expansion of the Deadhorse oil field supplies and services. (See Figure 2 in Appendix.)

During exploration, each offshore platform (mainly artificial islands) will accommodate both a drill rig and a crew camp. Most North Slope drill rigs come supplied with a camp. During the winter, these camps could be supplied from Anchorage or Fairbanks by cargo aircraft that could land on ice airstrips built near the drilling pads or at the Deadhorse airstrip. Deadhorse will probably be used as much as possible for a staging, supply, and communications center.

Unlike onshore exploration, Beaufort Sea exploration will be a year-round activity with construction of soil islands taking place in summer or winter. In the case of summer-constructed islands, drill rigs will be transported to the site by barge prior to freeze-up and drilling can continue throughout the fall and winter. In the case of ice islands and winter-constructed soil islands, the option of either rig mobilization by air or land (and over-ice) is available.

Although there is a pool of Arctic rigs at Prudhoe Bay, some of which are available for exploration, additional Arctic rigs will be required for exploration of State-Federal lease tracts, especially since many of those at Prudhoe are near the end of their life span. Much of the supplies, such as mud, cement, and casing, will be obtained from oil field suppliers at Deadhorse. These may not necessarily be trucked to the well site since trucking costs on the North Slope are similar to the costs of transportation by air.

SUPPORT FACILITIES -- PRODUCTION PHASE

Permanent onshore facilities, such as airfields, harbors, and base camps, will be built only after economically recoverable oil is found. Onshore field development activity will tend to be located as near as possible to the closest point of landfall for the offshore field. The onshore facilities required for the operation of an offshore oil and gas field (assuming that oil and gas treatment is conducted onshore at the pipeline landfall) include oil/gas/water separating plants (flow stations), a gas compression plant, pump station, a base camp, an airstrip, a dock/harbor, a storage area, and access roads. A number of environmental and engineering criteria will have to be met and will influence the actual site of onshore construction, such as avoidance of environmentally sensitive areas, availability of fresh water, proximity to gravel", soil stability and barge access. (See Figure 2 in Appendix.)

The location of onshore facilities will only coincidentally be at an existing DEW line site (Distant Early Warning System locations), as there is no infrastructure of sufficient value at such a site to attract facilities to its vicinity. The cost of deviating one or two miles from an acceptable site would far exceed the cost of any useable infrastructure a DEW line site might possess. Active and inactive DEW line sights with airstrips are shown on Figure 2.

No use of facilities at existing North Slope communities is anticipated. Even the two largest communities, Barrow and Kaktovik, do not have an infrastructure of sufficient economic value to justify relocation of support facilities from points nearest the offshore production wells. In addition, there are strong social reasons why oil companies will want to avoid development near an established North Slope community. Local Eskimo leadership is very sensitive to possible interference with the existing socioeconomic structure of their communities, and oil companies will not want to bear the responsibility for cultural changes imposed by establishing facilities in or near'the villages. Existing communities are shown on Figure 2 in the Appendix.

A detailed analysis will be required for site-specific planning of support facilities. The general criteria that should be used to select the location of a production base camp/staging area are briefly described below, These factors would essentially "fine tune" the location of the staging area since for each scenario there is a certain length of coastline in which a staging area could be located opposite the offshore field. While the closest landfall is the most favored site, the position of the hypothetical fields relative to the shoreline (long axis parallel or sub-parallel to the coastal trend), which is dictated by geologic structure, means that there is some flexibility in the selection of onshore staging areas/production facilities. For the selected (detailed) scenarios, the approximate length of coastline in which a staging area may be located opposite the offshore field(s) is:

Camden-Canning	40 kilometers (25 miles)
Prudhoe-Small	19 kilometers (12 miles)
Prudhoe-Large	32 kilometers (20 miles)
Cape Halkett	11 kilometers (7 miles)

Proximity to Offshore Production Field

The most important requirement for base camp location is its proximity to the area of offshore development. Close proximity minimizes the running time of supply ships, over-ice vehicles and helicopters. This is especially important during periods of inclement weather or emergency. Close proximity also minimizes the length and therefore the investment requirements for offshore pipelines which have landfalls at the service base, In the scenario analysis the postulated base camp or staging area locations, with the exception of the Cape Halkett scenario, are also the location of the oil and gas treatment facilities (oil and gas separation, dehydration, gas compression, etc.). Economic and environmental factors will encourage centralization of facilities and minimization of duplication. The assumption has been made that oil/gas processing will be done onshore in the case of the Camden-Canning scenario and possibly in the Prudhoe

scenarios. If oil/gas processing is done on the platforms, then the base camp/staging area does not need to be at the pipeline landfall. Scenario exploration/production staging areas are shown in Figure 2 in the Appendix.

Deep Water

Since the Beaufort Sea is shallow (the 20-meter isobath lies 16 to 72 kilometers or 10 to 45 miles offshore), depth of water close to shore is an important locational criteria for a port site. In general, the presence of shallow waters on the Beaufort Sea coast necessitates lightening of freight from deep draft vessels to shore in barges that draw less than 2.5 meters (8 feet) of water. Other factors that are important in port site location include submarine topography, the type of bottom sediments, coastal erosion, and near-shore sediment transport.

In addition to the requirement to offload oil field equipment and supplies brought in on an annual sea lift, a port facility also provides winter anchor for vessels constructing or servicing offshore production islands. Most of these are shallow draft vessels.

Few port sites capable of accommodating ocean going vessels are available on the Alaskan Beaufort coast. Ocean going tugs and barges that have been involved in the annual sea lifts to Prudhoe Bay draw 5.5 to 6 meters (18 to 20 feet) of water. Even with causeways several miles long, such barges cannot be offloaded without lightening onto shallow-draft tugs. Sites that have been identified as potential medium- to deep-draft ports on the Alaskan Beaufort coast include Pingak Island, Cross Island, Pole Island, Flaxman Island, and Kangigurik (Arctic Institute of North America, 1974). To some extent these sites are at exposed locations where large ice floes and summer storms impact.

Lightening and long causeways can be anticipated as necessary to Beaufort Sea petroleum development transportation since there are no suitable

port sites on the mainland adjacent to the scenario field locations. Considerable traffic in the vicinity of the platforms can also be expected. High density marine shipping zones and summer marine shipping zones are shown on Figure 2 in the Appendix.

Shelter

A sheltered harbor in the general proximity of the development area is a major factor in locating the supply base. Barges require protection from fall storms and movement of sea ice, This requires the construction of a jetty or causeway, or the location of the port in a protected, natural harbor, or inside a lagoon protected by offshore islands. Port sites have to be in the landfast ice zone. Potential port sites with suitable hydrographic conditions appear to lack shelter. The barrier islands do afford a significant amount of protection from pack ice and storm waves to inshore waters. However, these waters are generally too shallow to provide good port sites. Marine traffic in the Beaufort Sea will stay seaward of the barrier islands unless ice conditions force them shoreward, where speeds have to be reduced because of shoals.

Environmental Sensitivity

In selecting base camp/staging area sites, the location and timing of marine mammal and fish migrations must be considered (Table 1). Onshore habitats, such as the dens of polar bears, the calving areas of caribou, and the nesting and molting sites of waterfowl, have to be evaluated in the planning of ports and pipelines, and the timing of onshore construction. These marine and terrestrial? wildlife resources are important to the subsistence economies of the villages and the overall welfare of Arctic ecosystems. Regulatory protection can be expected.

Marine traffic routes and the timing of such traffic may create significant impacts to marine mammal populations. Studies on the impact of the Canadian artificial soil island program in the southern Beaufort indicate that disturbance of wildlife is probably the most important impact. Marine shipping zones are shown on Figure 2 in the Appendix.

TABLE 1

CRITICAL AREAS

SPECIES	LOCATION	REMARKS	USER GROUP
Bowhead and Belukha Whales	Point Barrow-Pitt Point Harrison Bay	Seward to about 15 miles	Barrow
Ringed Seals	Wainwright-Barrow	Landfast ice and grounded pack ice	Wainwright and Barrow
	Cape Simpson-Pitt Point	Landfast ice and grounded pack ice	Barrow
	Cross Island-McClure Island	Landfast ice and grounded pack ice	None
	Maguire Island-Camden Bay	Landfast ice and grounded pack ice	Kaktovik
Waterfowl and Shorebirds	Plover Islands	Staging and molting	Barrow
	Pitt Pt.-Cape Halkett-Teshekpuk L.	Staging and molting	Barrow and Nuiqsut
	Colville River Delta	Nesting	Nuiqsut
	Jones Islands	Nesting	Nuiqsut
	Howe Island	Only snow goose nesting colony in Alaska	Nuiqsut
	Kaparuk River Delta	Nesting	Nuiqsut
	McClure Islands	Nesting	Nuiqsut
	Canning River Delta	Nesting	Kaktovik
	Sadlerochit River-Aichilik River	Snow goose staging area	Kaktovik
Musk Oxen	Canning River-Okpilak River	Resident	Tourists in Arctic Wildlife Range
Caribou	Teshekpuk Lake-Cape Halkett	Calving and resident caribou herd	Nuiqsut and Barrow
	Oliktok Point-Bullen Point	Calving and summer range	Tourists at Prudhoe Bay
	Katakturuk-Kougakut River	Calving	Kaktovik
Fish	Lower Meade River	Overwintering	Barrow-Atkasook
	Teshekpuk Lake	Overwintering	Barrow-Nuiqsut
	Lower Colville River	Overwintering	Nuiqsut
	Lower Kuparuk	Overwintering	Nuiqsut
	Lower Sagavanirktok River	Overwintering	Nuiqsut
	Lower Canning River	Overwintering	Kaktovik

References: Alaska Department of Fish and Game, 1977; Bergman, 1974; Burns et al., 1976; Cameron and Whitten, 1976, 1977; Craig and McCart, 1976; Davis and Valkenburg, 1977; Gavin, 1974, Hemming, 1971; Selkregg, 1975; Ward and Craig, 1974; Weller, 1977; Yoshihara, 1973.

Gravel

The availability of gravel is an economic, environmental and locational consideration. If it is necessary to build where sand and gravel are in short supply, alternative construction methods or substitute materials are sometimes used. Environmental concerns regarding sand and gravel extraction include:

- Siltation of fish spawing streams.
- Siltation in offshore fish habitats.
- Acceleration of erosion on beaches, river and coastal bluffs, barrier islands, and tundra surface.

As a locational factor, however, the availability of gravel and sand will not be very important with respect to the siting of onshore facilities, although geotechnically gravel deposits tend to be thaw-stable materials and present fewer foundation problems. Rather, the importance of gravel availability affects construction economics since haul distance is a significant cost factor. Offshore petroleum development will probably require significantly more gravel for a given field size than an equivalent onshore Arctic field.

Water

Water resource availability is a major concern in Arctic petroleum development since water is required in large quantities during every phase of petroleum development. The water supply problem on the North Slope is compounded by environmental problems of its withdrawal in some areas. These include:

- Winter extraction from portions of rivers where fish winter.
- Winter extraction from deeper lakes where fish winter.

Like gravel availability, water availability will probably be only a minor influence in facilities siting, although the distance, and hence haulage or transmission costs , will be an economic factor in petroleum development.

Archaeological and Historical Sites

The discovery of important historic and archaeologic sites can modify the location of pipelines, base camps, etc. (The major river valleys of the North Slope, in particular, are historically and archaeologically important.) Archaeological surveys are generally conducted as part of siting studies and add to existing knowledge.

Description of a Typical Staging Area

Harbor facilities include a "T" shaped loading dock, perhaps constructed of sunken barges as at Prudhoe Bay, connected to the shore by a 30-meter wide (100-foot) causeway. Mooring space must be sufficient for the artificial island and platform construction and maintenance fleet, service vessels, shallow draft tugs, and lightening barges that winter here. A minimum water depth of about 2.4 meters (8 feet) must be provided at the dock to accommodate these vessels. Depending on bathymetric conditions, this may necessitate a causeway 1 to 2 kilometers (0.6 to 1.2 miles) or more long. A dredge channel may be required; the dredged material could be used for construction of the causeway or artificial islands. The causeway may carry the offshore pipelines either buried or elevated. A ramp is provided at the end of the causeway to permit access on and off the ice for trucks and tractors.

A marshalling area is developed near the dock for storage of such drilling equipment as casing and drill pipe, cement, drilling mud, water and fuel, tractors, skids and other inactive materials. Base operation buildings are constructed on gravel pads. The total storage area is estimated to be 0.8 to 1.6 hectares (2 to 4 acres).

An all-weather gravel airfield from 1,523 to 1,828 meters (5,000 to 6,000 feet) long, capable of handling Hercules and medium-sized jet aircraft, is required.

Oil/gas processing facilities include an oil/gas separation and dehydration plant (flow station/gathering center), pump station, gas conditioning and compression plant. A small power station serves the staging area. Other facilities include a permanent base camp and operations center, sewage treatment plant and water storage. The camp accommodations required for each selected scenario, as indicated by manpower estimates, are as follows:

	Number of Personnel Accommodated	
Scenario	Construction (Temporary Camp)	Operation (Permanent Camp)
Camden-Canning	2,000	650
Prudhoe-Small[1]	1,500	500
Prudhoe-Large[1]	2,500	800
Cape Halkett[2]	1,300	400

The staging area is at the beginning of a gravel haul road to Prudhoe Bay as well as the beginning of onshore truck pipelines to Prudhoe Bay.

Overall land requirements for such a staging area are difficult to estimate. However, unlike Prudhoe Bay, the staging area configuration is not constrained or dictated by the oil field area since the field is located offshore. Environmental and economic considerations will tend to encourage maximum utilization of space and minimization of land requirements.

---

(1) Sufficient capacity is assumed to be available at existing Prudhoe Bay camps.

(2) Some of the operation workers will be housed on the platforms.

CAMDEN-CANNING SCENARIO, 1.3 Bbbl

Tract Assumptions

The Camden-Canning scenario contains two major reservoir areas where surface expressions encompass 10,500 and 6,900 hectares (26,000 and 17,000 acres}. The areas are assumed to be elliptical, underlying all or part of the following tracts cataloged in the joint State-Federal lease sale:

Key: A - Joint and disputed ownership claim
B - Federal lands.
C - State lands.
D - Disputed

Camden Area - 18 tracts (19,578 hectares)

181 (A)	199 (A)	217 (A)	230 (C)
195 (A)	213 (A)	218 (A)	231 (C)
196 (A)	214 (C)	227 (C)	232 (C)
197 (A)	215 (C)	228 (C)	
198 (A)	216 (C)	229 (C)	

State, 52%; Joint and Disputed, 48%.

Canning Area - 16 tracts (17,464 hectares)

176 (C)	190 (C)	194 (c)	212 (c)
177 (c)	191 (c)	209 (C)	223 {C)
178 (A)	192 (C)	210 (c)	224 (C)
179 (A)	193 (A)	211 (c)	225 (C)

State, 82%; Joint and Disputed, 18%.

Alternative tract locations, with identical field expressions (area and shape) involved 37 tracts and a slightly different ratio of Federal and State interests:

Camden Alternate Area - 19 tracts (25,432 hectares)

663*	196 (A)	167 (B)	216 (C)	229 (c)
665*	197 (A)	181 (A)	217 (A)	230 (C)
191 (A)	198 (A)	214 (C)	218 (A)	231 (C)
195 (A)	199 (A)	215 (C)	228 (C)	

*Federal tracts of 2,304 hectares, not in joint State-Federal area. 24% Federal; 48% Joint and Disputed, 28% State.

Canning Alternate Area - 18 tracts (21,351 hectares)

150 (A)	163 (A)	177 (c)	191 (c)	210 (c)
151 (A)	164 (A)	178 (A)	192 (c)	211 (c)
152 (B)	165 (A)	179 (A)	193 (A)	
162 (C)	166 (A)	180 (A)	194 (c)	

9% Federal; 57% Joint and Disputed; 34% State.
See Figure 1 in the Appendix for lease tracts.

Physical Setting

The Camden-Canning oil fields straddle the barrier islands (an island roughly parallel to shore separated by a small body of water, such as a lagoon) with their long axis approximately parallel to the trend of the islands. Seaward of the barrier islands the 20-meter (60-foot) isobath lies for the most part just outside the 5-kilometer (3-mile) limit. Water depths at the field locations range from about 1 meter (3 feet) at the eastern end of Flaxman Island (inshore) to 4.3 meters (14 feet) about 600 meters (one mile) off Point Thompson to a maximum of about 15.4 meters (50 feet) outside the barrier islands.

