UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HYDROCARBON POTENTIAL, GEOLOGIC HAZARDS, AND THE TECHNOLOGY, TIME-FRAME AND INFRASTRUCTURE FOR EXPLORATION AND DEVELOPMENT OF THE LOWER COOK INLET, ALASKA

A PRELIMINARY ASSESSMENT

OPEN-FILE REPORT
75-549

This report is preliminary
and has not been edited or
reviewed for conformity
with Geological Survey
standards and nomenclature.

Menlo Park, California
November 1975

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HYDROCARBON POTENTIAL, GEOLOGIC HAZARDS, AND THE TECHNOLOGY, TIME-FRAME AND INFRASTRUCTURE FOR EXPLORATION AND DEVELOPMENT OF THE LOWER COOK INLET, ALASKA

A PRELIMINARY ASSESSMENT

By

L. B. Magoon, M. A. Hampton, E. G. Sable,
R. A. Smith *and* F. B. Chemlik

OPEN-FILE REPORT
75-549

Menlo Park, California
November 1975

Contents

Figures

Tables

HYDROCARBON POTENTIAL, GEOLOGIC HAZARDS, AND THE TECHNOLOGY, TIME-FRAME AND INFRASTRUCTURE FOR EXPLORATION AND DEVELOPMENT OF THE LOWER COOK INLET, ALASKA

A PRELIMINARY ASSESSMENT

By L. B. Magoon, M. A. Hampton, E. G. Sable, R. A. Smith *and* F. B. Chemlik

SUMMARY

The Lower Cook Inlet Outer Continental Shelf (OCS) contains 5600 km^2 of submerged land in less than 200 m of water 150 to 350 km southwest of Anchorage, Alaska. This area could contain from 0.3 to 1.4 billion barrels of oil and from 0.6 to 2.7 trillion cubic feet of natural gas depending upon the statistical confidence level indicated.

The known geology of this submerged area, is extrapolated to the offshore from onshore data. The sedimentary rocks are as old as Triassic and as young as Pleistocene. The Mesozoic strata include volcanic rocks, volcanoclastic and marine clastic sediments. Tertiary, rocks from which the oil and gas in Upper Cook Inlet are produced, consist of nonmarine conglomerate, sandstone, siltstone and coal. The potential objective section for oil and gas in this OCS area ranges from Middle Jurassic through the Tertiary.

The present structural configuration of this area is a northeast trending trough filled with Tertiary sediments. The trough is flanked by two major faults, the Bruin Bay fault on the northwest and the Border Ranges fault on the southeast. Between these faults is the OCS area containing anticlinal structures and faults which may be traps for hydrocarbons.

Potential geologic hazards are present in this area. It is an area of intense tectonism expressed as seismic activity (earthquakes) and volcanic eruptions which produce many natural disturbances including tsunamis. This distribution of soft sediment and other submarine features which relate to geologic hazards are only generally known.

The technology required for exploration and development in the Lower Cook Inlet is available, having been demonstrated by offshore oil and gas producing operations in the Upper Cook Inlet and recent developments in the North Sea and other offshore areas. Procedures for analizing seismic forces and for designing offshore structures to withstand earthquakes are available. New techniques for measuring and predicting maximum environmental forces are improving overall capability and reliability for design of offshore equipment.

Exploratory drilling in the Lower Cook Inlet may be accomplished by jack-up rigs as well as drill ships and semi-submersible vessels. Only 3 or 4 mobile drilling vessels are presently located in Alaska or on the West Coast of the United States. Mobile drilling units must be obtained from the Gulf of Mexico, North Sea or other parts of the world. Moving times will be long and costs high.

The reservoir of available skilled manpower in the Alaska area is relatively small due to the low population density and distance from significant industrial centers. Skilled manpower and manpower available for training is available in the Pacific Northwest and California.

The time frame for significant development will be relatively long due to high costs and environmental conditions. It is estimated that it will be 1-2 years after a lease sale until substantial exploratory drilling will occur, 5-8 years until initial production, and 6-10 years until maximum production.

INTRODUCTION

This report is a summary of the geologic framework, petroleum geology, oil and gas resources, environmental geology and operational considerations of the Lower Cook Inlet Outer Continental Shelf (OCS) area. It is preliminary to a more complete report that will be issued about January, 1976. The subsequent report will be more complete in that it will contain preliminary results of a multichannel seismic reflection survey, now being processed, and some additional geologic data from adjacent onshore areas acquired during the summer of 1975.

This report provides a preliminary assessment of the technology availability of drilling units and manpower, the time frame for possible oil and gas development of the Lower Cook Inlet Area, and comments on capital, manpower, and infrastructures necessary for the development of this area as requested by the Director, Bureau of Land Management.

Operations in the Lower Cook Inlet will be influenced to a great degree by environmental conditions in the form of relatively harsh climate, weather and sea conditions and possible seismic disturbances. In addition, a shortage of exploration drilling units, skilled manpower and the remoteness from industrial areas and supply centers could contribute to delays in the time frame for development and to increasing capital layout. This preliminary report is meant principally to aid the Bureau of Land Management (BLM) in selecting the area from which to call for nominations in October, 1975.

Location

The Lower Cook Inlet Outer Continental Shelf (OCS) area is located between north latitudes 58° 50' and 60° 20' and between west longitudes 150° 30' and 153° 35' (fig. 1). Major geographic features on the perimeter of the area are as follows: 1) The Aleutian Range on the northwest; 2) Kalgin Island on the northeast; 3) the Kenai Peninsula and Kachemak Bay to the east; 4) the Barren Islands on the southeast along the historic bay closure line, and; 5) the north end of the Alaska Peninsula on the southwest where the Katmai National Monument is located. Augustine Island, a prominent active composite volcano, lies 24 km north of the Alaska Peninsula in the southwest part of the Lower Cook Inlet.

The lower Cook Inlet is a bay surrounded on all sides by mountains except on the southeast where it opens into the Gulf of Alaska and the Shelikof Strait (fig. 2). The water depth in the OCS area is less than 200 m except for a small area around the Barren Islands. More than half the area is less than 100 m deep. The Inlet gradually deepens to the southeast.