The area outside the barrier islands may be affected by late summer storms and by grounding of pack ice ridges in fall and early winter. By late winter landfast ice will cover the field locations. Greater ice motion can be expected outside the barrier islands than landward of them. Offshore and onshore gravel resources can be anticipated in the Canning River delta area, the Shaviovik River, the barrier islands and coastal beaches between the Canning and Shaviovik Rivers".

Environmental Considerations

Exploration and development in the Camden-Canning area will require care in selection of staging areas, camps, and pipeline routes both offshore and onshore.

The calving area of the Central Arctic caribou herd extends from Bullen Point west to Oliktok. In addition, caribou make extensive use of beaches, spits, and river deltas from June to August to escape biting insects and parasitic flies. They also wade and swim in rivers and lagoons. Construction camps or above-ground pipelines in this area could cause critical summer ranges to be abandoned as observed by the Alaska Department of Fish-and Game at Prudhoe Bay (Cameron and Whitten, 1976; 1977). Coastal oil spills could influence caribou use of the coastal fringe. Burial of pipelines, especially through river deltas, would help to assure caribou passage.

Excessive disturbance at some barrier islands during exploration or construction of facilities can cause abandonment of seal pups and hauling-out areas. However, no concentration of seals have been reported in this area to date.

Water contamination from petrochemical pollution would be a threat to marine mammals, birds, fishes and the marine food web in general.

Critical fish overwintering areas have been identified on the deltas of the Kavik and Canning Rivers. Gravel mining or collection of potable water could seriously impact these areas (Wilson et al., 1977).

Dredged islands or onshore facilities with living facilities will undoubtedly attract Arctic foxes, even with good garbage disposal practices. Workers in the Arctic have not been able to resist the impulse to feed wildlife. Animals attracted by feeding are often killed by moving equipment or are shot when they become a nuisance.

Polar bears are known to den between the Sagavanirktok and Canning Rivers, but no traditional sites have been identified. The bears usually range beyond the shorefast ice, but must be considered a serious threat to man whenever they are nearby.

Facilities

The two fields are assumed to share an airstrip and harbor. However, separate construction camps, 24 kilometers (15 miles) apart, are assumed. One hundred three kilometers (sixty-four miles) of road between Deadhorse and the Canning camp are assumed, including the harbor connector. Another 24 kilometers (15 miles) of road are required for the Camden tie-in. A small boat ramp or removable pontoon pier is assumed at the camp not adjacent to the harbor.

After construction, a single base camp area near the harbor will be used. A flow center of 250 Mb/d and 230 MMcfd capacity onshore opposite the Camden field will service that field and a portion of state lands production. The flow station for the Canning field, 24 kilometers (15 miles) west, will service that field and the remaining state lands production. Nominal capacity needed would be 180 Mb/d and 150 MMcfd. In the vicinity of the Canning field flow station, compressor and pump stations will provide motive force for delivery of the production to the respective Prudhoe Bay stations. A power plant will be included in the Canning onshore plant complex.

Primary oil and gas separation is accomplished on each platform, which average 40 wells each. Some booster stations are used on the platforms to bring the oil ashore to the flow centers.

The exploration wells include, by allocation, all wells in the eastern Beaufort. Exploration within the Camden area is assumed complete with four wells; in the Canning, with five.

Platforms:		Soil/Gravel	Barge	Ice	Gravity
Camden:	Exploration	6	3	1	0
	Production	6	1	0	1
Canning:	Exploration	3	3	2	0
	Production	3	2	0	0

Wells:	Exploration	Oil	Gas	Development
Camden	10	262	7-8	53-52
Canning	8	171	5-4	22-23

Pipelines:	Oil		Gas		
	km	miles	km	miles	
Connectors	85	53	63	39	Offshore
Trunk	10	6	10	6	
Onshore Trunk	87	54	87	54	

PRUDHOE-SMALL SCENARIO, 0.8 Bbbl

Tracts Assumed

This scenario has a surface expression of 10,931 hectares (27,000 acres). The following tracts in the joint State-Federal leasing area are assumed:

22 tracts (22,177 hectares)

47 (A)	66 (c)	84 (C)	97 (A)	112 (A)
48 (A)	67 (C)	85 (C)	98 (A)	113 (A)
63 (A)	81 (A)	86 (C)	99 (c)	
64 (D)	82 (A)	95 (C)	110 (C)	
65 (A)	83 (A)	96 (A)	111 (A)	

37% State; 63% Joint and Disputed.
Tracts are shown in Figure 1 in the Appendix.

Physical Setting

The oil field lies between the inner barrier islands of Stump, Egg, and Long Islands and the outer barrier island, Midway Island. Water depths at the field location vary from about 6 meters (20 feet) near Stump Island, to about 8.5 meters {28 feet) midway between Stump Island and Midway Island, and to a maximum of nearly 18 meters (60 feet) 19 kilometers (12 miles) west-northwest of Midway Island. A number of offshore shoals occur over the western half of the field.

Most of the oil field is located within the landfast ice zone, although in fall and early winter pack ice ridges may ground on the shoals located in the northwest section of the field. Subsea ice-rich permafrost within 20 meters (66 feet) of the sea floor is restricted to Prudhoe Bay and in the lagoon between the mainland and barrier islands.

Significant offshore sand and gravel resources appear to be present within and adjacent to the oil field location; these deposits are located off the Sagavanirktok River delta, and in a band parallel to the bathymetric contours north of the barrier islands between Prudhoe Bay and the Colville River.

Environmental Considerations

Exploration and development will require care in selection of staging areas, camps and pipeline routes both offshore and onshore.

Critical wildlife concerns in this area include snow geese nesting on Howe Island; black brant nesting on the delta of the Kuparuk River; eider, gull, and tern nesting on offshore islands; caribou calving near the beach; and winter water removal from the Sagavanirktok River (Cameron and Whitten, 1977; Hemming and Moorehouse, 1976; Wilson et al., 1977).

The Alaska Department of Fish and Game has concluded that essentially all of the Prudhoe Bay oil field has been abandoned as a caribou calving area since about 1974 (Cameron and Whitten, 1976; 1977; White et al., 1975). Therefore, the oil field area would be the best place to locate exploration and production facilities. Due to the fairly extensive losses from the caribou calving area to date, the Alaska Department of Fish and Game can be expected to be quite restrictive of activities within the remainder of the calving area.

Howe Island at the mouth of the Sagavanirktok River supports the only snow goose colony on the Arctic coast of Alaska. This small colony of about 60 nesting pairs would be threatened by any land uses on Howe Island or if a summer oil spill occurred in the area. Other nesting birds such as glaucous gulls, Arctic terns, and eiders make extensive use of Niakuk, Gull, Cross and Stump Islands.

Collection of potable water and gravel mining near the mouth of the Sagavanirktok River associated with oil field development and construction of the trans-Alaska pipeline have impacted overwintering fish populations (Wilson et al., 1977; U.S. Fish and Wildlife Service, 1976).

Facilities

The Prudhoe-Small scenario will resemble the Prudhoe-Large scenario in the placement of facilities. Use of the infrastructure at Prudhoe Bay is assumed, without any of the processing facilities. Power may be purchased for an onshore flow center. No new harbor, base camp site, or airstrip is assumed.

A flow center at the shore with a capacity of 200 Mbbl/d and 250 MMcfd is the only major unit assumed onshore. Alternative treatment centers offshore will use smaller modules of 100 Mbbl/d and 120 MMcfd capacity. A single trunk line to the shore is assumed.

Only four of the twelve exploration wells associated with this scenario are within the field.

Platforms:	Barge	Soil/Gravel	Ice	Gravity
Exploration	4	6	2	0
Production	6	5	0	1

Wells:	
Exploration	- 12
Oil	- 270
Gas	- 13
Development	- 47

Pipelines:	Oil		Gas	
	km	miles	km	miles
Connectors	80	50	32	20
Offshore Trunk	6	4	6	4
Onshore Trunk	15	9.5	15	9.5

PRUDHOE-LARGE SCENARIO, 1.9 Bbbl

Tract Assumptions

This scenario encompasses 15,385 hectares (38,000 acres) of the central Alaskan Beaufort Sea. The tracts assumed involved in the surface expression of the reservoir are:

Prudhoe-Large, 31 tracts (34,157 hectares)

44 (A)	62 (C)	80 (C)	86 (c)	99 (c)	114 (A)
45 (A)	63 (C)	81 (A)	87 (C)	100 (A)	
46 (A)	64 (D)	82 (A)	95 (C)	110 (c)	
47 (A)	65 (A)	83 (A)	96 (A)	111 (A)	
48 (A)	66 (C)	84 (C)	97 (A)	112 (A)	
61 (A)'	67 (C)	85 (C)	98 (A)	113 (A)	

36% State, 64% joint and disputed.

As an alternate location, displaced a short distance into deeper water, the following tracts were involved. The shape and extent of the reservoir projection are identical, but the number of tracts involved is less.

Prudhoe-Large Alternate, 30 tracts (37,511 hectares)

427*	47 (A)	64 (D)	82 (A)	87 (C)	100 (A)
428*	48 (A)	65 (A)	83 (A)	96 (A)	111 (A)
429*	49 (A)	66 (c)	84 (C)	97 (A)	112 (A)
45 (A)	50 (A)	67 (C)	85 (C)	98 (A)	113 (A)
46 (A)	63 (A)	68 (c)	86 (C)	99 (c)	114 (A)

*Federal tracts of 2,304 hectares not included in joint State-Federal lease sale.
22% State; 18% Federal; 60% Joint and Disputed.

Although the Federal tracts are not included in the sale, it is reasonable to assume that they would be offered at a special sale, along with other open tracts, in the 1985-88 period. No adjustments or delays in development need be anticipated, since drilling and platform construction extend well beyond that period. Lease tracts are shown on Figure 1 in the Appendix.

The physical setting and environmental considerations for Prudhoe-Large are the same as for Prudhoe-Small.

Facilities

The Prudhoe-Large scenario is assumed to make use of the Prudhoe Bay infrastructure, although the oil facilities there are not considered to be available. New airstrip, harbor, and construction camp are not assumed. See Figure 2 in the Appendix for exploration/production staging areas.

Two flow centers onshore, each of about 325 Mbbl/d and 280 Mbbl/d nominal capacity, are considered. Twin trunk corridors to the shore may be used, although a single trunk line onshore is projected for the 15-kilometer (9.5 mile) distance to the Alyeska-Alcan terminals. If the flow center space at the shore is not made available, offshore processing can be undertaken. Modular treatment centers will be installed at each platform, possibly as an ancillary platform separated for safety. Flow center power is purchased from surplus or expansion of the Prudhoe Bay field, depending on whether the field output is expanded in the 1979-83 time period.

With respect to the 14 exploration wells allocated to the scenario, only 3 or 4 are projected within the field boundaries.

Platforms:	Barge	Soil/Gravel	Ice	Gravity
Exploration	4	7	3	0
Production	1	4	0	1

Wells:
Exploration - 14
Oil - 253
Gas - 15
Development - 22

Pipelines:	Oil		Gas	
	km	miles	km	miles
Connectors	68	42	48	30
Offshore Trunk	6	4*	6	4*
Onshore Trunk	15	9.5	75	9.5

* With twin corridors - 16 kilometers (10 miles)

CAPE HALKETT SCENARIO, 0.8 Bbbl

Tracts Assumed

The Cape Halkett field lies off Cape Halkett, north of Harrison Bay. The surface expression of the field encompasses 8,097 hectares (20,000 acres). The following tracts were involved in the assumed location of the field:

7	52	96	140
8	53	97	141
51	95	98	142

These are all Federal tracts of 2,304 hectares. The tracts contain 25,344 hectares (62,600 acres). Lease tracts are shown on Figure 1 in the Appendix.

Physical Setting

The most seaward part of the Cape Halkett field lies 19 kilometers (12 miles) northeast of Cape Halkett in about 13 meters (44 feet) of water while the portion nearest the shore lies in about 7.6 meters (25 feet) of water.

The field lies for the most part in the landfast ice zone, although a distinct shear line that follows the 10-meter (30-foot) bathymetric trend in west Harrison Bay may affect the outermost portion of the field location.

Based on limited data we assume bottom sediments in west Harrison Bay are silt and clay. Shoal areas located immediately north of the field and to the southeast in Harrison Bay (Pacific Shoal) may be composed of sandy or gravelly sediments. Approximately 122,000 cubic meters (160,000 cubic yards) of sand and sandy gravel have been mapped along the beaches within 10 kilometers (6 miles) of Cape Halkett.

Environmental Considerations

Except for waterfowl molting and staging areas just inshore of the exploration zone, there are relatively few potential conflicts with staging areas, camps, or offshore pipelines. However, the use of above-ground pipelines from landfall at Cape Halkett to Prudhoe Bay could seriously influence the distribution and movements of the Central Arctic caribou herd (Child, 1973; Cameron and Whitten, 1976; 1977).

Orientation of above-ground pipelines to an alignment immediately adjacent to the beach or increased use of undersea pipelines could significantly reduce adverse impacts on caribou.

Major waterfowl nesting areas and fish overwintering sites on the Colville River delta could be impacted by gravel mining, oil spills, and collection of potable water. Human activity, including movement of equipment and low-level aircraft operation, could result in desertion of nesting sights and seal hauling-out areas, and abandonment of seal pups.

Attraction of foxes and possibly polar bears by improper garbage handling or direct feeding will be a chronic impact requiring nearly constant attention.

Teshekpuk Lake lies a few miles inland from the coast and is a major fish overwintering area. It also supports a traditional subsistence fishery for local residents. Adverse impacts could result from extensive activity near the lake.

Facilities

The Cape Halkett field is nearly 150 kilometers (90 miles) from the Alyeska pipeline. The resulting cost of pipeline construction, makes the economics marginal for a field of this size. The petroleum facilities are assumed to be offshore, with one of the four platforms built into a

platform complex. A treatment facility with a 300 Mbbl/d capacity, on a segment of the complex, provides pumping power to the Alyeska terminus. It also separates gas for reinfection. Gas turbine power is used in the field.

At the east Harrison Bay shore, the only installation is the pipeline landfall and above-ground installation (which includes a road along the line). A base camp, harbor, and airstrip are assumed on Cape Halkett.

Three of the eight exploration wells lie in the field boundaries. An alternative pipeline route onshore would measure in excess of 200 kilometers (120 miles).

Platforms:	Barge	Soil	Ice	Gravity
Exploration	2	0	6	0
Production	0	2	0	2

Wells:

Exploration	8	
Oil	- 143	
Gas	3	(injection)
Development	- 14	

Pipelines:

Connectors	- 67 km (42 miles)
Offshore Trunk	- 82 km (51 miles)
Onshore Trunk	- 66 km (41 miles)

SMITH-DEASE SCENARIO, 0.4 Bbbl

Tracts Assumed

No tracts for exploration were selected. The areas considered open to exploration are the Federal offshore tracts out to the 20-meter depth in the western Beaufort. Smith Bay and Dease Inlet areas have been assumed as leased for exploration. Submerged lands within Dease Inlet and Smith Bay, the jurisdiction of which is in dispute, are not considered.

Physical Setting

The Smith-Dease field is located just seaward of Smith Bay, 4.8 kilometers (3 miles) due north of Drew Point. The most seaward point lies 19 kilometers (12 miles) from shore in 11 meters (36 feet) of water; most of the field is located in water depths of between 3.6 and 9 meters (12 and 30 feet).

The field lies well shoreward of the boundary between the landfast and pack ice (stamukhi zone). Subsea ice-rich permafrost probably underlies the shallow waters of Smith Bay at depths of 1 to 20 meters (3 to 66 feet) below the mudline.

Little data is available on the bottom sediments in the Smith Bay area and it is assumed that they are silt and clay. Onshore sand and gravel resources in the area are scarce. The extensive delta of the Ikpikpuk River, located at the head of Smith Bay, is composed of fine sand, silt, and mud. Beach development is poor along the shores of the bay and eastward to Point McLeod, with sand resources totalling only about 100,000 cubic meters (140,000 cubic yards).

Environmental Considerations

Smith Bay lies within a major migration zone for the belukha and endangered bowhead whales. Any offshore exploration or development within this area could influence whale migration and could come under criticism (or control) by whale hunters from Barrow, city and borough governments, the Alaska Department. of Fish and Game, and the National Marine Fishery Service. Whales use this area between April and late September.

The Plover Islands area is an extremely important shorebird staging area from mid-July to August. Red phalaropes are the most abundant species. From Pitt Point to Cape Halkett, shorebirds and molting oldsquaws form dense aggregations in mid-summer (Weller et al., 1977). Oil spills or harassment could seriously affect these large concentrations of birds.

Attraction of foxes and possibly polar bears by improper garbage handling or direct feeding will be a chronic impact requiring nearly constant attention.

Onshore above-ground pipelines between Smith and Prudhoe Bays could seriously influence the distribution and movements of the Central Arctic caribou herd.

Facilities

No permanent facilities are invested in this scenario. Use of available facilites at Lonely are assumed. Temporary camp sites are cleaned out after use, and all of the drilling platforms are temporary -- barges or ice islands.

II. ASSESSMENT OF NATURAL PHYSICAL ENVIRONMENT, GROWTH AND DEVELOPMENT: NON-OCS SCENARIO, 1977-2000

Introduction

The purpose of this section is to assess the regional and community trends and impacts of continued North Slope development. This does not include any new oil and gas development on the outer continental shelf. Furthermore, it will describe expected impacts on the natural physical environment as a result of forecasted population and employment increases and changes in the man-made environment. In particular, local natural resources, subsistence hunting and fishing, water resources, water quality and sanitation are discussed.

Water quality, resources and sanitation will be impacted primarily because most North Slope communities are without a community water supply and distribution system and do not have adequate sanitation facilities.

Sand and gravel resources will be impacted due to current and future needs of local communities, current and future needs of the petroleum industry and future demands due to development of other hydrocarbon resources (e.g. coal), metallic and non-metallic mineral.

Fish and wildlife resources will be impacted due to current and future subsistence hunting and fishing. Also, sport hunting and fishing is increasing and this will cause a significant impact.

Identification of Impacts

FISH AND WILDLIFE RESOURCES

Alaska's human population has been increasing at a rather rapid rate since World War II. The greatest growth has occurred in the Anchorage-Fairbanks area, and except for Prudhoe Bay there has been little population change on the Arctic coast. Recreational hunting and fishing has increased rapidly during this period whereas subsistence activity has decreased.

Traditionally animals killed by hunters provided important raw materials for clothing, shelter, boats, and sleds. However, much of the biomass collected annually by Arctic residents was used as dog food. In the early 1960's Arctic residents took an average of 18,000 seals per year but by the 1970's seal harvests had declined to about 7000 to 9000 seals per year (Alaska Department of Fish and Game, 1976).

There are several major reasons for reduced harvest of subsistence species in the Arctic. Perhaps the most significant change occurred in the mid 1960's when northern residents traded dogs for snow machines as a primary mode of local transportation. By eliminating dog teams, residents no longer needed to harvest vast quantities of wild animals for dog food (Hemming, 1975; Alaska Department of Fish and Game, 1976). Snow machines increased the range and efficiency of hunters making it easy to provide needed food for their families. Life styles also changed as snow machine owners found it necessary to spend at least part time working for wages in order to have money to buy fuel, lubricant, and spare parts.

In 1972 the Marine Mamma' Protection Act was passed. It prohibited the taking of seals, whales, walrus, and polar bears by non-natives and placed restrictions on commercial users. More recently, restrictive quotas on bowhead whales have been established that will sharply reduce harvest by local natives.

Prior to 1972 a few seals were taken by sport and recreational hunters, but this never accounted for more than 10 percent of the harvest (Alaska Department of Fish and Game, 1976). There was, however, much interest in sport hunting polar bears and an active commercial trade of seal products and polar bear skins.

Prior to the Marine Mammal Protection Act there was significant trade in raw seal skins. The act prohibited the possession of raw marine mammal products by non-natives. The net result was a loss of income to local residents.

Even though subsistence harvests have decreased, the demand for fish and wildlife has not. The annual number of licenced sport hunters and fishermen in Alaska increased by more than 100,000 between 1965 and 1975 (Alaska Department of Revenue, 1976). There has been a rather sharp increase in sport fishing for lake trout, arctic char and grayling on the North Slope associated with development of the Prudhoe Bay oil field, and the trans-Alaska pipeline and haul road. Sport hunting for moose, sheep, and caribou in the Brooks Range and on the coastal plain has also increased in recent years except for the trans-Alaska pipeline corridor, which was closed to big game hunting and sport fishing by the Board of Fish and Game.

WATER QUALITY, WATER RESOURCES AND SANITATION

On the North Slope, water has historically been procured from lakes, ponds, or streams, or from melting ice. Waste disposal has been confined to pit privies, honey buckets, and open discharges to the ground. Current and probable water supplies, distribution methods, and waste disposal practices in the villages of Barrow, Kaktovik, Wainwright, and Nuiqsut are discussed here. (See Figure 2 in the Appendix for existing community locations.)

The existing community water supplies and facilities in Barrow, Kaktovik, Wainwright, and Nuiqsut are generally inadequate and do not meet regulatory agency standards for drinking water. All four villages depend upon surface water from lakes or streams (ice in the winter), which usually receives no treatment. There are no community water systems, hence individuals haul water (or ice) via tank truck, 200-liter (55-gallon) drums, or buckets. Few dwellings have running water. (It should be noted the conversions between metric and American are approximate and reflect the level of accuracy of the data.)

Barrow does not have a community water supply and distribution system, but the Bureau of Indian Affairs (BIA) school and hospital and the Naval Arctic Research Laboratory (NARL) do. The BIA's water source is at the west end of Isatkoak Lagoon. Water is hauled by tank truck to the treatment plant. Barrow residents can purchase treated water from the BIA, but many residents haul water or ice from Emaiksoun Lake, 3 miles south . This lake is unsanitary and may freeze to the bottom during winter. Some homes have water piped from a storage tank to sinks and flush toilets, but wastes still have to be hauled away. Because of the limited supply of potable water and the effort involved in hauling water, Barrow residents use an average of about 40 liters (10 gallons)" per capita per day (10 gpcpd) (CCC/HOK, 1977). The 1977 population of 2,200 (U.S. Census, North Slope Borough) indicated about 83,000 liters (22,000 gallons) of water consumed per day.

In Wainwright the U.S. Environmental Protection Agency has constructed a multi-purpose facility that provides treated water and laundry facilities. It is reported, however, that many residents continue to haul water (or ice) because of the chlorine taste in the treated water. Wainwright uses an average of 8 liters (2 gallons) per capita per day (CCC/HOK, 1977). In 1977 the population was 398 (U.S. Census, North Slope Borough), so water use averages more than 3,000 liters (800 gallons) per day.

Kaktovik and Nuiqsut rely totally on water hauled from lakes or streams. Kaktovik residents obtain water from Fresh Water Lagoon, west of the village. Neither village has treated water and residents in both average about 8 lpcpd (2 gpcpd) (CCC/HOK, 1977). The 1970 populations of these villages were 123 in Kaktovik and O in Nuiqsut (Selkregg, 1975), but in 1977 Kaktovik had 134 residents and Nuiqsut 157 (U.S. Census, North Slope Borough).

Waste disposal facilities in North Slope villages are generally inadequate and do not meet regulatory standards. Most residents use honey buckets for disposal of human waste, since none of the villages have community sewers or sewage treatment. Human wastes, in plastic bags or 200-liter (55-galion) drums, are hauled to community dumps. Kaktovik is somewhat unique in this respect because all human wastes are stored in 200-liter (55-gallon drums) that are supposed to be removed from the village once a year. With few exceptions, water used for cooking, cleaning, and washing is discharged directly onto the ground outside each home or dwelling in all the villages.

Wainwright's multi-purpose building houses a sewage treatment plant, laundry, and solid waste disposal facility. None of the villages have sanitary landfills, because permafrost precludes their construction.

The BIA and NARL in Barrow operate sewage treatment plants. Some houses have chemical toilets and holding tanks, which are periodically emptied by a vacuum tank truck and transported to the BIA treatment plant.

Improvements to the water and waste disposal facilities are planned in all North Slope villages, however, a time frame for this construction has not been established. In general, this comprises development of adequate water supplies, water treatment facilities that include central dispensing point, sewage disposal systems, and central facilities housing laundries, showers, and toilets. Piped water and sewer systems are planned for Barrow and Kaktovik. The Barrow system will be designed to

serve a population of 4,350 with an average water use of 170 lpcpd (45 gpcpd) (Alaska Consultants, Inc., 1978).

SAND AND GRAVEL RESOURCES

In assessing the potential non-OCS petroleum development impacts on mineral resources, it is necessary to separate minerals that may be used locally such as gravel, sand and quarry stone from minerals that would be transported outside the North Slope-Beaufort Sea region for industrial consumption elsewhere, such as the various metallic minerals and hydrocarbons. With the exception of the oil and gas infrastructure, none exists for the extraction of minerals. Sand and gravel are the only minerals in demand locally.

The assessment of impacts on North Slope mineral resources, therefore, naturally falls into the following areas of inquiry:

- The current and future demands of local communities on mineral resources of the region. (See Figure 2 for locations of existing communities.)

- The current and future demands of the petroleum industry on mineral resources of the region.

- The impact of current and future petroleum development on the development of minerals other than hydrocarbons.

The areas of inquiry detailed above, for the purposes of this analysis, can be simplified to reflect the key local and regional problems. These are:

- The only local mineral resource required by both the petroleum industry and local communities is gravel and sand. (The North Slope communities also require fuels which, for the most part,

are shipped in from southern Alaska and not obtained locally. An exception is Barrow which obtains natural gas from small adjacent fields.) Potential conflicts between community and petroleum industry demands on gravel and sand resources may exist.

- Environmental impacts of onshore and offshore gravel extraction, particularly those which relate to subsistence food resources and water quality may exist.

- The potential stimulus provided by oil and gas development to the development of other hydrocarbon resources (e.g. coal), metallic, and non-metallic minerals should be evaluated.

Detailed information on North Slope gravel and sand consumption by communities, the military (e.g. DEW line stations) and petroleum operators is not available.

Average gravel demands for Barrow, the largest community on the North Slope, have been on the order of 7,646 cubic meters (10,000 cubic yards) a year. However, major construction projects such as the Barrow airport have significantly increased the demand in a given year. Apart from major construction projects, the gravel demands of the villages for housing and public buildings is assumed to be similar to 7,646 cubic meters or slight when compared with petroleum development.

Through February 1976, when an estimated 95 percent of Alyeska's requirements for the trans-Alaska pipeline had been met, about 47 million cubic meters (61 million cubic yards) had been used, (Berger and Swenson, 1977). About 50 percent of Alyeska's total borrow (material which is removed for use as fill at another location) requirements have been taken from floodplains. North of the Brooks Range the figure is almost 100 percent. Little data are available on the gravel used in construction of the Prudhoe Bay facilities, but estimates indicate that more than

76 million cubic meters (100 million cubic yards) had been used by 1974 (Arctic Institute of North America, 1974).

Offshore to date, there has been little demand for gravel since only two wells have been drilled in the Alaskan Beaufort Sea, both by British Petroleum. Both were located on man-made islands. One was constructed by building up an existing island (sandbar) with gravel (Niakuk Island), the other by backfilling an excavation in the ice with gravel (Sag Delta Island); 19,879 cubic meters (26,000 cubic yards) and 29,437 cubic meters (38,500 cubic yards) of gravel, respectively, were required for construction of each island. The gravel was trucked across the ice to the well sites from onshore borrow pits about 8.5 kilometers (5 miles) up the Sagavanirktok River.

Assessment of Impacts

FISH AND WILDLIFE RESOURCES

The human population of the North Slope is predicted to remain fairly constant in the future. Construction of the Alcan gas pipeline is expected to cause an increase of about 1500 residents between 1979 and 1983. However, the predicted North Slope population in the year 2000 is expected to be around 9000, which is essentially the same as North Slope Borough census figures for 1977.

Regardless of reduction in levels of subsistence harvest due to a gradual shift to a cash economy, the preservation of traditional culture and historical patterns of subsistence is of major concern to the people of the Arctic coastal region. Residents of small villages most frequently name hunting and fishing as the aspect of village life they like best (North Slope Borough, 1977) . This interest will probably remain high in the future, but due to reduced requirements for meat and fish and a stable human population, long-term harvests should continue at a relatively low level. The greatest potential for change lies with recreational

hunters and fishermen who live away from the Arctic coast, but show increasing interest there. An increase in sport hunting and fishing would increase the demand for guides, transportation, fuel, food, and accommodations.

Between Wainwright and Kaktovik there is only one viable commercial fishery. Slightly more than 60,000 cisco and whitefish have been harvested annually from the Colville River Delta since 1950 (Selkregg, 1975). However, the short fishing season and unfavorable economic factors appear to be limiting further commercial fishing activity.

Except for the areas in the immediate vicinity of Wainwright, Barrow, Nuiqsut, Prudhoe Bay, and Kaktovik, there has been little modification of fish and wildlife habitat on the coastal plain. An exception is the trans-Alaska pipeline corridor where gravel mining plus road and work pad construction have taken habitat out of production: The data has not been published to substantiate this because the evaluation is still in progress by the U.S. Fish and Wildlife Service.

Disturbance of wildlife has been an area of particular concern in arctic Alaska as well as northern Canada. It has been determined that seals, whales, waterfowl, and caribou can be displaced from critical areas by human activity, particularly when vehicle traffic is involved (L.G.L. Limited, Environmental Research Associates, 1977; Canadian Department of Fisheries and Environment, 1977; Cameron and Whitten, 1976, 1977). Thus far the only measurable impact or disturbance in northern Alaska has been the displacement of caribou calving from the Prudhoe Bay oil field since 1974.

Along the Arctic coast ducks and geese are hunted primarily for domestic consumption with most harvest occurring outside the legal hunting season (Alaska Department of Fish and Game, 1976). All of the coastal villages harvest waterfowl but a majority of the annual Arctic waterfowl is harvested at Barrow, and consists mainly of eiders. Government enforcement

officers have been quite lenient about enforcing waterfowl hunting regulations because of traditional native dependency on the resource and because harvest levels have not been considered excessive.

Sport hunting for waterfowl has been limited primarily to the Barrow area, but there has been some activity near DEW line sites and oil drilling camps. Interest has been low because there are few resident sportsmen. Duck hunters living in other parts of Alaska have not been active on the Arctic coast because most birds have begun their autumn migration before the hunting season opens on September 1st and the cost of transportation and accommodations are high. The Alaska Department of Fish and Game (1976) has predicted that "neither sport hunting, domestic utilization, or nonconsumptive use of waterfowl is expected to appreciably increase in the foreseeable future."

In the future, the most serious impacts on fish and wildlife will probably result from habitat disturbance through gravel mining, collection of potable water, and siting of facilities. Impacts will also result from harassment or disturbance of wildlife by boats, aircraft, road vehicles or other human activity that increases through improved access.

Excessive harvest of fish and wildlife has not been a problem except in the case of the Arctic caribou herd. This problem can be adequately handled by regulatory control and enforcement. However, even though wildlife populations can be adequately protected, conflicts between user groups, namely subsistence versus recreation, may result in very complex political problems.

WATER QUALITY, WATER RESOURCES AND SANITATION

The impact of human use on water resources between now and the year 2000, assuming no OCS development occurs, will correspond to the population growth in each village and to changes in water supply and waste disposal methods and practices.

Barrow is the only village anticipated to experience significant in-migration during this period. The populations of the other villages are expected to increase only slowly from births. Consequently, if the per capita water use remains relatively constant in Kaktovik, Nuiqsut, and Wainwright, the impact of water withdrawal and use will remain essentially unchanged. The variable that is impossible to predict at this time is the potential increase in per capita water use when water supply improvement goals have been met. Given the relatively low populations in Nuiqsut, Kaktovik, and Wainwright, an increase from about 8 lpcpd to 40 lpcpd (2 gpcpd to 10 gpcpd) is not likely to place much stress on the water resource. However, an increase to 190 lpcpd or 260 lpcpd (50 or 70 gpcpd) could create severe problems during the winter low water period if sufficient storage capacity is not, or could not, be made available.

Barrow is expected to grow considerably, and plans are under way to install a water system capable of serving 4,350 residents, each using 170 lpcpd (45 gpcpd). This level of water use, particularly during winter, could seriously stress the raw water resource. However, ample storage capacity can prevent this. For example, if Beaufort Sea water is desalinized the impact on the freshwater resource will be lessened.