Anchorage, a major city in Alaska, lies 320 km northeast of Cape Douglas, the farthest point in this OCS area. Production, pipeline, refining and other related facilities are available in the Upper Cook Inlet around Anchorage.

Available Public Data

The literature that describes the onshore geology dates back to the turn of the century. The subsurface geology of the Upper Cook Inlet

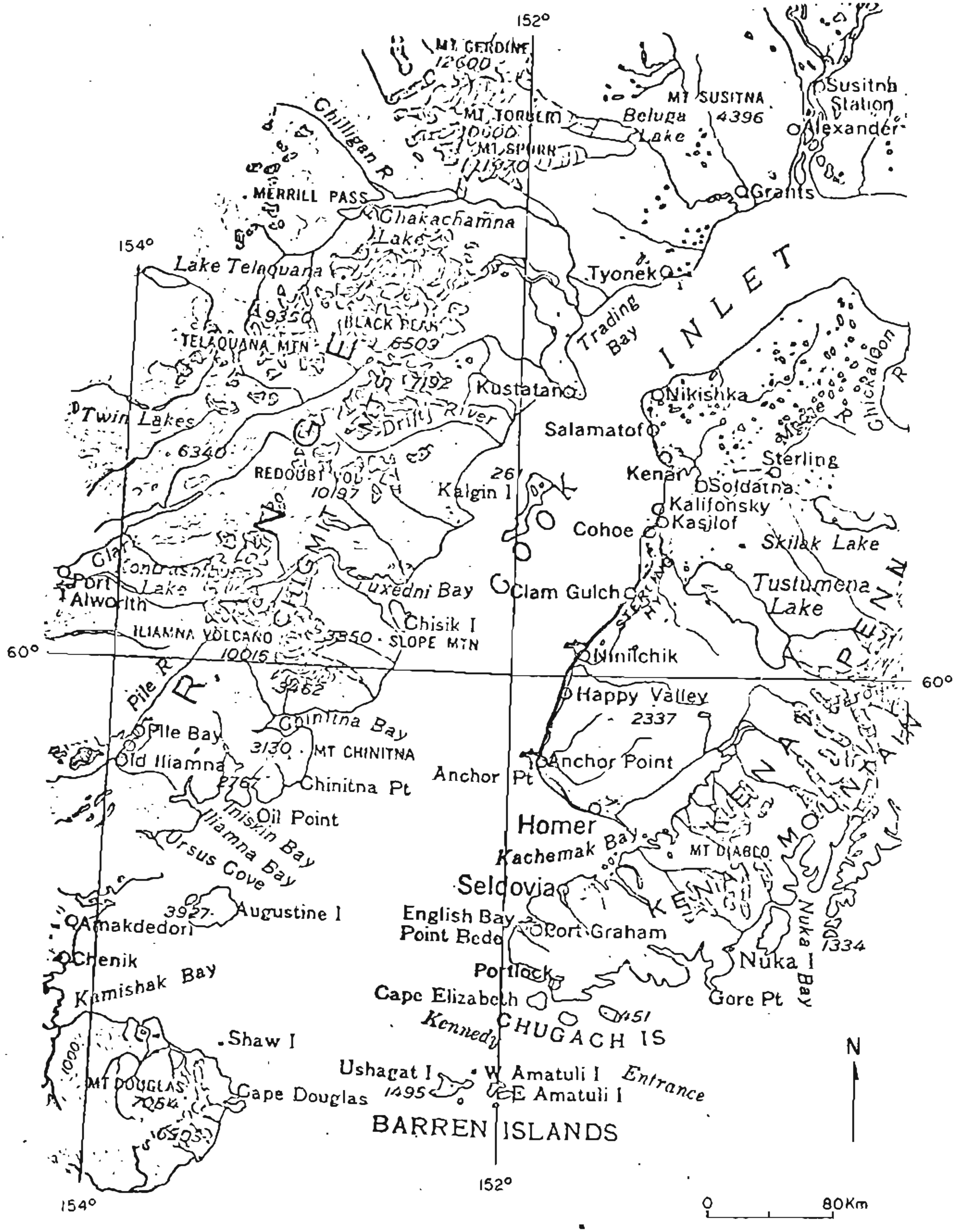
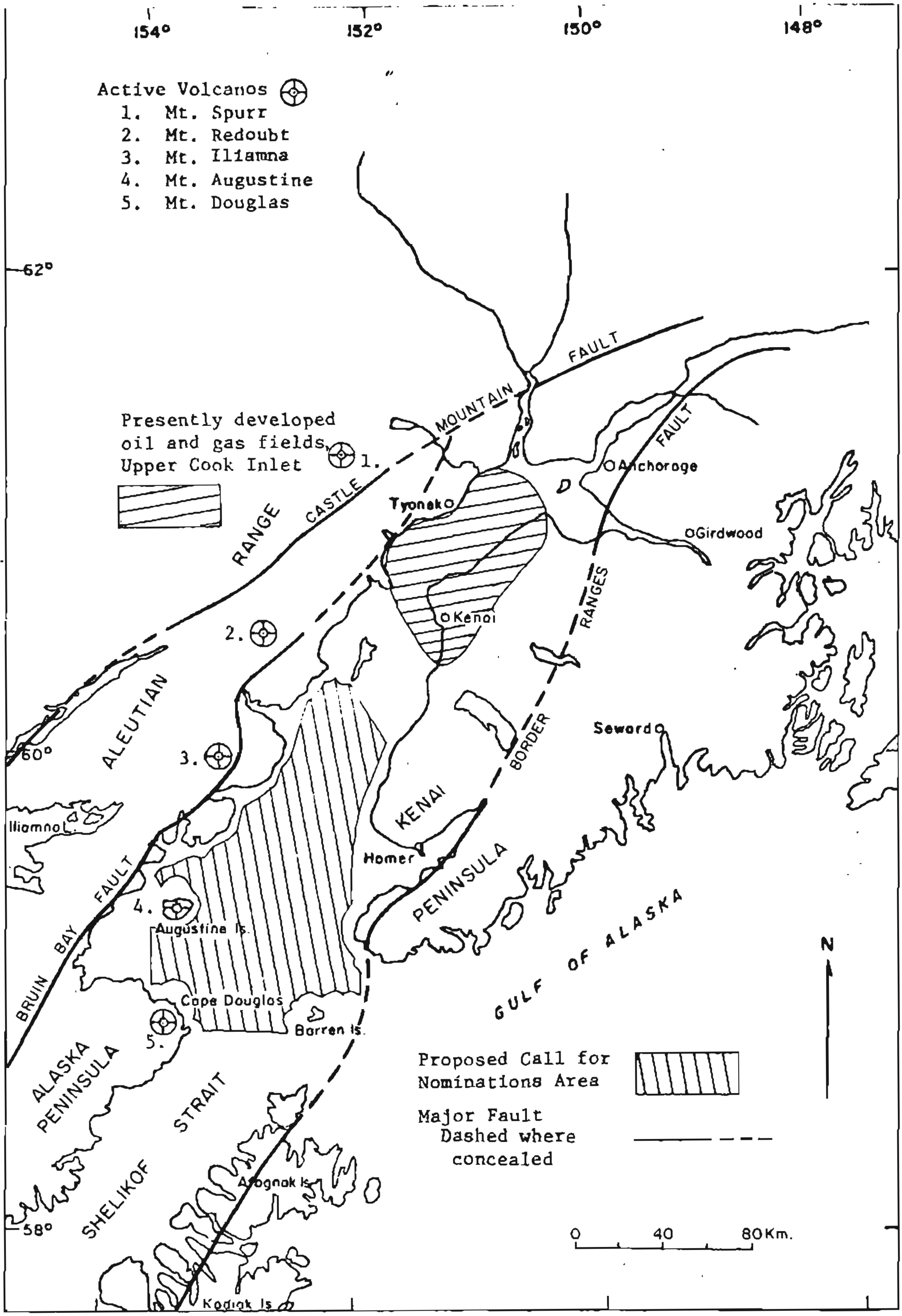