On the North Slope the water resource is impacted by the current waste disposal techniques. Human wastes as well as solid waste and wash water contaminate areas within each village. Waste products are quite mobile since they are exposed to birds, wild animals, dogs, people, vehicles, and water. The planned waste treatment and isposal practices, when completed and implemented, will be a positive impact on the water resource. It is likely that once wastes are handled in a sanitary manner, the amount of uncontaminated fresh water will increase.

SAND AND GRAVEL RESOURCES

If Beaufort Sea petroleum development does not occur, there will be continuing and significant demands placed upon the gravel and sand resources of the North Slope. Most demands will come from onshore petroleum development and the possible development of other minerals such as coal, phosphates, and various metals, principally located in the Brooks Range and northern foothills of the Brooks Range. The demands of some developments such as the Alcan gas pipeline can be predicted with some degree of accuracy. Other non-OCS petroleum developments, such as would occur after the discovery of commercial reserves in NPR-A and additional onshore reserves in the Prudhoe Bay area, are more difficult to predict. Described briefly below are planned or possible developments on the North Slope that will require significant quantities of gravel and sand for construction. [Pipeline corridors and NPR-A staging sites are shown on Figure 2 in Appendix.)

The Alcan gas pipeline, scheduled to commence construction in 1980, will require more than 8 4 million cubic meters (11 million cubic yards) of gravel, a detailed breakdown of which is given in Table 2 (Alcan Pipeline Company, 1976b). Between Prudhoe Bay and Fairbanks the Alcan line will, for the most part, parallel and use the work pad of the Alyeska line as well as the existing haul road. Consequently, significantly less gravel will be required in that section (mile for mile) than that required for the Alyeska line. It can be assumed that of Alcan's total borrow requirements, less than 20 percent will be required north of the Brooks Range. Many of the Alyeska borrow sites will be used by Alcan, although a few new sites will have to be developed (Alcan Pipeline Company, 1977a).

In a study of North Slope petroleum development, the Alaska Department of Natural Resources (Gibson and Kerschner, 1977) projected gravel demands for a set of development scenarios for both onshore and offshore areas. Projected gravel requirements for the onshore North Slope scenarios are summarized in Table 3. Given the most optimistic anticipation of

TABLE 2

ALCAN (NORTHWEST) PIPELINE BORROW MATERIAL REQUIREMENTS

ACTIVITY	Cubic Meters	Cubic Yards
Pipeline Construction		
1. Work Pad Extension		
Granular Borrow	4,310,815	5,638,000
Rock Borrow (Quarry)	220,205	288,000
Pad Subtotal	4,531,020	5,926,000
2. Backfill - Crushed and Select	2,784,673	3,642,000
3. Access Roads	87,929	115,000
Pipeline Total	7,403,622	9,683,000
Other		
1. Compressor Stations -		
Borrow fill material	894,582	1,170,000
Crushed top dress	47,405	62,000
Concrete aggregate	42,053	55,000
Topsoil	19,880	26,000
Compressor Station Subtotal	1,003,920	1,313,000
2. Meter Stations	11,469	15,000
3. Campsites	91,752	120,000
4. Pipeyards	91,752	120,000
5. Operating and Maintenance Facilities	61,168	80,000
Total	1,260,060	1,648,000
Total Borrow Requirements	8,663,683	11,331,000

Source: Alcan Pipeline Company, 1976b.

Note: Assumed to be completed from 1980-1984. Minima? maintenance requirements through 2000.

TABLE 3

PROJECTED GRAVEL REQUIREMENTS FOR NORTH SLOPE PETROLEUM DEVELOPMENT SCENARIOS[1]

Scenario	Field Reserves Oil MMBbl	Field Location	Discovery Date	Production Start-Up Date	Total Gravel Requirements Cubic Meters (Cubic Yards)	Notes
Prudhoe Bay State Lands (PBSA-7)[2]	600	South and southeast of Prudhoe Bay	1987/1988	1990/1991	3,485,811 (4,559,000)	Two fields; TAPS connection
National Petroleum Reserve - Alaska (NPRA-5)[2]	1,000	Northeast sector of reserve	1978	1987	6,119,094 (8,003,000)	TAPS connection
National Petroleum Reserve - Alaska (NPRA-6)[2]	600	Northeast sector of reserve	1982	1992	4,087,552 (5,346,000)	TAPS connection
National Petroleum Reserve - Alaska (NPRA-7)[2]	300	Southwest sector of reserve	1986	1993	1,383,926 (1,810,000)	TAPS connection
Central North Slope (CNSA-2)[2]	900	South and southwest of Prudhoe Bay	1978/1980	1982/1983	4,989,015 (6,525,000)	Two fields; Arctic Slope Regional Corporation Lands
Western Arctic (WAA-2)[2]	900	North Slope, west of NPR-A	1979/1981	1987	11,939,993 (15,616,000)	Two fields; TAPS connection
Arctic National Wildlife Range (ANWR-3)[2]	5,000	East of Prudhoe Bay near coast	1993	1999	11,782,486 (15,410,000)	TAPS connection

1 Source: Alaska Department of Natural Resources, (Gibson and Kerschner, 1977).
2 Abbreviations (PBSA-7 etc.) for scenario designation as used in source reference.

future (onshore) North Slope discoveries, the total projected requirements for gravel on the North Slope from 1978 to 2000 are 40.3 million cubic meters (52.7 million cubic yards). These totals include gravel for production facilities (flow stations, pump stations, etc.), camps, roads and airstrips. Adding the requirements for that portion of the Alcan gas pipeline north of the Brooks Range (probably about 1.5 million cubic meters or 2 million cubic yards), gives a total maximum projected gravel requirement for future North Slope (onshore) petroleum development of about 42 million cubic meters (55 million cubic yards).

The estimated amount of gravel which can be extracted without impacting the environment cannot be predicted at the present time. While broad ranges of gravel requirements for petroleum developments and the locational implications of those requirements can be predicted, only the general environmental problems can be outlined. The specific impacts of gravel extraction will depend on the following variables which are unknown at the present time:

- The location of selected borrow sites;
- The environmental stipulations imposed upon onshore and offshore gravel requirements related to Beaufort Sea oil and gas lease sales;
- The effectiveness of environmental monitoring and surveillance of gravel mining operations.

Further, although any gravel mining creates an impact, it is a matter of judgement at what amount of extraction a negative or significant impact occurs. Such a judgement requires very site specific data which can only become available when drilling applications or development plans are submitted to regulatory agencies.

It should be emphasized that the scenarios formulated by the Alaska Department of Natural Resources {Gibson and Kerschner, 1977) consider only the development of oil and assume that production will be transported by west-east North Slope pipelines to an interconnection with the trans-Alaska pipeline. Another Prudhoe Bay-sized discovery on the North Slope is highly unlikely and scenarios constructed for both onshore and offshore development (Gibson and Kerschner, 1977; Dames & Moore, 1978) indicate the reserves will be insufficient to justify a second or twin trans-Alaska oil pipeline. Thus, gravel requirements of future development are unlikely to ever be as great as that of the Alyeska pipeline and Prudhoe field development. When compared with total Alyeska (north of the Brooks Range) and Prudhoe Bay gravel use, the projected demand of future non-OCS development is probably less than half.

The future gravel requirements of *the* North Slope communities will probably be insignificant when compared with the demands of the petroleum industry. If an annual demand of 7,646 cubic meters (10,000 cubic yards) of gravel and a major construction project every five years requiring about 114,690 cubic meters (150,000 cubic yards) is assumed for Barrow, the largest North Slope community, a total gravel demand from 1977 to 2000 would be on the order of 584,506 cubic meters (771,000 cubic yards). That figure is equivalent to the requirements for 42 miles of pipeline haul road (State secondary standards). In the context of locally avai' able sand and gravel resources, however, such a demand represents a serious problem, a problem that could be exacerbated if significant commercial) finds of oil and gas were discovered in the Barrow area.

Although economically and environmentally developable borrow resources are limited in the Barrow area, the available resources and projected demand are not significantly disparate. However, if significant oil reserves are discovered within 48 kilometers (30 miles) or so of Barrow in the northeast sector of NPR-A, a major resource conflict could occur between local and industry demands for gravel. Scenarios NPRA-5 and

NPRA-6 (Table 2) that postulate major discoveries in the northeast sector of NPR-A, estimate gravel requirements of 6,119,093 cubic meters (8,003,000 cubic yards) and 4,087,551 cubic meters (5,346,000 cubic yards) for one billion barrel and 600 million barrel fields, respectively. Such requirements probably exceed significantly the available coastal gravel resources between Point Barrow and the Colville River delta that are economically and environmentally feasible to extract. See Figure 2 in the Appendix for NPR-A staging sites.

Entrapment of fish in depressions in floodplains, berms, and settling basins due to gravel extraction is an important problem. Potential fish traps on the Sagavanirktok River were first reported by Weinhold (1971) and subsequently investigated by Northern Engineering Services and Aquatic Environments Ltd (1975). The latter investigators observed that fish enter borrow pits in the Sagavanirktok River through breaches in the berms and that fish were trapped where channels were bermed. Gravel mining may also cause siltation of fish streams as well as having a potential for altering groundwater flow to fish overwintering areas.

Since most of NPR-A is characterized by a scarcity of gravel, similar problems can be anticipated elsewhere in the reserve. Other communities located in or adjacent to the reserve including Atkasook, Nuiqsut and Wainwright, may have problems similar to Barrow. Commercial oil and gas discoveries on Arctic Slope Regional Corporation lands west of NPR-A could impact Wainwright whereas developments in the central portion of NPR-A could impact Atkasook. The gravel and sand requirements of these communities is not known but can be anticipated to be somewhat less than Barrow. Wainwright and Atkasook are also located in the coal-rich Kuk-Kugru and Meade-Ikpikpuk River districts. Development of these resources involving transportation to a port on the Chukchi Sea coast would significantly impact the limited gravel and sand resources of the western Arctic Slope region. (See Figure 2 in Appendix for community locations.)

Kaktovik, which lies in the Arctic National Wildlife Range, is unlikely to be affected by gravel demands of petroleum activities. The gravel needs of Kaktovik are and will probably remain minimal; there appears to be no potential shortage of borrow materials in this part of the North Slope.

III. PROJECTED IMPACTS OF OCS DEVELOPMENT: CAMDEN-CANNING SCENARIO

Introduction

The projected impacts for the Camden-Canning scenario are discussed in this section. The analysis of these impacts describes the expected conflicts with the natural physical environment as a result of forecasted population and employment increases and changes in the man-made environment.

Impacts may occur to fish and wildlife resources due to present and future subsistence hunting and fishing as well as commercial and port hunting and fishing. Also, impacts may occur to fish streams from sand and gravel mining operations. In addition to the above, other impacts such as disturbance of critical wildlife habitats may occur.

Water quality, water resources and sanitation may be impacted due to increased population and industry in the Beaufort Sea region. Also, sand and gravel resources will be impacted with the increase in community and industrial demands for the resource.

Identification of Impacts

FISH AND WILDLIFE RESOURCES

The relatively recent focus on development of petroleum resources along the Arctic coast, an area where only limited ecological information has been gathered previously, leaves us with insufficient biological data to quantitatively assess the impacts of such activities. A wide variety of studies have been initiated but the interim nature of data to date limits this evaluation to subjective analysis.

Fish and wildlife resources within a day's access of villages are used most intensively for subsistence. In nearshore areas, spotted seals,

ringed seals, and bowhead and belukha whales are taken. Ringed seals are the most common species utilized by coastal residents. As mentioned in an earlier section, natives still depend on seals for some products, but somewhat less than in prior years. Caribou, waterfowl, and fish are also important for domestic consumption, particularly when whale meat is not available. Within the Brooks Range and its northern foothills Dan sheep, caribou, moose, grizzly bear, lake trout, arctic char and arctic grayling are becomming increasingly more important for recreational users.

In addition to the direct impact of increased hunting and fishing resulting from exploration, development and production of petroleum resources sensitive fish and wildlife habitat can be damaged if precautions are not taken. Some industry workers, on their off time hunt and fish. Due to their prohibition in construction camps, guns are picked up at commercial facilities outside of camps. Workers can have guns flown to Prudhoe, Umiat, Barrow, Kaktovik, etc. and then can proceed to nearby areas where hunting is legal. As a result of the potential impacts described above, resource management agencies would have to give special attention to spawning areas, overwintering areas, calving grounds, nesting sites and molting areas to assure long term viability with increasing petroleum development.

Productivity in coastal estuaries is limited because tidal influence is insufficient to create large productive intertidal flats. Waterfowl habitat is quite stable except for the barrier islands which remain in flux due to storm and tidal action. The islands and the inshore lagoons they create form critical wildlife habitats. With few exceptions, barrier islands should not be used as drilling platforms, staging areas or as sources of gravel materials.

WATER QUALITY, WATER RESOURCES AND SANITATION

Water will be required for drilling wells, equipment operation, and human consumption. Potable water required by drilling camp personnel on the North Slope averages about 260 liters per capita per day (lpcpd) or 70 gallons per capita per day (gpcpd) (Dames & Moore, 1977). The average water consumption for exploratory wells in NPR-A is given as 25 barrels (160 liters or 42 gallons per barrel) for domestic use and about 600 barrels for rig operation (U.S. Department of the Navy, 1977). The latter use includes mixing drilling mud and cement and washing down the drilling floor.

Similar daily water requirements *for* production wells can be anticipated, although total consumption will generally be significantly less than for exploration wells since production wells can be completed in about half the time (about 40 days vs. 80 days).

Snow roads, airstrips, and ice islands require vast amounts of water. For example, a snow road one mile long and 25 feet wide would require about 1,900,000 liters or 500,000 gallons of water with each 15 centimeter (six-inch) application. Ice islands are assumed to be constructed using sea water.

Waste materials produced in the drilling of exploration and production wells and related support activities include drill cuttings, drill mud, domestic wastewater, and solid waste.

Drill cuttings are separated from the mud during drilling and discharged onto the sea floor. Drill mud is recycled during drilling although occasional dumping is required to change the mud characteristics or chemistry for changing conditions as the well gets deeper. Mud remaining upon completion of the well may be recycled to drill other wells or disposed of depending on maximum benefit analysis.

Disposal of mud in the ocean must be in compliance with OCS operating orders. In state waters, mud must be disposed onshore at approved landfill sites.

In addition to the cutting and mud volumes indicated above, there will be solid waste of about 4.5 kilograms (10 pounds) per capita per day generated at temporary construction and drill site camps. Water usage and thus. domestic wastewater discharge can be expected to be about 270 lpcpd (70 gpcpd, Dames & Moore, 1977).

Disposal of these wastes will follow applicable state and federal regulations. Domestic wastewater will probably be treated to secondary standards before discharge into the sea. Solid wastes will probably be separated into combustible and noncombustible materials with the combustible disposal by incineration. Noncombustibles will be taken to an approved landfill.

SAND AND GRAVEL RESOURCES

Beaufort Sea petroleum development will pose significant demands on both the onshore and offshore gravel and sand resources of the region. Prediction of the impact of these demands on the resource base is even more difficult than the assessment of future demands of non-OCS development.

Water Quality

Water quality problems can occur as a result of gravel extraction in or adjacent to stream channels. Erosion of the stream bed is believed to account for the most severe water quality problems. Erosion products are carried into the stream and increase the water's turbidity and solids content (Woodward Clyde Consultants, 1976).

Siltation is a significant impact associated with gravel extraction. It can be caused by excavation in the stream channel, gravel washing or

Table 4

Summary of Gravel Requirements for Beaufort Sea Petroleum Development

Facility	Dimensions	Gravel Requirements	Comments
Exploratory Islands			
a. Winter constructed, shallow water island	121 meters x 99 meters (400 feet x 325 feet), 1.2 hectares (2.98 acres); freeboard 1.5 meters (5 feet); water depth 1.2 meters (4 feet).	36,700 cubic meters (48,000 cubic yards)	E.g. BP's Sag Delta Island. Winter islands can also be constructed of silt.
b. Sandbag retained island	Circular, 98 meters (320 feet) diameter, working surface; 0.75 hectares (1 .86 acres) freeboard 5 meters (15 feet), water depth 10 meters (30 feet).	278,650 cubic meters (364,438 cubic yards)	
c. Sacrificial beach island	Circular, 206 meters (675 feet) diameter, 98 meters (320 feet) diameter working surface; 0.75 hectares (1 .86 acres) working surface, 33 hectares (81.5 acres) total surface area; freeboard 5 meters (15 feet); water depth 8.5 meters (28 feet).	1,200,000 cubic meters (1 ,600,000 cubic yards)	Only economic if on-site fill is available with no barge-haul involved.
Production Island (caisson-retained or sheet piling)	Circular, 190 meters (623 feet) diameter, 2.8 hectares (7 acres); freeboard 5 meters (15 feet); water depth 7.6 meters (25 feet)	477,030 cubic meters (621 ,133 cubic yards)	Use of caissons or sheet piling may effect significant savings in gravel requirements
Pipeline Work Pad	1.5 meters (5 feet) thick; 20 meters (65 feet) wide.	30,177 cubic meters/km (63,555 cubic yards/mile)	Typical Alyeska dimensions for aboveground pipe; scenario work pads may be somewhat narrower.
Pipeline Access Road	1.5 meters (5 feet) thick; 8.5 meters (22 feet) wide.	10,214 cubic meters/km (21 ,511 cubic yards/mile)	
Pipeline Haul Road	1.5 meters (5 feet) thick; 9 meters (30 feet) wide.	13,928 cubic meters/km (29,333 cubic yards/mile)	
Airstrip (all weather)	1,523 meters x 40 meters (5,000 feet x 150 feet) ; 1.2 to 1.8 meters (4 to 6 feet) thick.	84,955 to 126,159 cubic meters (1 10,000 to 165,000 cubic yards)	
Camp and Drill Pad (onshore exploratory well)	128 meters x 98 meters (420 feet x 320 feet), 1.27 hectares (3.1 acres).	26,760 to 38,230 cubic meters (35 ,000 to 50,000 cubic yards)	
Causeway	30 meters (100 feet) wide, average water depth of 1.5 meters (5 feet) and freeboard of 4.5 meters (15 feet) .	185,706 cubic meters/km (391 ,000 cubic yards/mile)	Hypothetical example based on approximate dimensions of prudhoe Bay (west bay) causeway
Staging Area/Production Center		573,450 to 746,000 cubic meters (750,000 to 1,000,000 cubic yards)	Estimate for an onshore staging area/production center at landfall of offshore pipelines and start of Prudhoe Bay pipeline connection. Facilities would include causeway/ dock, storage yard, gas and oil treatment plants, airstrip, base camp, roads, storage yards and permanent camp.

increased erosion of the river channel and adjacent banks. Siltation was one of the more common stipulation violations on the Alyeska pipeline, and was generally caused by equipment working in or near active channels or through leaching of silt-laden effluents from material sites to productive streams (Burger and Swenson, 1977). Siltation problems can be avoided or corrected by the use of settling basins, diversionary channels, stabilization of borrow stockpiles and site rehabilitation measures such as replacement of topsoil, restoration of pre-mining vegetation and contours and various erosion control procedures.

Siltation has a number of impacts on the aquatic biota. It can reduce fish food organisms, eliminate spawning gravel beds, and adversely affect egg development and fry emergence e.g. smother ng of eggs, interfering with oxygen supply).

It is assumed that water quality problems could occur n all of the scenarios. Gravel for staging areas will probably come from rivers such as the Canning River.

Since very little is known about offshore sand and gravel resources, offshore petroleum development introduces two new elements into impact assessment.

Offshore development will involve construction of facilities that require significant quantities of gravel. These include artificial soil islands (exploration and production), causeways, and docks which are in addition to the facilities related to oil and gas processing and transport onshore. For the same field size, it can be anticipated that an offshore field will require significantly more gravel than an onshore North Slope field assuming that artificial soil islands will comprise the majority of drilling platforms. A summary of gravel requirements for facilities construction in Beaufort Sea petroleum development is given in Table 4.

The second major contrast with onshore petroleum development is that offshore construction will use offshore borrow materials obtained by dredging.

The major variables that will affect the gravel requirements for Beaufort Sea development in addition to economic and environmental concerns are:

- The numbers of artificial islands, their design and water depth location;
- The length and dimensions of haul road and pipeline work pad (i.e. the distance to the Prudhoe Bay TAPS or Alcan interconnection);
- Location of processing facilities - onshore or on production platform;
- Field size.

Onshore, studies of arctic gravel mining and environmental impacts are limited and have concentrated on stream and floodplain resources. The principal source of borrow materials used for the Alyeska pipeline and Prudhoe Bay field was from river floodplains. The U.S. Fish and Wildlife Service has considered the effects of gravel removal in arctic and subarctic streams based upon an evaluation of 28 borrow sites (Woodward Clyde Consultants, 1976). Monitoring of gravel removal operations on the Alyeska pipeline and guidelines for gravel mining have been described by the Joint State/Federal Fish and Wildlife Advisory Team (Netsch, 1974; Burger and Swenson, 1977). The selection of borrow sites and mining methods for the proposed Arctic Gas pipeline (now defunct) have been described by Northern Engineering Services Company, Ltd. (1974). Northern Engineering Services have also evaluated trans-Alaska pipeline material sites, extraction methods and impacts to aquatic habitats (Northern Engineering Services and Aquatic Environments, Ltd., 1975). However, the above material does not adequately describe the availability of the resource.

In Canada, the effects of gravel dredging and artificial island construction in the southern Beaufort Sea have been evaluated by F. F. Slaney and Company (1976, 1977) for Imperial Oil and summarized by the Canadian Department of Environment (1977). The effects of beach borrow at Barrow have also been documented (Hume and Schalk, 1964). The concerns of arctic scientists with respect to artificial island and causeway construction and grave? mining are summarized in Arctic Project Bulletin No. 15 (OCS Environmental Assessment Program, 1977). Apart from the above cited references, the literature on possible impacts of offshore gravel mining in arctic environments is sparse. Inferences have to be drawn from a variety of technical papers on such problems as coastal erosion (Lewellen, 1970, 1977), coastal transport (Dygas and Burrell , 1975) and oceanography (Wiseman et al., 1974).

Environmental Impacts of Gravel and Sand Extraction

The assessment of the environmental impacts of gravel and sand mining related to OCS petroleum development involves both offshore and onshore borrow operations whereas non-OCS development primarily involves onshore borrow operations. Further refinement can classify the gravel and sand resources for impact analys' s into submarine, coastal, riparian and upland situations each with contrasting problems.

Arctic scientists have listed sources of fill material in increasing order of preference (OCS Environmental Assessment Program, 1977):

- Barrier island systems.
- Beaufort Sea beaches and sea bottom inside the 5-meter (16-foot) isobath.
- River beds.

- Sea bottom outside the 5-meter (17-foot) isobath.

- Terrestrial mining of the open pit type.

- Abandoned artificial islands and causeways (recycling). This practice has already been adopted in the southern Canadian Beaufort Sea.

Onshore Impacts of Gravel Extraction

Much of the current knowledge of borrow extraction in Arctic Alaska comes from studies of the Alyeska pipeline and Prudhoe Bay field construction activities. Because most of the gravel for these projects has been extracted from river floodplains, the emphasis is upon impacts to the aquatic environment. The major environmental concern of alluvial gravel mining is destruction or modification of aquatic habitats. There are also a number of impacts to the physical environment relating to the alteration of hydrologic and geomorphic processes and esthetic concerns. Many of the impacts result from the physical alteration of river channels and valleysides including construction of diversion dikes, channel plugs, settling basins and cut slopes. It is assumed that this impact will occur in all the scenarios unless precautions are taken,

Alterations to Stream Morphology

Alteration of stream morphology by construction of diversion dikes, settling basins and channel plugs may negatively impact aquatic organsims. Destruction or modification of the gravelly channel substrate may eliminate fish spawning areas. Alterations to the channel gradient, width and depth can create velocity or physical barriers that can block passage of fish to spawning or overwintering areas. Accommodation of fish passage proved to be one of the most frequently cited problems on the trans-Alaska pipeline (Burger and Swenson, 1977; Weinhold, 1971; Northern Engineering Services and Aquatic Environments, Ltd., 1975). It is assumed that this will also be a problem with OCS development.

Coastal Erosion

The affects of beach and barrier Island gravel mining along the Beaufort Sea coast are a major concern of Arctic researchers. The entire coast from Point Barrow to the Mackenzie River is receding due to thermal erosion.

The impact of accelerated shoreline erosion as a result of beach borrowing has been documented by Hume and Schalk (1964) and summarized by Labelle (1973). Mining of beaches since 1945, including removal of 30,584 cubic meters (40,000 cubic yards) in 1961 causing a local shoreline recession of 3.1 meters (10.2 feet), has been estimated to accelerate shoreline retreat four to five times,

The Barrow experience indicates that coastal transport studies and shoreline erosion studies should be conducted at planned coastal borrow sites. Where gravel volumes to be extracted exceed net coastal transport, borrowing should probably be discouraged.

Detailed recommendations and conclusions by JFWAT investigators on gravel extraction based on Alyeska experience can be obtained from Burger and Swenson (1977).

The above impacts could result if beach mining occurs. While the JFWAT investigators prefer the selection of upland borrow sites in many areas, they recognize that on the North Slope few suitable sites other than floodplains exist due to permafrost, geotechnical and resource availability problems.

Offshore Gravel Extraction

Offshore gravel and sand is mined primarily to construct artificial soil islands for exploration and production of oil and gas. Extraction involves dredging by barge mounted or land-based clamshell dredges, barge mounted suction dredges or draglines.

Artificial soil islands can either be constructed from local gravel or sand deposits in the vicinity of the island or by barged-in material from borrow sites a good distance away. In the former case, the most efficient construction method is to use a suction dredge and floating slurry line to the island site. In the southern Canadian Beaufort Sea, several islands of the sacrificial beach design have been constructed in this way.

The impacts of Imperial Oil's artificial island-based exploration program in the southern Beaufort Sea have been studied in detail by F. F. Slaney & Company, Ltd. (1976, 1977). These and other investigations have been summarized by a recent Canadian study which has reviewed the potential environmental impacts of artificial islands including dredging in the southern Beaufort Sea (Canada Department of the Environment, 1977). While these findings may not be directly applicable to the Alaskan Beaufort Sea due to variations in oceanography and biology, the principal conclusions provide important indicators for the research that will have to be conducted on a site-specific basis in the Alaskan Beaufort.

The study, which pertains to the sixteen artificial soil islands constructed for oil and gas exploration off the Mackenzie Delta in the Beaufort Sea since 1972, concludes:

> "No significant environmental problems have yet been identified. As construction moves farther offshore and into the deeper and less turbid waters of the nearshore Beaufort Sea, some potential resource conflicts are foreseen.
>
> (1) It is not anticipated that the current rate of construction will have significant impact on the chemical and physical oceanography of the area.
>
> (2) Localized regeneration of nutrients from resuspended dredge spoils and hydraulic fill operations may result in short-term increases in phytoplankton production.
>
> (3) Increased turbidity resulting from construction activities may depress phytoplankton productivity. The impact will be localized and insignificant in terms of total production.

(4) Localized destruction of benthos will occur as a result of direct burial at the island location or by fallout from the turbidity plume. The rate of recolonization and re-establishment of a stable benthic community is unknown.

(5) No significant impacts on fish populations are anticipated.

(6) Increased support traffic through Shal low Bay and in the travel corridor from the Tuft Point materials site to construction areas may have significant impacts on belukha or white whales.

(7) Air traffic between onshore support bases and offshore construction areas can be routed to avoid passing over critical waterfowl areas. Erosion and deposition along the Tuktoyaktuk Peninsula resulting from granular material extraction may have detrimental impacts on both waterfowl feeding and staging areas. In the event that traffic through Shallow Bay is restricted because of potential disturbance to belukhas, there may be pressure to permit traffic to proceed along river channels passing through the Kendal Island Bird Sanctuary. Because of the very low reproductive success of Snow Geese in the sanctuary over the past several years any disturbance to the colony may be critical. Since there may be no compromise solution to the problem of protecting both waterfowl and belukha populations, it may be necessary to prohibit barge traffic through both areas.

(8) Unless Properly charted and marked, abandoned artificial" is" ands may constitute a hazard to navigation.

(9) Artificial is" ands should be constructed so as to be readily destructed by wind and wave action following the removal of erosion control materials such as filter cloth and sandbagging. "

It is assumed that the above impacts and conclusions pertain to OCS development in the Alaskan portion of the Beaufort Sea.

Localized erosion or deposition on coastlines adjacent to borrow pits could be caused through modification of wave refraction processes and

alteration of the bottom equilibrium profile. The degree and extent of the effects will be dependent upon such factors as the proximity of the borrow pit to the coastline, shoreline stability and the size of the borrow pit. Impacts on the physical-chemical oceanographic environment from borrow extraction and island construction are not believed to be significant although the data base is still limited.

The principal biologic concern of Canadian researchers is the impacts of the artificial island program on the white whale or belukha. Specifically, these concerns are:

- Disturbance due to construction activities that may cause abandonment of traditional calving areas, feeding areas and travel routes.

- Interference with whale movements from marine and air traffic associated with construction and support activities; and

- The presence of artificial islands, borrow pits or staging areas may interfere with calving or feeding areas or travel routes.

In the Alaskan Beaufort, the most sensitive areas, with respect to summer habitat, of the belukha and endangered bowhead whale lie west of Cape Halkett and include Smith Bay and Dease Inlet. Initial petroleum development in the Alaskan Beaufort, however, will take place outside this area being confined to the central Alaskan Beaufort between the Canning and Colville Rivers.

Impacts of sediment plumes and increased turbidity from dredging and hydraulic fill operations on planktonic communities, benthic organisms and fish were not regarded as significant. Some direct loss or degradation of habitat equivalent to the area of the islands and borrow pits can be anticipated for these organisms and possibly for an unknown portion of

the sediment plume. In terms of the total area of the southern Beaufort, this area is insignificant, especially since the islands and borrow sites of the current exploration program are spread out over a large area. In the case of more closely spaced islands and borrow sites, which could occur in the event of commercial discoveries and production, the impacts of island construction and borrow extraction would be significantly greater.

Possible impacts from construction of gravel islands, causeways, and onshore and offshore borrow extraction in the Alaskan Beaufort Sea have been summarized in Arctic Project Bulletin No. 15 (OCS Environmental Assessment Program, 1977). The principal concerns are:

- Borrow extraction, especially from the barrier islands, beaches, and nearshore bottom sediments (depths less than 5 meters or 17 feet);

- Location of artificial islands within lagoons and bays, and between barrier islands;

- Location of causeways inshore of the 5-meter (17-foot) isobath, between barrier islands, across bays and lagoons.

Assessment of Impacts

FISH AND WILDLIFE RESOURCES

The Camden-Canning exploration area is more than 100 kilometers from Kaktovik, the nearest village. Since most hunting and fishing occurs within one day's travel from the village there should be little direct impact on these activities.

Critical geographic areas include fish overwintering on the eastern channels of the Canning River delta, musk oxen range from the Canning River eastward, caribou calving east of the Canning River and west of Bullen Point, high density ringed seal activity from the Maguire Islands to Camden Bay and waterfowl nesting on the Canning River delta.

Care in selection of staging areas, camps and pipeline routes can eliminate most conflicts except for disturbance of seals in the Maguire-Flaxman Island offshore zone (Burns et al., 1976) and potential influence on caribou movements if operational facilities are developed between Bullen Point and Prudhoe Bay (Cameron and Davis, personal communication). Research biologists from the Alaska Department of Fish and Game have suggested that maximization of buried pipeline modes particularly through river deltas and floodplains plus beach oriented pipeline routes will reduce impacts on caribou.

The hunting of musk oxen is prohibited at the present time but these rather unique animals are of special interest to wildlife photographers and hikers within the Arctic National Wildlife Range. According to the Alaska Department of Fish and Game musk oxen numbers have increased since their reintroduction to the Arctic slope in 1969. As the population increases, its range can be expected to expand along the Arctic coast and hunting of a limited number of musk oxen may be allowed in the future (Alaska Department of Fish and Game, 1976).

The presence of increased numbers of exploration or field workers in the Camden-Canning area will result in increased traffic to observe musk oxen and other wildlife in the area. There would be potential for the people of Kaktovik to act as guides for photographers and possibly hunters.

Development of roads, staging areas and pipelines would not affect the present musk oxen population, but such perturbations could influence the long-term expansion of musk oxen west of the Canning River.

Polar bears are known to den between the Sagavanirktok and Canning Rivers, but no traditional sites have been identified. The bears usually range beyond the shorefast ice, but must be considered a serious threat to man whenever they are nearby.