Figure 1 --Map of Cook Inlet area showing named features.



COOK INLET AREA

Figure 2

is generally known from exploratory and development wells. A bibliography of geological literature on Cook Inlet was published by Maher and Trollman (1969). Selected references are listed on pages 20-26.

Little, if any, data exists that pertain directly to the offshore Lower Cook Inlet. However, a great deal of the onshore geology can be extended offshore using geological and geophysical techniques. In the summer of 1975, 500 km of 3600% Common Depth Point (CDP) seismic data was acquired, and two onshore areas were mapped geologically with the express purpose of extending this control offshore into the OCS area. This new data will be incorporated into later published reports.

FRAMEWORK GEOLOGY

General Geology

The Lower Cook Inlet is part of the Tertiary intermontane trough that extends to the northeast into the hydrocarbon rich Upper Cook Inlet and southwest into the Shelikof Strait. Major lineaments which are parallel but flank this trough are the Bruin Bay and Border Ranges faults (fig. 2). The Bruin Bay fault is a high angle reverse fault that juxtaposes granitic rock, Early Jurassic and older sedimentary rocks, against middle Jurassic and younger sedimentary strata. The Border Range fault is considered the boundary between the subducted oceanic plate and the continental plate (MacKevett and Plafker, 1974).

The fault trace extends well beyond the area of interest but does go southeast of Anchorage, through Seldovia and east of the Barren Islands. Movement along this fault is late Mesozoic-early Tertiary as only Mesozoic rocks are involved. Middle Tertiary rocks do not seem to be involved.

Onshore Stratigraphy

The stratigraphic column ranges in age from Triassic through Quaternary. As discussed below, rocks older than Middle Jurassic can be considered the basement complex. The discussion of the stratigraphy is from oldest to youngest.

The oldest rocks, of Triassic age, consist of metamorphosed limestone, chert, sandstone, shale and basaltic lava flows (Detterman and Hartsock, 1966). These rocks are found at scattered places on the northwest side of the Bruin Bay fault.

The Lower Jurassic rocks are represented by volcanic agglomerates and breccias of the Talkeetna Formation (Detterman and Hartsock, 1966). These are the extrusive andesitic volcaniclastic rocks emanating from the magma chamber that was later to become the Alaskan batholith. This unit is represented near Seldovia by pillow lavas. The Lower Jurassic volcanics are considered the reflection seismic "basement" and economic "basement" because of its presumed inability to reflect seismic sound waves and its lack of reservoir or source rock characteristics necessary to contribute hydrocarbons to this province.

Unconformally overlying the Lower Jurassic is the Middle to Upper Jurassic Tuxedni Group. This unit probably represents erosion of the area over the Alaskan batholith. The unit consists of alternating fossiliferous greywacke sandstone and siltstone deposited in a shallow marine environment. The Tuxedni Group is 1675-2745 m thick near the Iniskin Peninsula (Detterman and Hartsock, 1966).

The Upper Jurassic Chinitna Formation overlies the Tuxedni Group. It ranges in thickness from 550 to 730 m. The Chinitna Formation is predominantly dark grey siltstone that commonly includes large concretions. This siltstone is the most likely petroleum source rock in the Jurassic. Exposures of this marine siltstone extend from Iniskin Bay on the southwest to Chisik Island in Tuxedni Bay on the northeast.

The Upper Jurassic Naknek Formation overlies the Chinitna Formation. It outcrops on the northwest side from the Alaskan Peninsula northeast to Tuxedni Bay. In outcrop the thickness is as much as 1465 m. Lithologically it is arkosic marine sandstone with some conglomerate and siltstone. The conglomerate contains granitic boulders which are radiometrically the same age as the Alaskan batholith (Detterman and others, 1965). This is the first indication that the Alaska batholith actually became a source for sediments. The Naknek Formation was deposited in a shallow marine environment.

The Lower Cretaceous rocks unconformably overlie the Upper Jurassic beds at the northeastern end of the Alaskan Peninsula in the Kamishak Hills. This unnamed shallow marine unit is as much as 215 m thick and consists of sandstone and siltstone. Marine fossils are abundant. Rocks of the same age have been described in the Nelchina area and in the Herendeen Bay area on the Alaska Peninsula (Jones and Detterman, 1966). Because of its lateral extent, the Lower Cretaceous unit is expected to subcrop in the Lower Cook Inlet.