Drilling platforms or onshore facilities with living quarters will undoubtedly attract arctic foxes and perhaps wolves, even with good garbage disposal practices. Workers in the Arctic have not been able to resist the impulse to feed wildlife. Animals attracted by feeding are often killed by moving equipment or are shot when they become a nuissance (Milke, 1977).

WATER QUALITY, WATER RESOURCES AND SANITATION

The Camden-Canning scenario cites 18 exploratory wells to be drilled between 1980 and 1987, with no more than three wells to be drilled in any one year. Each exploratory well will require 600 barrels per day of water for rig operation and 25 barrens per day for domestic use. This amounts to 99,000 liters (26,250 gallons) per day. If three wells are drilled concurrently, the water demand becomes 298,000 liters (78,750 gallons) Superimposed on the above water use is the demand generated by the personnel not on each rig. Manpower is low the first year -- 85 people requiring about 23,000 liters (6,000 gallons) of water per day. Manpower peaks in year seven at 1,365 (using about 363,000 liters or 96,000 gallons per day) and then drops slightly until production begins in both fields. A total of 433 production wells are slated with a maximum of 64 in any one year. The water required for each production well is the same as the exploratory wells on a per day basis, but it takes about half as long to complete a production well. Assuming 10 production wells are being drilled at the same time, the water required becomes 6,250 barrels or 984,000 liters (260,000 gallons) per day plus approximately 265,000 liters (70,000 gallons) per day (1,000 people) for camp use. Total water use will peak during the early stages of production and then decline.

Mater use and waste disposal at the Camden-Canning complex will not directly impact the residents in Kaktovik or other villages. Petroleum development is assumed to be of the enclave type and it is anticipated that there will be little if any travel to Kaktovik. Indirect impacts, however, could affect Kaktovik residents. For example, water withdrawal

Table 5

Camden-Canning Scenario (1,3 Bbbl Reserves)[1] - Summary of Gravel Requirements

CONSTRUCTION SCHEDULE	FACILITY	SPECIFICATIONS	GRAVEL REQUIREMENTS* CUBIC METERS	(CUBIC YARDS)	COMMENTS
1980 - 1987	Exploratory Islands	9 Soil Islands	3,440,700	(4,500,000)	Assumes average of 382,000 cubic meters (500,000 cubic yards) per island; production islands include mix of sandbag-retained, sacrificial beach and shallow water pad designs.
		6 Barges (with berms)	91,752	(120,000)	
1985 - 1990	Production Islands	9 Soil Islands	3,440,700	(4,500,000)	Assumes average of 352,000 cubic meters (500,000 cubic yards) per island; production islands larger than exploratory islands but caisson or sheet pile design will effect gravel savings.
	Pipeline Work Pad	87 kilometers (54 miles)	2,625,399	(3,431 ,97o)	
	Pipeline Haul Road	87 kilometers (54 miles)	1,211,736	(1 ,583,982)	
	Airstrip	1 - 1,829 meter (6,000 feet)	122,336	(160,000)	
	Causeways	2 - (each 2.4 kilometers or 1.5 miles long)	891,388	(1,173,000)	At landfall of each field.
	Staging Area/ Production Center	2 flow stations 1 pump station 1 compressor plant storage areas 1 camp/operations center	1,529,200	(2,000,000)	
	Total		13,353,211	(17,360,952)	

1 Scenario comprises two adjacent fields which share staging area, base camp, harbor, storage facilities and airstrip but each have separate flow stations at pipeline landfalls.

2 Gravel requirements for staging area/production center facilities including storage areas, camp/operations center, flow stations, pump stations and compressor plants have been estimated by scaling down Prudhoe Bay facilities. Other estimates are based on Alyeska and Canadian Beaufort Sea experience (also see Table 3).

from the deltas of the Kavik and Canning Rivers during winter could affect overwintering fish, which could impact the villager's subsistence fishing success. Also, if offshore drilling impairs water quality to the extent that fish and whale populations are affected by turbidity or other perturbations, the local residents would be affected. Potential impacts on wildlife as a result of water withdrawal or water quality changes are highest in the later stages of exploration and the periods of peak production drilling.

SAND AND GRAVEL RESOURCES

The gravel requirements for the Canning-Camden scenario are summarized in Table 5.

There is insufficient gravel resource data to indicate possible borrow sites or to properly assess the impact on the resource base. However, the most likely onshore source will be the Canning River delta; the Canning River is a braided stream with a predominantly gravel floodplain. The Shaviovik River floodplain could also be a major onshore gravel source. Borrowing from the Beaufort Sea beaches and barrier islands will probably be discouraged.

Offshore borrow areas cannot be anticipated at present since there is no data on subsea bottom stratigraphy in this area. Surficial deposits between Prudhoe Bay and Flaxman Island comprise sandy sediments and an area of gravelly bottom sediments has been mapped off the Sagavanirktok River delta in the vicinity of McClure Island (see Technical Report No. 10).

Unlike the western North Slope/Beaufort Sea, it is unlikely that there will be insufficient gravel and sand resources for petroleum development although environmental concerns will probably limit the number and location of borrow sites. On a site specific basis, the lakes in the

Canning River delta are important habitats for waterfowl and shorebirds. Gravel mining in the floodplain away from these lakes would be preferable. However, a few bird species (e.g. semi-palmated plover) use bare gravel bars for nesting habitat. As with other anadromous fish streams, gravel extraction from the Canning River should be scheduled outside of critical life history periods of fish such as the arctic char. Fish overwintering sites are extremely senstive such as the channels in the eastern portion of the Canning River delta.

Offshore gravel mining operations should consider possible disturbance to high density ring seal areas which occur seaward of Flaxman and Maguire Islands on grounded ice ridges. The nearshore zone off the Canning River delta is a biologically productive area for food chain species and represent extremely environmentally sensitive areas. Borrow sites outside the barrier islands are probably the least environmentally sensitive.

Summary

Following is a summary of impacts for the Camden-Canning Scenario.

Table 6

Summary of Impacts on Fish and Wildlife Resources

AREA	RESOURCE	POTENTIAL IMPACT
Camden-Canning	Seals	Direct disturbance from boats and aircraft in the Maguire Islands - Camden Bay area.
	Whales	Some direct disturbance from boats and aircraft within shipping zones and the oil field.
	Polar Bear	Some potential for influence on denning.
	Foxes and Wolves	Increased mortality from vehicle hits when animals are attracted by direct feeding or improper garbage disposal
	Caribou	Some direct disturbance of caribou calving and movements from motorized vehicle traffic east and west of the Canning River.
	Musk Oxen	Some potential for disturbance from motorized vehicles east of the Canning River.
	Waterfowl	Direct disturbance from boats and aircraft; nesting habitat loss from gravel mining on the Canning River delta or barrier islands.
	Fish	Siltation of feeding and spawning areas from gravel mining; blockage to fish passage by gravel mining - caused changes to stream channels; modification of groundwater flow to fish overwintering areas on the Canning River delta from gravel mining.
	Hunting and Fishing	Minimal influence on target species with-in one day's travel from Kaktovik.

Table 7

Summary of Impacts

Water Qua" ity, Water Resources and Sanitation

Camden-Canning Scenario

WATER QUALITY	Increased turbidity and contaminants will occur, however, if there is compliance with OCS operating orders and state operating orders, water quality impacts will be minimal.
WATER RESOURCES	Increased water withdrawal may affect the Kavik and Canning Rivers and overwintering fish. There may also be minor conflicts between village and industry water resource requirements.
SANITATION	Sanitation or waste disposal will not directly impact Kaktovik or other vil ages. If state and federal waste disposal regulations are complied with there wil be minimal environmental impacts.

Table 8

Summary of Sand and Gravel Resource Impacts:

Camden-Canning Scenario

TOTAL GRAVEL REQUIREMENTS CUBIC METERS (CUBIC YARDS)	AVAILABILITY OF GRAVEL	POTENTIAL IMPACTS
13,353,211 (17,360,952)	Sufficient onshore borrow exists; most likely onshore sources are Canning River delta and Shaviovik River floodplain. Limited data on offshore resources although regional geology indicates the possibility of significant deposits.	Fish overwintering areas need to be avoided in eastern channels of Canning River as do waterfowl and shorebird habitats in lakes of delta.

IV. PROJECTED IMPACTS OF OCS DEVELOPMENT: PRUDHOE - HIGH CASE SCENARIO

Introduction

The projected impacts of OCS development for the Prudhoe-High case scenario are discussed in this section, The analysis of these impacts describes the expected conflicts with the natural physical environment as a result of forecasted population and employment increases and changes in the man-made environment.

Impacts may occur to fish and wildlife resources due to present and future subsistence hunting and fishing as well as commercial and sport hunting and fishing. Also, impacts may occur to fish streams from sand and gravel mining operation. In addition to the above, other impacts such as disturbance of critical wildlife habitats may occur.

Water quality, water resources and sanitation may be impacted due to increased population and industry in the Beaufort Sea region. Also, sand and gravel resources will be impacted with the increase in community and industrial demands for the resource.

Identification of Impacts

FISH AND MILDLIFE RESOURCES

There is relatively little subsistence hunting or fishing activity within the Prudhoe Bay area and recreational fishing and hunting of big game is prohibited by the Alaska Department of Fish and Game.

Migratory species such as caribou from the Arctic and Porcupine caribou herds have historically ranged through the Prudhoe Bay area (Hemming, 1971; Child, 1973), These herds are harvested by hunters from the villages of Kaktovik, Nuiqsut, Barrow and Wainwright. Areas that were

used fairly intensively by caribou in the summer near Prudhoe Bay have reflected a decrease in caribou use since 1974 (White et al, 1975; Cameron and Whitten, 1976; Hemming and Morehouse, 1976; Cameron and Whitten, 1977). In addition, the resident Central Arctic caribou herd identified by Cameron and Whitten (1976) has shifted its calving activity away from the Prudhoe Bay oil field. Therefore, in comparison to undisturbed areas, the oil field area would be the best place to locate new exploration and production facilities. The use of existing dock facilities, roads, airports, etc. would significantly reduce impacts to fish and wildlife resources of the area when compared to development of new facilities.

For more information refer to the Camden-Canning Scenario section, Identification of Impacts.

WATER QUALITY, WATER RESOURCES AND SANITATION *

The impacts to water quality, water resources and sanitation within the Prudhoe-High case scenario will be similar to those discussed for the Camden-Canning Scenario on page 49. Please refer to this section.

SAND AND GRAVEL REQUIREMENTS

The impacts to sand and gravel resources within the Prudhoe-High case scenario will be similar to those discussed for the Camden-Canning Scenario on page 50. Please refer to this section.

Assessment of Impacts

FISH AND WILDLIFE RESOURCES

No direct problems are anticipated with marine mammal populations except the potential for disturbance of ringed seals from Cross Island eastward. Critical wildlife areas include waterflow nesting on the Sagavanirktok delta, the Kuparuk River delta, and the Jones Islands, and caribou calving east and west of Prudhoe Bay.

Howe Island, at the mouth of the Sagavanirktok River, supports the only snow goose colony in Alaska. This small nesting colony of about 60 pairs (Gavin, 1974) would be threatened by excessive disturbance, gravel mining or siting of facilities on the island or by oil spills.

Collection of potable water and gravel mining near the mouth of the Sagavanirktok River has impacted fish populations and the additional demands of exploration and development in adjacent offshore areas will require new techniques and procedures, if further impacts are to be avoided.

Boat and aircraft traffic associated with exploration, gravel extraction, and offshore production will undoubtedly result in periodic harassment of birds or mammals. Direct disturbance will probably be the most common problem associated with development of the area.

WATER QUALITY, WATER RESOURCES AND SANITATION

The Prudhoe-Large scenario slates 14 exploration wells to be drilled between 1981 and 1987, with three wells the first year, two wells in years two, three, four, five and seven. One exploration well will be drilled in the sixth year and production drilling starts that year. Water use is essentially the same in the Prudhoe-Large scenario as the Prudhoe-Small scenario for the first seven years.

Personnel water use peaks in year eight at 484,000 liters (128,000 gallons) per day, drops to 291,000 liters (77,000 gallons) per day when production begins in 1990 and remains at this level for four years followed by a gradual decline to 197,000 liters (52,000 gallons) per day the year before shut-in.

It is anticipated that 253 production wells will be drilled, and 44 will be drilled in one year. Assuming seven wells are drilled at the same time during the peak year results in a water demand of 696,000 liters

(184,000 gallons) per day, which is in addition to the personnel needs cited above.

The peak manpower of 1,833 in year eight will generate approximately 82,000 kilograms (18,000 pounds) of solid waste and 484,000 liters (128,000 gallons) of sewage each day. Sewage will be treated to at least the secondary level prior to discharge to the sea. The combustible portion of the solid waste will be incinerated and the ash and non-combustibles will be deposited in a state-approved landfill.

The above water usage levels and amounts of wastes discharged will not directly impact the villages on the North Slope. It is anticipated that the existing Prudhoe Bay-Deadhorse complex will serve as the staging area for this scenario, thereby eliminating any need for the villages to add support services. However, negative impacts could result if winter water withdrawal near the mouth of the Sagavanirktok River damaged overwintering fish populations. This should not occur, however, because state and federal regulatory agencies supervise winter water withdrawal by a permitting system. Additionally, sufficient water may be available from the Webster reservoir and from the reservoir that NANA Corporation plans to construct on the Sagavanirktok River.

SAND AND GRAVEL RESOURCES

The gravel requirements for the Prudhoe High Case scenario is given in Table 9.

Significant quantities of gravel have already been extracted from the Sagavanirktok River delta and floodplain for Prudhoe Bay field construction and Alyeska pipeline. Additional gravel in the Prudhoe Bay area will be required for Kuparuk oil production west of the Prudhoe Bay field and continued exploration in the Prudhoe Bay area as well as OCS development off Prudhoe Bay. Some of the infrastructure at Prudhoe Bay, such as the causeway/dock, storage areas, access roads and field support services

Table 9

Prudhoe Bay Offshore Scenario (1.9 Bbbl Reserves) - Summary of Gravel Requirements

CONSTRUCTION SCHEDULE	FACILITY	SPECIFICATIONS	GRAVEL REQUIREMENTS' CUBIC METERS	(CUBIC YARDS)	COMMENTS
1981 - 1987	Exploration Islands	7 Soil Islands	2,676,100	(3,500,000)	Assume average of 382,000 cubic meters (500,000 cubic yards) per island; islands include mix of sandbag-retained, sacrificial beach and shallow water pad designs.
		4 Barges (with berms)	61,168	(80,000)	
19B4 - 1988	Production Islands	4 Soil Islands	1,528,000	(2,000,000)	Assume average of 382,000 cubic meters (500,000 cubic yards) per island; islands larger than exploratory islands but caisson or sheet pile design will effect gravel savings.
	Pipeline Work Pad	15 kilometers (9.5 miles)	452,655	(603,772)	
	Pipeline Haul Road				Existing Prudhoe roads utilized, minor construction of additional access roads.
	Airstrip				Existing Prudhoe Bay and Deadhorse airstrips utilized.
	Causeways				Existing Prudhoe Bay causeway/dock utilized with minor expansion of facilities.
	Staging Area/ Production Center	2 flow stations 1 pump station 1 compressor station operations center storage areas	382,300	(500 ,000)	New processing facilities constructed (flow stations, etc.) but existing Prudhoe Bay camps and Deadhorse services utilized.
	Total		5,100,223	(6,683,772)	

1 Gravel requirements for staging area/production center facilities including flow stations, pump stations, compressor plants, operations centers, and storage areas have been estimated by scaling down Prudhoe Bay facilities. Other estimates are based on Alyeska and Canadian Beaufort Sea experience (also see Table 3).

will be used for offshore development, thus decreasing, to some extent, new construction and the need for gravel. There are probably sufficient onshore and offshore gravel and sand resources for offshore petroleum development in the Prudhoe Bay. There are probably sufficient remaining onshore gravel resources for construction of the OCS shore facilities, that can be mined with environmental compatibility in the Prudhoe Bay " area (Grundy, 1978, personal communication). Limited boring data in Prudhoe Bay indicates significant gravel deposits at depths beneath the surficial sands and muds. Since modern suction dredges can strip significant overburden and develop subsurface borrow materials (to maximum depths of 15 to 18 meters or 50 to 60 feet), a knowledge of offshore stratigraphy is important in the identification of offshore borrow sites; information on the surficial deposits is not adequate.