Unconformably overlying the Lower Cretaceous unit is the Upper Cretaceous Kaguyak Formation (Keller and Reiser, 1959). This unit is about 1370 m thick at Kaguyak bay. Just north of Kaguyak Bay in the Kamishak Hills there are 60 m of basal sandstone which contains marine fossils. In Kaguyak Bay there are 760 m of dark grey bioturbated siltstone. The upper 610 m of this formation contains interbeds of deep water turbidite sandstone and siltstone. This unit is tentatively correlated with the Matanuska Formation to the northeast of Anchorage. Because this unit is present to the northeast and southwest of the OCS area, it is projected into the subsurface of the Lower Cook Inlet.

Tertiary rocks unconformably overlie the Mesozoic strata and constitute the important oil and gas producing unit in upper Cook Inlet. The thickness may be as much as 7600 m (Hartman and others, 1972) The section is nonmarine and consists of conglomerate, sandstone, siltstone, coal and some shale. In Lower Cook Inlet Tertiary rocks are as much as 6100 m thick (Hartman and others, 1972). Tertiary rocks exposed at Cape Douglas are 1675 m. The Tertiary can be divided into two sedimentary sequences. The older sequence includes Paleocene and Eocene rocks. The older Tertiary generally contains more heterogenous rock fragments and volcanic detritus. The younger sequence includes the Kenai Group of Oligocene through Pliocene age. It contains more arkosic debris and no volcanic detritus. The younger unit is also the more petroliferous.

Geologic History

The known geologic history of the Cook Inlet trough extends from early Mesozoic (Triassic) time through the Quaternary time. During Triassic time a ridge complex probably extruded basaltic lava. Limy sediments or ooze were deposited in sediment starved areas, and volcanic activity provided the silica necessary for chert formation. It is suspected that the general breakup of the continents in late Triassic to early Jurassic time radically changed the sedimentary and volcanic processes to set the stage for emplacement of the Jurassic Alaskan batholith and Talkeetna extrusive volcanics.

The early Jurassic Alaskan batholith was probably the magma chamber for a coincident volcanic arc that extruded andesitic flows and volcaniclastic sediments that are known today as the Talkeetna Formation. The hydrographic configuration of the ocean during early Jurassic time is poorly known, but the water depth probably increased gradually to the southeast. Here andesitic volcanic flows, breccias and agglomerates were deposited.

Volcanic activity seemed to subside at the end of early Jurassic time, and marine clastic sedimentation produced sandstone and siltstone. The sediments increased in arkosic content from the middle Jurassic Tuxedni Group up through the late Jurassic Chinitna and Naknek Formations. Presumably during middle Jurassic time, the volcanic arc was being eroded and redeposited in the marine environment. By the time the basal conglomerate (Chisik Conglomerate member) of the Naknek Formation was deposited, the granitic material of the Alaskan batholith was being eroded.

The Bruin Bay fault is a compressional high angle reverse fault whose movement could have been initiated during middle Jurassic time and continued through late Cretaceous to early Tertiary time. This fault may have separated the source area on the northwest from the depositional basin on the southeast. Regional uplift and truncation occurred prior to the deposition of the lower Cretaceous beds.

The lower Cretaceous rocks are exposed at the northeast end of the Alaskan Peninsula in the Kamishak Hills. The fossiliferous basal sandstone was probably deposited in shallow water that received little sediment but which supported vast clam beds as these sediments contained Inoceramus prisms and shell fragments. Water depth and/or energy regime fluctuated as the rocks consist of interbedded sandstone and siltstone. Following deposition of the lower Cretaceous, regional uplift and erosion removed an unknown amount of sediment before deposition of the upper Cretaceous beds.

The basal sandstone of the upper Cretaceous was probably deposited in shallow marine water. As the basin subsided and water depth increased, a dark grey siltstone was deposited that was continually burrowed and churned by organisms. Continued deepening of the basin created an environment conducive to the development of turbidite sequences. Siltstones and some graded sandstones showing sole markings and load structures, are characteristic of this unit. To the northeast of Anchorage, regional compression resulted in uplift that provided a source area for conglomerates in late Cretaceous time. Shortly thereafter the whole area underwent some compressional uplift followed by tensional downwarp that formed the Tertiary intermontane trough.

Deposition of the nonmarine Tertiary rocks on an erosional Mesozoic surface occurred rather rapidly. Uplift of both the northwest and southeast flanks of the basin provided sediment source areas for the trough. Though faulting might have been involved in creating source areas, there is no indication of it. The thickness of all Tertiary sedimentary beds are lenticular shaped (Hartman, and others, 1972). The oldest Tertiary sequence includes volcaniclastics and extends from the center of the trough northwest of the Bruin Bay fault toward Iliamna Lake, whereas the younger and thickest sequence is more restricted in aerial extent. It consists of basal congloerate that is overlain by sandstone, siltstone and coal higher in the section. Volcanoclastics are absent. These sedimentary rocks were deposited as regressive fluvial sequences whose source areas were changing as minor tectonic pulses modified the configuration of the sedimentary trough.

Specific Structures

There is indication that the Bruin Bay fault, discussed in the previous section, was active during middle to late Tertiary time (Detterman and Hartsock, 1966). Rocks on the southeast or downthrown side of the fault are steeply dipping to overturned. These beds reverse dip into a syncline and gradually attenuate into an anticline. This anticline is parallel to the fault trace between Chenik Lake and the Iniskin Peninsula. The information on the Border Ranges fault to the southeast is presently insufficient to know whether associated structures lie offshore. The oil producing structures in the upper Cook Inlet are asymmetrical, faulted, northeast-trending compressional anticlines. These structures can only be mapped with reflection seismic data. This type of structures may be present in Lower Cook Inlet, but this is unknown. Seismic data acquired this summer (1975) should help answer this question.

PETROLEUM GEOLOGY

Related Hydrocarbon Production

The oil and gas fields in the Upper Cook Inlet lie between Kalgin Island and the Susitna River (fig. 7, page 62) Most of the productive fields are offshore along the northwest side of the Inlet (table 1). Minor onshore production includes the Swanson River oil field and the Beluga and Kenai gas fields. The oil production with some associated gas comes from the lower portion of the late Tertiary cycle, whereas the non-associated gas production comes from the upper portion of this cycle.