The Alaska Department of Fish and Game is encouraging the adoption of intensive site gravel extraction involving a deep excavation surrounded by a berm in alluvial deposits for future mining at Prudhoe Bay. Excavations would ultimately be used as fresh water storage reservoirs. The department is trying to discourage surface skimming mining techniques.

Consideration in borrow site location should be given to snow goose habitat on Howe Island in the delta of the Sagavanirktok River and the importance of the barrier islands as nesting sites for waterfowl, gulls, and terns. As mentioned in the discussion of the Canning-Camden scenario, offshore borrow sites are best located seaward of the barrier islands rather than off the river deltas or in nearshore lagoons.

Summary

Following is a summary of impacts for the Prudhoe-High Case Scenario.

Table 10

Summary of Impacts on Fish and Wildlife Resources

AREA	RESOURCE	POTENTIAL IMPACT
Prudhoe-Large and Small	Seals	Some direct disturbance from boats and aircraft from Cross Island eastward.
	Whales	Minimal potential for disturbance of migrating whales.
	Polar Bear	Minimal potential for influence on denning.
	Foxes and Wolves	Increased mortality from vehicle hits when animals are attracted by direct feeding or improper garbage disposal.
	Caribou	Direct disturbance of caribou calving east and west of Prudhoe Bay.
	Waterfowl	Direct disturbance from boats and aircraft; nesting habitat loss from gravel mining on the Kuparuk and Sagavanirktok River deltas or on offshore islands, e.g. Howe Island supports the only snow goose colony in Alaska.
	Fish	Siltation of feeding and spawning areas from floodplain gravel mining; blockage to fish passage from gravel mining - caused changes to stream channels; disturbance of fish overwintering areas from collection of potable water or gravel mining.
	Hunting and Fishing	Very low potential for negative impact due to existing hunting and fishing regulations.

Table 11

Summary of Impacts

Water Quality, Water Resources and Sanitation

Prudhoe Bay High Case Scenario

WATER QUALITY	Increased turbidity and contaminants may occur, however, if there is compliance with OCS operating orders and state operating orders, water quality impacts will be minimal.
WATER RESOURCES	Increased water withdrawal may affect the Sagavanirktok River and overwintering fish. There may be minor conflicts between village and industry water needs, however, sufficient water may be available from the proposed Webster reservoir.
SANITATION	Sanitation or waste disposal will not directly impact Prudhoe Bay-Deadhorse. Increased sewage treatment facilities will negate any potential impacts.

Table 12

Summary of Sand and Gravel Resource Impacts:

Prudhoe 1.9 Bbbl Scenario

TOTAL GRAVEL REQUIREMENTS CUBIC METERS (CUBIC YARDS)	AVAILABILITY OF GRAVEL	POTENTIAL IMPACTS	COMMENTS
5,100,223 (6,683,772)	Probably sufficient onshore resources. Sagavanirktok River has already been heavily mined and additional suitable borrow sites will be more difficult to select. Borings offshore in Prudhoe Bay indicate significant subsurface gravel deposits.	Important waterfowl and shorebird habitats in delta of Sagavanirktok and adjacent islands should be avoided. Destruction of fish overwintering areas has been a primary concern related to borrow extraction for Prudhoe Bay/Alyeska construction.	Use of some of existing Prudhoe/Deadhorse infrastructure reduces gravel requirements. Alaska Department of Fish and Game is encouraging use of intensive site gravel extraction.

v. PROJECTED IMPACTS OF OCS DEVELOPMENT: PRUDHOE - MODAL SCENARIO

Introduction

The projected impacts for OCS development for the Prudhoe-Modal scenario are discussed in this section. The analysis of these impacts describes the expected conflicts with the natural physical environment as a result of forecasted population and employment increases and changes in the man-made environment.

Impacts may occur to fish and wildlife resources due to present and future subsistence hunting and fishing as well as commercial and sport hunting and fishing. Also, impacts may occur to fish streams from sand and gravel mining operation. In addition to the above, other impacts such as disturbance of critical wildlife habitats may occur.

Water quality, water resources and sanitation may be impacted due to increased population and industry in the Beaufort Sea region. Also, sand and gravel resources will be impacted with the increase in community and industrial demands for the resource.

Identification of Impacts

FISH AND WILDLIFE RESOURCES

The impacts to the fish and wildlife resources within the Prudhoe-Modal case scenario will be similar to those discussed on page 47 of the Prudhoe-High Case Scenario Identification of Impacts scenario.

WATER QUALITY, WATER RESOURCES AND SANITATION

The impacts to water quality, water resources and sanitation within the Prudhoe-Modal scenario will be similar to those discussed on page 49 of the Camden-Canning Scenario.

SAND AND GRAVEL RESOURCES

The impacts to sand and gravel resources within the Prudhoe-Modal scenario will be similar to those discussed in the Camden-Canning Scenario on page 50.

Assessment of Impacts

FISH AND WILDLIFE RESOURCES

Influences on fish and wildlife resources will be essentially the same as described for the Prudhoe Bay-Large scenario. However, decreased size of the exploration and development area and a smaller work force would result in a correspondingly lesser impact.

WATER QUALITY, WATER RESOURCES AND SANITATION

The Prudhoe-Small scenario slates 12 exploration wells to be drilled between 1981 and 1987, with three wells the first year, two wells in each of the following three years, and one well during each of the next three years. Personnel will range from 60 the first year to 265 in the seventh year. This level of effort will require 30,000 liters (78,750 gallons) of water per day for a maximum of 80 days the first year for rig operation, assuming that all three rigs are operating at the same time. Also, slightly more than 15,000 liters (4,000 gallons) per day will be used by personnel. In the seventh year, however, personnel use will be up to about 72,000 liters (19,000 gallons) per day. This is the year in which the last exploration well is drilled and production drilling begins. The eighth year marks the point of peak manpower -- 1,005 using in excess of 265,000 liters (70,000 gallons) per day. Of 270 projected production wells, it is anticipated that no more than 26 will be drilled in any one year. Since production wells only take an average of 40 days to drill, it is unlikely that drilling on more than five at a time will occur. Assuming five are being drilled at the same time will result in

a daily demand of about 492,000 liters (130,000 gallons) for rig operations. Other personnel needs may be as high as 227,000 liters (60,000 gallons) per day. As production continues, water use will decline until it reaches 95,000 liters (25,000 gallons) per day prior to shut-in.

The peak manpower of 1,005 in year eight will generate roughly 4,500 kilograms (10,000 pounds) of solid waste and 265,000 liters (70,000 gallons) of sewage each day. The latter will be treated to at least the secondary level prior to discharge to the sea. The solid waste will be separated and the combustibles incinerated and the noncombustibles will be deposited in a state-approved landfill.

The environmental consequences of this scenario, as they relate to water usage and waste disposal, will be similar to those delineated in the Prudhoe-Large scenario.

SAND AND GRAVEL RESOURCES

The gravel requirements for the Prudhoe-Modal Scenario is given in Table 13. The environmental consequences of this scenario on the sand and gravel resources will be essentially the same as described for the Prudhoe Bay-High case scenario. However, the decreased size of the exploration and development area will result in a correspondingly lesser impact.

Summary

Following is a summary of impacts for Prudhoe-Modal Scenario.

Table 13

Prudhoe Bay Offshore Scenario (0.8 Bbbl Reserves) - Summary of Gravel Requirements

CONSTRUCTION SCHEDULE	FACILITY	SPECIFICATIONS	GRAVEL REQUIREMENTS[1] CUBIC METERS (CUBIC YARDS)	COMMENTS
1981 - 1987	Exploration Islands	6 Soil Islands 4 Barges (with berms)	2,295,000 (3,000,000) 61,200 (80,000)	Assume average of 382,000 cubic meters (500,000 cubic yards) per island; islands include mix of sandbag-retained, sacrificial beach and shallow water pad designs.
1985 - 1993	Production Islands	5 Soil Islands	1,911,500 (2,500,000)	Assume average of 382,000 cubic meters (500,000 cubic yards) per island; islands larger than exploratory islands but caisson or sheet pile design will effect gravel savings.
	Pipeline Work Pad	15 kilometers (9.5 miles)	452,655 (603,772)	
	Pipeline Haul Road			Existing Prudhoe roads utilized, minor construction of additional access roads.
	Airstrip			Existing Prudhoe Bay and Deadhorse airstrips utilized.
	Causeways			Existing Prudhoe Bay causeway/dock utilized with minor expansion of facilities.
	Staging Area/ Production Center	2 flow stations 1 pump station 1 compressor station operations center storage areas	267,610 (350,000)	New processing facilities constructed (flow stations, etc.) but existing Prudhoe Bay camps and Deadhorse services utilized.
	Total		4,986,733 (6,533,772)	

[1] Gravel requirements for staging area/production center facilities including flow stations, pump stations, compressor plants, operations centers, and storage areas have been estimated by scaling down Prudhoe Bay facilities. Other estimates are based on Alyeska and Canadian Beaufort Sea experience (also see Table 3).

Table 14

Summary of Impacts on Fish and Wildlife Resources

AREA	RESOURCE	POTENTIAL IMPACT
Prudhoe-Large and Small	Seals	Some direct disturbance from boats and aircraft from Cross Island eastward.
	Whales	Minimal potential for disturbance of migrating whales.
	Polar Bear	Minimal potential for influence on denning.
	Foxes and Wolves	Increased mortality from vehicle hits when animals are attracted by direct feeding or improper garbage disposal.
	Caribou	Direct disturbance of caribou calving east and west of Prudhoe Bay.
	Waterfowl	Direct disturbance from boats and aircraft; nesting habitat loss from gravel mining on the Kuparuk and Sagavanirktok River deltas or on offshore islands, e.g. Howe Island supports the only snow goose colony in Alaska.
	Fish	Siltation of feeding and spawning areas from floodplain gravel mining; blockage to fish passage from gravel mining - caused changes to stream channels; disturbance of fish overwintering areas from collection of potable water or gravel mining.
	Hunting and Fishing	Very low potential for negative impact due to existing hunting and fishing regulations.

Table 15

Summary of Impacts

Water Quality, Water Resources and Sanitation

Prudhoe Bay High Case Scenario

WATER QUALITY	Increased turbidity and contaminants may occur, however, if there is compliance with OCS operating orders and state operating orders, water quality impacts will be minimal.
WATER RESOURCES	Increased water withdrawal may affect the Sagavanirktok River and overwintering fish. There may be minor conflicts between village and industry water needs, however, sufficient water may be available from the proposed Webster reservoir.
SANITATION	Sanitation or waste disposal will not directly impact Prudhoe Bay-Deadhorse. Increased sewage treatment facilities will negate any potential impacts.

Table 16

Summary of Sand and Gravel Resource Impacts:

Prudhoe 0.8 Bbbl Scenario

TOTAL GRAVEL REQUIREMENTS CUBIC METERS (CUBIC YARDS)	AVAILABILITY OF GRAVEL	POTENTIAL IMPACTS	COMMENTS
4,986,733 (6,533,772)	Probably sufficient onshore resources. Sagavanirktok River has already been heavily mined and additional suitable borrow sites will be more difficult to select. Borings offshore in Prudhoe Bay indicate significant subsurface gravel deposits.	Important waterfowl and shorebird habitats in delta of Sagavanirktok and adjacent islands should be avoided. Destruction of fish overwintering areas has been a primary concern related to borrow extraction for Prudhoe Bay/Alyeska construction.	Use of some of existing Prudhoe/Deadhorse infrastructure reduces gravel requirements. Alaska Department of Fish and Game is encouraging use of intensive site gravel extraction.

VI. PROJECTED IMPACTS OF OCS DEVELOPMENT: CAPE HALKETT SCENARIO

Introduction

Identification of Impacts

The projected impacts for OCS development for the Cape Halkett Scenario are discussed in this section. The analysis of these impacts describes the expected conflicts with the natural physical environment as a result of forecasted population and employment increases and changes in the man-made environment.

Impacts may occur to fish and wildlife resources due to present and future subsistence hunting and fishing as well as commercial and sport hunting and fishing. Also, impacts may occur to fish streams from sand and gravel mining operation. In addition to the above, other impacts such as disturbance of critical wildlife habitats may occur.

Water quality, water resources and sanitation may be impacted due to increased population and industry in the Beaufort Sea region. Also, sand and gravel resources will be impacted with the increase in community and industrial demands for the resource.

The impacts expected for this scenario are similar to those for the Camden-Canning scenario and a discussion of these impacts for fish and wildlife resources can be found on page 47. Water quality, water resources and sanitation impacts are similar to the Camden-Canning Scenario as are sand and gravel resource impacts. A discussion of these can be found on pages 49 and 50 respectively.

Assessment of Impacts

FISH AND WILDLIFE RESOURCES

The level of hunting and fishing activity increases westward from the Colville River, because of the relatively large human population at Barrow and the relatively recent settlement of the village of Nuiqsut. Waterfowl, whales, seals and caribou are the most important species for domestic consumption.

The greatest concentrations of waterfowl in Arctic Alaska occur west of the Colville River (Selkregg, 1975). Each summer following the nesting season large numbers of waterfowl congregate during the molting period in nearshore areas in lagoons or onshore zones such as the lake covered flat from Teshekpuk Lake to the coast. The loss of feathers leaves the birds flightless for a time. Other aggregations occur just prior to the fall migration. During such periods of high density the birds are particularly vulnerable to the hazards of fuel spills or harassment by motorized vehicles. Careful identification of critical areas and time periods during the planning stages of drilling operations, gravel mining and associated efforts should minimize serious conflicts.

In recent years the Alaska Department of Fish and Game has placed greater emphasis *on* caribou research on the Arctic Slope. Last year it was verified that a new caribou herd had been identified near Teshekpuk Lake (Davis, personal communication). A caribou herd is defined as a group of animals that use the same area each year for calving, but may mingle with adjacent herds at other times of the year. This new herd appears to be a non-migratory population that occurs between Cape Halkett and Teshekpuk Lake. The use of aboveground pipelines from a landfall at Cape Halkett to Prudhoe Bay could seriously influence the distribution of both the Teshekpuk and Central Arctic caribou herds. Orientation of above-ground pipelines to an alignment immediately adjacent to the beach or increased use of undersea pipelines could significantly reduce adverse impacts on caribou.

Quotas imposed as a result of the Marine Mammal Protection Act and the Endangered Species Act will reduce the harvest of bowhead whales from 15 to 30 per year (Alaska Department of Fish and Game, 1976) to a maximum of 12 as established by the International Whaling Commission in 1978. Severe restrictions on harvest of large whales will probably shift pressure to belukha whales, seals and waterfowl. Increasing marine traffic related to the development and operation of offshore platforms will come under increasing scrutiny by hunters from Barrow and Nuiqsut if there is any evidence of marine mammal harassment. The major items of concern related to marine mammals are:

- Direct modification of habitat or productivity resulting from construction of drilling platforms or islands, underwater pipelines, camps, and staging areas.

- Displacement of marine mammals from traditional migration routes, hauling out areas, pupping areas, etc. due to excessive human activity or as a result of petrochemical pollution.

WATER QUALITY, WATER RESOURCES AND SANITATION

A general discussion of North Slope waste and water impacts can be found in the Camden-Canning Scenario *on* page 50.

The Cape Halkett scenario slates eight exploration wells to be drilled between 1985 and 1989, with two wells the first year, three wells the second, and one well each in years three, four, and five. Assuming the exploration drilling of the three wells in the second year occurs at the same time will create a water demand of 299,000 liters (79,000 gallons) per day. Personnel needs in this year add an additional 23,000 liters (6,000 gallons) per day.

Production drilling starts in 1990. Of the 143 production wells to be drilled during this scenario, 24 will be drilled the same year. However,

only four will be drilled at one time, which will require 397,000 liters (105,000 gallons) of water per day. Manpower reaches its peak at the beginning of production drilling and may require as much as 235,000 liters (62,000 gallons) of water per day. This level of use drops the following year when production begins to about 159,000 liters (42,000 gallons) per day and continues a gradual decline to 87,000 liters (23,000 gallons) per day the last year of operation.

The peak manpower in year seven will generate approximately 40,000 kilograms (8,800 pounds) of solid waste and 897,0001 iters (105, ooo gallons) of sewage per day. Sewage treatment will be effected prior to releasing the effluent to the sea. The combustible solid waste will be incinerated and the ash and noncombustible portion will be deposited in a state-approved landfill.

Water withdrawals for the Cape Halkett scenario will not-be made in the same location that Nuiqsut villagers use to obtain their water. Likewise, sewage treatment plant effluents and solid waste disposal will not directly impact these people.