The oil fields in the Upper Cook Inlet are as follows: McArthur River, Middle Ground Shoal, Swanson River, Granite Point and Trading Bay. Present cumulative production is about .6 billion barrels of oil. Stratigraphically, 80% of the production comes from the Hemlock Conglomerate, the lowermost unit in the late Tertiary cycle. Much of the remaining 20% comes from the Tyonek Formation which directly overlies the Hemlock Conglomerate. Less than 2% of the production comes from the West Foreland Formation of the oldest Tertiary cycle.

The non-associated gas production comes from the following gas fields: Kenai, North Cook Inlet, Beluga River and other small fields. Most of the production comes from the Beluga and Sterling Formations which are in the upper part of the late Tertiary cycle. Other older units produce minor amounts of non-associated gas. Presumably the bulk of this gas is biogenic or bacterial degradation of the organic matter in the coal deposits found in these units.

TABLE 1

OIL AND GAS FIELDS

UPPER COOK INLET

To Dec. 31, 1974

OIL

(Associated gas not included)

Field	Cum Prod. (000 bbl.)	Reserves API & AGA (000 bbl)	Total (000 bbl.)
McArthur River	253,341	249,660	503,001
Middle Ground Shoal	87,663	97,836	185,499
Swanson River*	154,322	68,878	223,200
Granite Point	56,136	53,864	110,000
Trading Bay	56,449		56,449

GAS

(Associated condensate not included)

Field	Cum. Prod. ($X10^9$ CF)	Reserves API & AGA ($X10^9$CF)	Total ($X10^9$ CF)
Kenai*	565	2,461	3,023
North Cook Inlet	222	979	1,201
Beluga River*	28	972	1,000

*onshore fields

API and AGA reveal reserves, productive capacity of big U.S. fields, April 21, 1975, Oil and Gas Journal pg. 40-41.

Probability of Hydrocarbon Accumulations

Hydrocarbon Model-- The necessary ingredients required to create a commercial oil and/or gas field are as follows: 1) source rock, 2) reservoir rock and 3) cap rock and 4) trap. These items not only have to be present, but they have to be put together in time and space to allow hydrocarbons to be generated from the source rock, then migrate through a conduit to some obstruction or trap, and accumulate in a reservoir in sufficient quantities to be commercial. The reservoir must have adequate porosity and permeability. Each of these parameters will be discussed separately as it relates to the Lower Cook Inlet OCS area.

Source rocks.-- The potential but undocumented source rocks that might contain enough organic material to be source beds are the Triassic, Upper Jurassic, and Upper Cretaceous rocks for oil and associated gas, and the Tertiary rocks for non-associated gas. Of these potential source rocks, the Triassic is the least likely. It is highly altered northwest of the Bruin Bay fault, and where it is unaltered in Puale Bay on the Alaskan Peninsula, it is too far south to project into the OCS area. Also the Triassic rocks underlie the volcanics and volcaniclastics of the Talkeetna Fromation, making it difficult for any generated hydrocarbons to migrate into the younger and shallower reservoir units. The Upper Jurassic source rock is the Chinitna Formation, a dark grey marine siltstone. The Kaguyak Formation is the Upper Cretaceous source rock. The Tertiary coals, some of which are present on Cape Douglas, are potential source rocks for non-associated gas.

Thermal history.-- The generation of hydrocarbons from a source rock with sufficient organic quantity requires heat over a sufficient period of time (Hood, and others, 1975). Sediments generally undergo an increase in temperature for many reasons but two possibilities in this area are as follows. First, there is probably an increase in geothermal gradient from the Upper Cook Inlet Tertiary province to a predominantly Mesozoic province in Lower Cook Inlet. Second, the proximity of intrusive and extrusive volcanics may locally affect the country rock as in the Cape Douglas area. A cumulative thickness of over 7600 m for Mesozoic and Tertiary units seems to be sufficient reason to suggest maturity for some of these source rocks.

Reservoir Rocks.-- Exposed reservoir beds are restricted to the Upper Jurassic, Lower Cretaceous, and Upper Cretaceous rocks and the Tertiary conglomerates. At the mouth of Douglas River and on Augustine Island, the Upper Jurassic Naknek Formation is friable and porous enough to be an adequate reservoir or migration conduit.

The basal sandstone of the Lower Cretaceous crops out in Kayugak Bay and in the Kamishak Hills, and it appears to have sufficient porosity. This unit probably is present in the subsurface under OCS waters.

The Upper Cretaceous Kaguyak Formation is of questionable reservoir quality in outcrop. The upper 610 m of this unit consists of deep water turbidite sandstones and siltstones. A high clay content is suspected but similar turbidite sandstones are productive in the Ventura basin in Southern California.

Cap Rocks-- Cap rocks are important for both migration paths and traps. Lithogically a cap rock is any strata impervious to the flow of hydrocarbons, but generally it is restricted to siltstone and shale. In this area a cap rock is difficult to designate because there are too few wells in the Mesozoic to indicate subsurface physical characteristics, and surface exposures generally are altered significantly by weathering. Most of the strata in this area can be considered cap rocks except for the potential reservoir rocks mentioned above.

Traps.-- A trap exists when reservoirs and cap rocks occur together in such a way as to obstruct the flow of the hydrocarbons. Generally three categories of traps are considered; 1) structural, 2) stratigraphic and 3) combination. Presently there is insufficient data to know what types of traps are present in the OCS area, but faulted anticlinal traps similar to those in Upper Cook Inlet may exist in Lower Cook Inlet. The Lower Cretaceous rocks may form potential stratigraphic traps locally because these beds probably are regionally truncated by the Upper Cretaceous rocks. Also possible are combination traps that are neither purely stratigraphic nor structural.

Timing.-- Timing is of great importance to the accumulation of commercial quantities of hydrocarbons. If a trap forms after hydrocarbons have migrated through an area, there is no chance for an accumulation. A significant amount of work remains to be done on this parameter, but if the timing in the Upper Cook Inlet is similar to this area, there is reason to believe that structures, if present, developed prior to hydrocarbon migration.

Hydrocarbon indications.-- Indications of oil and gas in the Lower Cook Inlet are sparse but significant. The North Fork field, located about 10 miles north of Homer is the best indication of subsurface oil and gas in the Tertiary rocks. This field consists of one shut-in gas well, but some oil was recovered from the basal sandstone, probably equivalent to the Hemlock Conglomerate. On the Iniskin Peninsula a few wells have been drilled into the Jurassic rocks and indications of oil and gas in the Middle and Upper Jurassic beds were reported.

Surface indications of oil and gas are restricted to the Jurassic rocks on the Iniskin Peninsula (Detterman and Hartsock, 1966) and Kamishak Bay area (Miller and others, 1959). The rocks of Jurassic age at the mouth of the Douglas River in the Kamishak Bay area smell of oil.

Summary.-- Available data suggests there is a good possibility that commercial quantities of hydrocarbons are present in Lower Cook Inlet. Oil and gas are produced in Upper Cook Inlet from rock units that are also present in Lower Cook Inlet. Surface and subsurface indications of hydrocarbons are sparse and widely scattered in the Mesozoic and Tertiary rocks. Source, reservoir and cap rocks probably are present. The stratigraphic column is sufficiently thick to generate hydrocarbons, and structures were possibly formed early enough to trap migrating oil and gas. Additional work must be done to define these parameters more precisely, but presently the Lower Cook Inlet OCS should be regarded with optimism.

Selected References

Adkison, W. L., and Newman, K. R., 1973, Lithologic characteristics and palynology of Upper Cretaceous and Tertiary rocks in the Deep Creek Unit well, Kenai Peninsula, Alaska: U. S. Geol. Survey open-file report, 271 p.

Alaska, State of, 1974, Annual report: Department of Natural Resources, Division of Oil and Gas, Anchorage, 31p.

API and AGI reveal reserves, productive capacity of big U.S. fields, April, 1975: Oil & Gas Journal pgs. 40-41.

Beikman, H. M., compiler, 1974, Preliminary geologic map of the southwest quadrant of Alaska: U.S. Geol. Survey Misc. Field Studies Map MF-611, scale 1:1,000,000.

________1974, Preliminary geologic map of the southeast quadrant of Alaska: U.S. Geol. Survey Misc. Field Studies Map MF-612, scale 1:1,000,000.

Blasko, D. P., 1974, Natural gas fields -- Cook Inlet basin, Alaska: U.S. Bur. Mines open-file report 35-74, 24 p.

Blasko, D. P., Wenger, W. J., and Morris, J. C., 1972, Oilfields and crude oil characteristics, Cook Inlet basin, Alaska: U.S. Bur. of Mines Rept. of Inv. 7688, 25 p.

Calderwood, K. W., and Fackler, W. C., 1972, Proposed stratigraphic nomenclature for Kenai Group, Cook Inlet Basin, Alaska: Am. Assoc. Petroleum Geologists Bull., v. 56, no. 4, p. 739-754. (Reprinted for private circulation).

Carter, R. D., and Adkison, W. L., 1972, Correlation of Subsurface Tertiary rocks, Cook Inlet Basin, Alaska: U.S. Geol. Survey open-file report.

Crick, R. W., 1971, Potential petroleum reserves, Cook Inlet, Alaska, _in_ Future petroleum provinces of the United States -- their geology and potential: Am. Assoc. Petroleum Geologists Mem. 15, v. 1, p. 109-119.

Detterman, R. L., 1973, Geologic map of the Iliamna B-2 quadrangle, Augustine Island, Alaska: U.S. Geol. Survey, Geol. Quad. Map GQ-1068.

Detterman, R. L., and Hartsock, J. K., 1966, Geology of the Iniskin-Tuxedni Region, Alaska: U.S. Geol. Survey Prof. Paper 512, 78p.

Detterman, R. L., and Jones, D. L., 1974, Geologic notes, Mesozoic fossils from Augustine Island, Cook Inlet, Alaska: Am. Assoc. Petroleum Geologists Bull., v. 58, no. 5, p. 868-876.

Detterman, R. L., Reed, B. L., 1964, Preliminary map of the geology of the Iliamna Quadrangle, Alaska: U.S. Geol. Survey Misc. Geologic Inv. Map I-407, scale 1:250,000.

Detterman, R. L., and Reed, B. L., 1973 (1974), Surficial deposits of the Iliamna quadrangle, Alaska: U.S. Geol. Survey Bull. 1368-A, p. A1-A64.

Detterman, R. L., Reed, B. L., and Lanphere, M. A., 1965, Jurassic plutonism in the Cook Inlet region, Alaska, _in_ Geological Survey research 1965: U.S. Geol. Survey Prof. Paper 525-D, p. D16-D21.

Gates, G. O., Grantz, Arthur, and Patton, W. W., Jr., 1968, Geology and natural gas and oil resources of Alaska, _in_ B. W. Beebe and B. F. Curtis, eds., Natural gases of North America: Am. Assoc. Petroleum Geologists Mem. 9, v. 1, p. 3-48.

Grantz, Arthur, Zietz, Isidore, and Andreasen, G. E., 1963, An aeromagnetic reconnaissance of the Cook Inlet area, Alaska: U.S. Geol. Survey Prof. Paper 316-G, p. 117-134.

Hartman, D. C., Pessel, G. H., and McGee, D. L., 1972. Preliminary report on stratigraphy of Kenai Group, Upper Cook Inlet, Alaska: Div. of Geol. Survey, Dept. of Nat. Res., State of Alaska, Special Report 5.

Hood, A., Gutjahr, C. C. M., and R. L. Heacock, 1975, Organic metamorphism and the generation of petroleum, Am. Assoc. Petroleum Geologists, v. 59, no. 6, p. 986-996.

Imlay, R. W., and Detterman, R. L., 1973, Jurassic paleobiogeography of Alaska: U.S. Geol. Survey Prof. Paper 801, 34 p.

Jones, D. L., 1963, Upper Cretaceous (Campanian and Maestrichtian) Ammonites from Southern Alaska: U.S. Geol. Survey Prof. Paper. 432, 53 p. 41 Illus.