Teshekpuk Lake is a critical wildlife area. Also, the Colville River delta has major waterfowl nesting areas and fish overwintering sites that could be adversely impacted if too much water was withdrawn. Any adverse impact to the waterfowl and/or fish will ultimately be felt by the North Slope villagers using this area for their subsistence way of life.

Nuiqsut residents will feel a direct impact on their local water resource if an onshore pipeline is built from Cape Halkett to Prudhoe Bay. This alternate pipeline corridor passes near the village. The pipeline work pad and haul road will alter local drainage patterns and may affect the water quality at stream crossing sites.

SAND AND GRAVEL RESOURCES

A general discussion of North Slope sand and gravel impacts can be found in the Camden-Canning Scenario on page 64.

The gravel and sand requirements for the Cape Halkett scenario are given in Table 17. The requirements for this scenario are significantly less than the Prudhoe Bay and Camden-Canning scenarios. Not only is the size of the field smaller than the other hypothetical discovery sites, but the scenario also predicts the use of ice islands, barges and gravity structures for drilling and minimal use of soil islands (the facility with the greatest borrow requirement), The scenario also postulates that oil and gas processing will be conducted on the platform obviating the need for a large shore base. In addition, the most direct route to Prudhoe Bay was selected for the connecting pipeline; this involved a long submarine crossing of Harrison Bay rather than a more circuitous land route around the bay. All these factors combine to reduce the gravel required for construction of the petroleum facilities. A scarcity of gravel resources onshore and possibly offshore west of the Colville River was an element in predicting the technical framework of the scenario. If extensive use of gravel had been indicated in the scenario, a significant impact on the gravel and sand resources could have predicted. It is doubtful that there is sufficient borrow west of the Colville river to support major offshore petroleum development without significant environmental impact and/or long barge haul of material.

The potential also exists for greater environmental impacts from onshore and offshore gravel mining west of Cape Halkett. There is a greater chance for encounters with marine mammals in this area than in the Prudhoe Bay and Canning-Camden areas. Smith Bay, for example, is critical summer habitat for the endangered Bowhead whale, Belukha whale and ringed seal which could be seriously disturbed by the marine traffic associated with dredging and island construction.

Table 17

Cape Halkett Scenario (0.8 Bbbl Reserves) - Summary of Gravel Requirements

FACILITY	SPECIFICATIONS	GRAVEL REQUIREMENTS' CUBIC METERS (CUBIC YARDS)		COMMENTS
Exploration Islands	2 Barges (with berms)	30,584	(40,000)	
Production Islands	1 Soil Island	3B2 ,000	(500 ,000)	Caisson or sheet pile design effecting gravel savings,
Pipeline Work Pad	66 kilometers (41 miles)	1,991,682	(2,605,755)	
Pipeline Haul Road	66 kilometers (41 miles)	919,248	(1,202,653)	
Airstrip	1 - 1,829 meter (6,000 feet)	122,336	(160,000)	
Causeways'	2 - (each 2.4 kilometers or 1.5 miles long)	891,388	(1,173,000)	One located at landfall of pipeline in east Harrison Bay and one located at staging area at Cape Halkett.
Staging Area	Camp Storage area	191,150	(250,000)	Oil/gas processing facilities, pump station and compressor station are located on platforms.
Total		4,528,388	(5,931 ,408)	

1 Gravel requirements have been estimated by scaling down Prudhoe facilities or based on Alyeska and Canadian Beaufort Sea experience.

Inland from Cape Halkett, gravel extraction of such deposits as the beaches of Teshekpuk Lake could involve significant impacts to the lake's fish resources and a small resident caribou herd.

Summary

Following is a summary of impacts for the Cape Halkett Scenario.

Table 18

Summary of Impacts on Fish and Wildlife Resources

AREA	RESOURCE	POTENTIAL IMPACT
Cape Halkett	Seals	Direct disturbance from boats and aircraft; modification of pupping or hauling-out areas by oil field development; attraction of migration due to human activity and water pollution.
	Whales	Direct disturbance from boats and aircraft; displacement from calving areas and migration routes due to human activity or petrochemical pollution.
	Foxes and Wolves	Increased mortality when animals are attracted by direct feeding or improper garbage disposal.
	Caribou	Direct disturbance of resident caribou near Teshekpuk Lake from human and vehicle activity and pipelines.
	Waterfowl	Direct disturbance of nesting, molting and migrating waterfowl from boats, aircraft and ground vehicles; nesting habitat loss from gravel mining.
	Fish	Siltation of feeding and spawning areas from gravel mining; blockage to fish passage from gravel mining - caused changes to stream channels; disturbance of fish overwintering areas from collection of potable water or gravel mining at Teshekpuk Lake on the Colville River delta.
	Hunting and Fishing	Increased marine traffic may displace bowhead and belukha whales from traditional hunting areas. Siltation of Teshekpuk Lake from gravel mining could reduce harvests of local fishermen. Shore based construction and vehicle traffic could displace waterfowl and caribou used by people from Barrow and Nuiqsut.

Table 19

Summary of Impacts

Water Quality, Water Resources and Sanitation

Cape Halkett Scenario

WATER QUALITY	If an onshore pipeline is built there may be water quality impacts stemming from drainage pattern alterations. Increased turbidity and contaminants may occur, however, if there is compliance with OCS operating orders and state operating orders, water quality impacts will be minimal.
WATER RESOURCES	A possible impact will occur if an onshore pipeline is built due to increased water withdrawal from Teshekpuk Lake and the Colville River delta.
SANITATION	Assuming sewage treatment will take place by industry, minimal affects will occur to the environment.

Table 20

Summary of Sand and Gravel Resource Impacts:

Cape Halkett Scenario

TOTAL GRAVEL REQUIREMENTS CUBIC METERS (CUBIC YARDS)	AVAILABILITY OF GRAVEL	POTENTIAL IMPACTS	COMMENTS
4,528,388 (5,931 ,408)	There is a scarcity of of onshore and possibly offshore gravel resources in the Cape Halkett area. It is doubtful that there is sufficient borrow west of the Colville River to support major petroleum development without significant environmental impact and/or long barge haul .	West of the Colville there are important summer habitats of the bowhead and belukha whales and ringed seals which could be seriously impacted by offshore gravel extraction particularly disturbance from marine traffic.	Gravel requirements are significantly less than the Canning-Camden and somewhat less than the Prudhoe scenarios because oil/gas treatment is conducted offshore and major use of soil islands is not postulated.

VII. REFERENCES

Alaska Consultants, Inc., 1978. Alaska OCS Socioeconomic Studies Program, Working Paper #10 Local Government Services and Revenues Standards, The Beaufort Sea Region, prepared for Peat, Marwick, Mitchell & Co. by Alaska Consultants, Inc.

Alaska Department of Fish and Game, 1976. Alaska Wildlife Management Plans, Arctic Alaska. Alaska Dept. of Fish and Game, Federal Aid in Wildlife Restoration. Project W-17-R, Juneau. 139 pp.

Alaska Department of Revenue, 1976. Summary of Alaska Department of Fish' and Game Hunting and Fishing License Sales. Juneau.

Alcan Pipeline Company, 1976. Application of Alcan Pipeline Company for for Certificate of Public Convenience and Necessity, Exhibit 2-1, Volume 1, Alaska.

_____, 1976b. Application of Alcan Pipeline Company at Docket No. CP76 for Certificate of Public Convenience and Necessity, Exhibit 22, Supplementary Details.

Arctic Institute of North America, 1974. The Alaskan Arctic Coast, A Background Study of Available Knowledge. Anchorage, U.S. Department of the Army, Corps of Engineers, Alaska District, 551 pp.

Berger, C. and L. Swenson, 1977, Environmental Surveillance of Gravel Removal on the Trans-Alaska Pipeline System with Recommendations for Future Gravel Mining. Joint State/Federal Fish and Wildlife Advisory Team, Special Report No. 13, Anchorage, Alaska.

Burns, J. J., L. H. Shapiro and F. H. Fay, 1976. The Relationship of Marine Mammal Distribution, Densities and Activities to Sea Ice Conditions. Alaska OCS Principal Investigator's Annual Reports, Vol. 1, Marine Mammals: 387-430.

Cameron, R. D. and K. R. Whitten, 1976, First Interim Report of the Effects of the Trans-Alaska Pipeline on Caribou Movements. Joint State/Federal Fish and Wildlife Advisory Team Special Report No. 2. 53 pp.

_____, 1977. Second Interim Report of the Effects of the Trans-Alaska Pipeline on Caribou Movements. Joint State/Federal Fish and Wildlife Advisory Team Special Report No. 8. 44 pp.

Canada Department of the Environment, 1977. Artificial Islands in the Beaufort Sea: A Review of Potential Environmental Impacts. Canada Department of the Environment, Fisheries and Marine Services Environmental Secretariat, September, 1977.

Canadian Department of Fisheries and Environment, 1977. Artificial Islands in the Beaufort Sea, a review of potential environmental impacts. Fisheries and Marine Service, Winnipeg. 41 pp.

Child, K. N., 1973. The reactions of Barren-Ground Caribou (Rangifer tarandus Granti) to Simulated Pipeline and Pipeline Crossing Structures at Prudhoe Bay, Alaska. Alaska Cooperative Wildlife Research Unit, University of Alaska, College. 49 pp.

CCC/HOK, 1977. Alaska Ocs Socioeconomic Studies Program, Baseline Studies of the Physical and Man-Made Environment, The Beaufort Sea Region, prepared for the Bureau of Land Management Alaska Outer Continental Shelf Office.

Dames & Moore, 1977. Water Supply and Waste Treatment in Cold Region Construction Camps, Draft Report for New England Division of Army Corps of Engineers Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, May.

Dames & Moore, 1978. Alaska OCS Socioeconomic Studies Program, Beaufort Sea Petroleum Development Scenarios for the State-Federal and Federal Outer Continental Shelf, Draft Report, prepared for the Bureau of Land Management, Alaska Outer Continental Shelf Office.

Dygas, J. A. and D. C. Burnell, 1975. Dynamic Sedimenological Processes along the Beaufort Sea Coast of Alaska, in Assessment of the Arctic Marine Environment: Selected Topics, D. W. Hood and D. C. Burnell, eds., University of Alaska Institute of Marine Science, Fairbanks, Alaska.

Gavin, A., 1974. Wildlife of the North Slope/a five year study, 1969-1973. Atlantic Richfield Co., 61 pp.

Gibson, K. J. and P. A. Kerschner, 1977. Alternatives for the Future Petroleum Development Study, North Slope of Alaska. State of Alaska Department of Natural Resources. 407.pp.

Grundy, S., 1978. Regional Director, Alaska Department of Fish and Game, personal communication.

Hemming, J. E., 1971. The Distribution and Movement Patterns of Caribou in Alaska. Alaska Dept. of Fish and Game. Wildlife Technical Bulletin No. 1. 60 pp.

Hemming, J. E., 1975. Alaskan Problems and Prospects. Pp 11-14. In Proceedings First International Reindeer and Caribou Symposium, Fairbanks, Alaska. 551 pp.

Hume, J. D. and M. Schalk, 1964. The Effects of Beach Borrow in the Arctic Shore and Beach, Vol. 32, pp. 37-41.

H. V. Lounsbury & Associates, 1973. Cooper Island Borrow Material Feasibility Study. Report prepared for North Slope Borough, December, 1973.

ISER, 1978a. Alaska OCS Socioeconomic Studies Program, Model Output: Non-OCS Scenario, Working Paper No. 4, prepared for the Bureau of Land Management, Alaska Outer Continental Shelf Office, February 13, 1978.

_____, 1978b. Alaska OCS Socioeconomic Studies Program, Model Output: Non-OCS Scenario, Working Paper No. 7, prepared for the Bureau of Land Management, Alaska Outer Continental Shelf Office, February 13, 1978.

L.G.L. Limited, Environmental Research Associates, 1974. Disturbance to birds by gas compressor noise simulators, aircraft and human activity in the Mackenzie Valley and the North Slope, 1972. Arctic Gas Biological Report Series, Vol. 14. 305 pp.

Labelle, J. C., 1973. Fill materials and aggregate near Barrow, Naval Petroleum Reserve No. 4, Alaska. Arctic Institute of North America, 146 pp.

Lewellen, R., 1970. Permafrost Erosion Along the Beaufort Sea Coast. Published by the author, Littleton Co., 25 pp.

Lewellen, R., 1977. A Study of Beaufort Sea Coastal Erosion, Northern Alaska. National Oceanic and Atmospheric Administration - Bureau of Land Management, Outer Continental Shelf Environmental Assessment Program, Final Report, Research Unit No. 407, 1977.

Milke, G., 1977. Animal Feeding Problems and Solutions. Joint State/Federal Fish and Wildlife Advisory Team, Special Report No. 14. 1? pp.

Netsch, N., 1974. Gravel Removal from Streams and Floodplains - General Guidelines, JFWAT Viewpoint. Joint State/Federal Fish & Wildlife Advisory Team, Memorandum dated October 10, 1974.

North Slope Borough, 1977. Beaufort Sea Study, Historic and Subsistence Site Inventory. North Slope Borough, Barrow, Alaska. 113 pp.

Northern Engineering Services Company, Ltd., 1974. Pipeline Related Borrow Studies. Report prepared for Canadian Arctic Gas Study, Ltd., Calgary, Alberta.

Northern Engineering Services Company, Ltd. and Aquatic Environments, Ltd., 1975. Reconnaissance of the Alyeska Pipeline - Material Source Borrow Methods and Evaluation of These Methods with Respect to Aquatic Habitats. Canadian Arctic Gas Study, Ltd., Calgary, Alberta.

Outer Continental Shelf Environmental Assessment Program, 1977. Arctic Project Bulletin No. 15. Beaufort Sea Synthesis Report: Environmental Impacts of OCS Development in Northern Alaska (Draft). NOAA-BLM, June 1, 1977.

Selkregg, L. L. cd., 1975. Alaska regional profiles -- Arctic region. Arctic Environmental Information and Data Center, Anchorage. 218 pp.

Slaney, F. F. & Co. Ltd., 1976. Summer environmental program. Mackenzie River Estuary. Vol. 1, Aquatic Studies, prepared for Imperial Oil Ltd. , Calgary by F. F. Slaney & Co. Ltd., Vancouver, Canada.

Slaney, F. F. & CO. Ltd., 1977. Environmental Assessment of Construction and Construction Support Activities related to the Proposed Ten-Year Beaufort Sea Offshore Exploration Program. Volumes 1 and 2, prepared for Imperial Oil Ltd., Calgary by F. F. Slaney & Co. Ltd., Vancouver, Canada.

U.S. Census, North Slope Borough.

U.S. Department of the Navy, 1977. Final Environmental Impact Statement -- Continuing Exploration and Evaluation of Naval Petroleum Reserve No. 4, vol. II. Naval Petroleum and Oil Shale Reserves, Washington, , D.C.

U.S. Fish and Wildlife Service, 1976. Preliminary Report - Gravel Removal Studies in Selected Arctic and sub-Arctic Streams in Alaska. Office of Biological Services, Washington, D.C. 127 pp.

Weinhold, R. S., 1971. Sagavanirktok River Gravel Removal. U.S. Fish and Wildlife Service, unpublished report.

White, R. G., D. Roby and D. R. Klein, 1975. Evidence for Caribou Use of Tundra Between Aligun Pass and Prudhoe Bay, Alaska. Pp. 50-55. *In* Ecological and Limnological Reconnaissance from Prudhoe Bay into the Brooks Range, Alaska, Summer 1975. Research on Arctic Tundra Environments, USA, CRREL, Hanover, N. H.

Wilson, W. J., et al., 1977. Winter Water Availability and Use Conflicts as Related *to* Fish and Wildlife in Arctic Alaska -- A Synthesis of Information. U.S. Fish and Wildlife Service. 243 pp.

Wiseman, W. J., J. N. Suhayda, S. A. Hsu, and C. D. Walters, 1974. Characteristics of Nearshore and Oceanographic Environment of Arctic Alaska, in the Coast and Shelf of the Beaufort Sea, J. C. Reed and J. E. Sater (eds.). Arctic Institute of North America, Proceedings of a Symposium on Beaufort Sea Coast and Shelf Research, pp. 49-64.

Woodward-Clyde Consultants, 1976. Preliminary Report, Gravel Removal Studies in Selected Arctic and Sub-Arctic Streams in Alaska. Prepared for U.S. Fish and Wildlife Service, Biological Services Program, 127 pp.