Jones, D. L., and Clark, S. H. B., 1973, Upper Cretaceous (Maestrichtian) fossils from the Kenai-Chugach Mountains, Kodiak and Shumagin Islands, southern Alaska: Jour. Research U.S. Geol. Survey, v. 1, no. 2, p. 125-136.

Jones, D. L., and Detterman, R. L., 1966, Cretaceous stratigraphy of the Kamishak Hills, Alaska Peninsula: U.S. Geol. Survey Prof. Paper 550-D, p. D53-D58.

Keller, A. and Reiser, H. N., 1959, Geology of the Mount Katmai area, Alaska: U.S. Geol. Survey Bull. 1058-G p. 261-298.

Kelley, J. S., 1973, Preliminary study of the heavy minerals from cores of Tertiary rocks in the Deep Creek Unit well, Kenai Peninsula, Alaska: U.S. Geol. Survey open-file report, 9 p.

Kellum, L. B., 1945, Jurassic stratigraphy of Alaska and petroleum exploration in northwest America: New York Acad. Sci. Trans., ser. 2, v. 7, no. 8, p. 201-209.

Kirschner, C. E., and Lyon, C. A., 1973, Stratigraphic and tectonic development of Cook Inlet petroleum province, in Arctic geology: Am. Assoc. Petroleum Geologists Mem. 19, p. 396-407.

Kirschner, C. E., and Minard, D. L., 1949, Geology of the Iniskin Peninsula, Alaska: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 95, scale 1:48,000.

Klein, R. M., Lyle, W. M., Dobey, P. L., O'Conner, D. M., 1974, Energy & mineral resources of Alaska & the impact of federal land policies on their availability: State of Alaska, Dept. of Nat. Res., Div. of Geol. & Geophy. Surveys, Energy Res. Sect. open-file report 50, 24 p.

Laughbaum, G. H., Jr., Chm., and others, 1970, Oil and Gas Fields in the Cook Inlet Basin, Alaska; Geol. Soc. Alaska, 84 p.

MacKevett, E. M., Jr., and Plafker, George, 1974; The border ranges fault in south-central Alaska: Jour. Research U.S. Geol. Survey, v. 2, no. 3, p. 323-329.

Maher, J. C. and Trollman, W. M., 1969, Geological literature on the Cook Inlet basin and vicinity, Alaska: State of Alaska, Department of Natural Resources in cooperation with the U. S. Geol. Survey, 82 p.

Martin, G. C., Johnson, B. L., and Grant, U.S. 1915, Geology and mineral resources of Kenai Peninsula, Alaska: U.S. Geol. Survey Bull. 587, p. 38-118.

Martin, G. C. and Katz, F. J., 1912, A Geologic reconnaissance of the Iliamna region, Alaska; U.S. Geol. Survey Bull. 485, 138 p.

Mather, K. F., 1923, Mineral resources of the Kamishak Bay region (Alaska): U.S. Geol. Survey Bull. 773, p. 159-182.

Miller, B. M., and others, 1975, Geologic estimates of undiscovered recoverable oil and gas resources in the United States: U.S. Geol. Survey Circular 725, 78 p.

Miller, D. J., Payne, T. G., and Gryc, George, 1959, Geology of possible petroleum provinces in Alaska, with an annotated bibliography by E. H. Cobb: U.S. Geol. Survey Bull. 1094, 131 p.

Reed, B. L., and Lanphere, M. A., 1969, Age and chemistry of Mesozoic and Tertiary plutonic rocks in south-central Alaska: Geol. Soc. America Bull., v. 80, no. 1, p. 23-43.

________1973, Plutonic rocks of Alaska-Aleutian range batholith, in Arctic geology: Am. Assoc. Petroleum Geologists Mem. 19, p. 421-428.

________1974, Chemical variations across the Alaska-Aleutian Range batholith: U.S. Geol. Survey, Jour. Research v. 2, p. 343-352.

Stanton, T. W., and Martin, G. C., 1905, Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull, v. 16, p. 391-410.

RESOURCE APPRAISAL ESTIMATE

Appraisal Procedure

The proposed federal lease sale area (fig. 1) lies within the total Cook Inlet province which was evaluated recently in a U. S. Geological Survey study of the Nation's resources (Miller and others, 1975). All of the proposed lease sale area is in less than 200 m of water and it contains about 5600 square km.

The appraisal procedure for any province consists of: 1) data assembly; 2) preliminary resource appraisals by individuals and groups, considering volumetric-yield procedures, basin analysis, Hendricks' potential-area categories, and documented appraisals; 3) computation of the probability distribution by computer fitting of lognormal curves to the low, high, and modal values of preliminary appraisals of the Resource Appraisal Group.

Data Assembly

The estimates given below are based on data obtained from U.S. Geological Survey geologists, published references, and unpublished U.S. Geological Survey materials. The geology as relates to the petroleum potential of the Cook Inlet province is discussed earlier in this report. For resource appraisal purposes, geologic data were summarized on data format sheets which contained an inventory of information sources and categorized the basic geology and pertinent exploration, production, and resource data. The data formats were reviewed by Resource Appraisal Group and other U.S. Geological Survey personnel, with emphasis on accuracy of planimetered areal measurements, thickness and volume of sediments, and selection of realistic geologic analogs and yield values.

Data format information for onshore and offshore Cook Inlet province was summarized on single-page data summary sheets (Form 3, page 34) to facilitate data handling during resource appraisal.

Appraisal Methods

Several resource appraisal methods were applied to the overall Cook Inlet Province utilizing the information given in the data summary sheets. The total onshore and total offshore parts of the province were appraised separately. The offshore part was treated both independently and in reference to the onshore.

A series of geological and volumetric-yield analog procedures was applied to determine a range of oil and gas yield values. Geologic analogs can be considered as only approximately analogous, and those for which volumetric yield data were available were limited to the United States and Canada. Those analogs selected for offshore Cook Inlet were the Ventura Basin, California, considered similar in tectonic setting, and the McAlester Basin, Oklahoma, with somewhat similar rock types and thickness. Onshore Cook Inlet was also used as an analog during the appraisal procedure. Only rock volumes above the depth of 9,144 m were considered.

In addition to the volumetric-analog method, a series of Hendricks' productive-area categories was calculated for each commodity on the basis of province area. Finally, all published and documented resource appraisal estimates were compiled on a summary form (Form 4A, Page 37) along with all of the estimates calculated by the methods discussed above.

A comprehensive review of all the above information was made by a Resource Appraisal Group geologist, who then, assuming the existence of oil and gas in commercial quantities in the province, made an initial resource appraisal by a subjective probability technique as follows:

1. A low resource estimate corresponding to a 95 percent probability (19 in 20 chances) that there is at least that amount present.
2. A high resource estimate with a 5 percent probability (1 in 20 chance) that there is at least that amount present.

3. A modal estimate of the resource which the estimator associates with the highest probability of occurrence that there will be that amount.
4. A statistical mean which is calculated by adding the low value, the high value, and the modal value and dividing the sum by 3.

These estimates were recorded on the resource appraisal summary sheets (Form 4) for use in the final evaluation.

The final figures determined by Resource Appraisal Group for the low (95 percent), high (5 percent), mode, and calculated mean were considered preliminary estimates which were statistically analyzed as discussed below.

Methodology for Processing Probabilistic Assessments

The procedures described for estimating the undiscovered oil and gas for the Cook Inlet province involve subjective probabilities (Raiffa, 1968). Subjective judgments were made for the province as percentile assessments limited to quantities associated with the 5 and 95 percent range. These moderate intervals were selected to realistically account for at least 90 percent of the range of the probable undiscovered oil and gas resources. Also included were the assessment of a modal value and a calculated statistical mean.

A lognormal distribution was fitted by computer program (Kaufman 1962) to the high, low, and modal value of the Resource Appraisal Group's assessments to compute the probability distribution for each province. Lognormal curves for oil and gas (fig. 3 and 4) were generated for the full range of probability values. Higher or lower estimates than those within the 5 and 95 percent probability range can be read from the curve. For instance, the 1 percent (1 in 100 chance) probability value for oil in figure 3 is about 4 billion barrels.

OIL

Pacific Margin
Total Cook Inlet Offshore

(0-200M.)

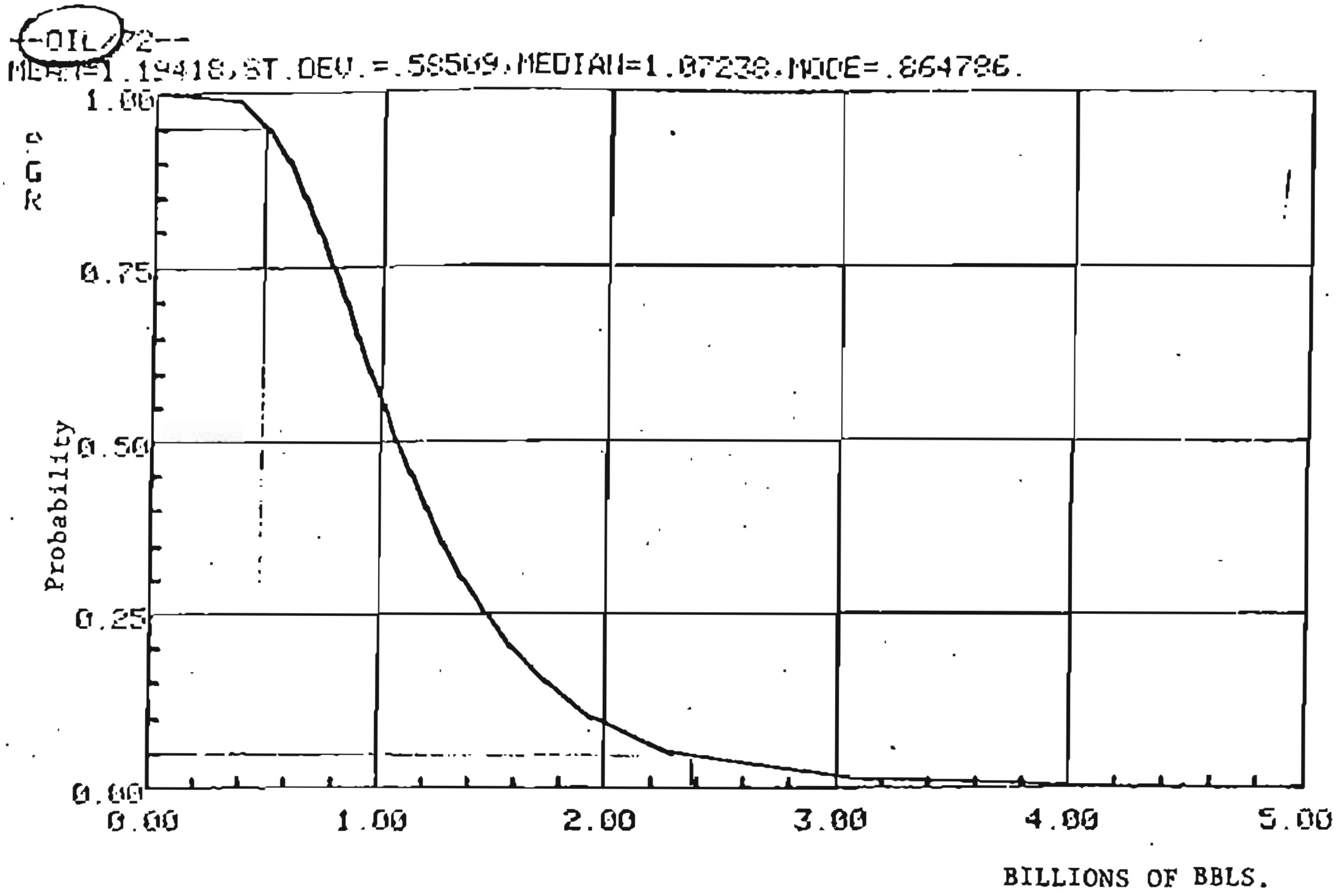


Figure 3.--Lognormal distribution curve showing probability values for oil in total offshore Cook Inlet province.

GAS

Pacific Margin
Total Cook Inlet Offshore

(0-200M.)

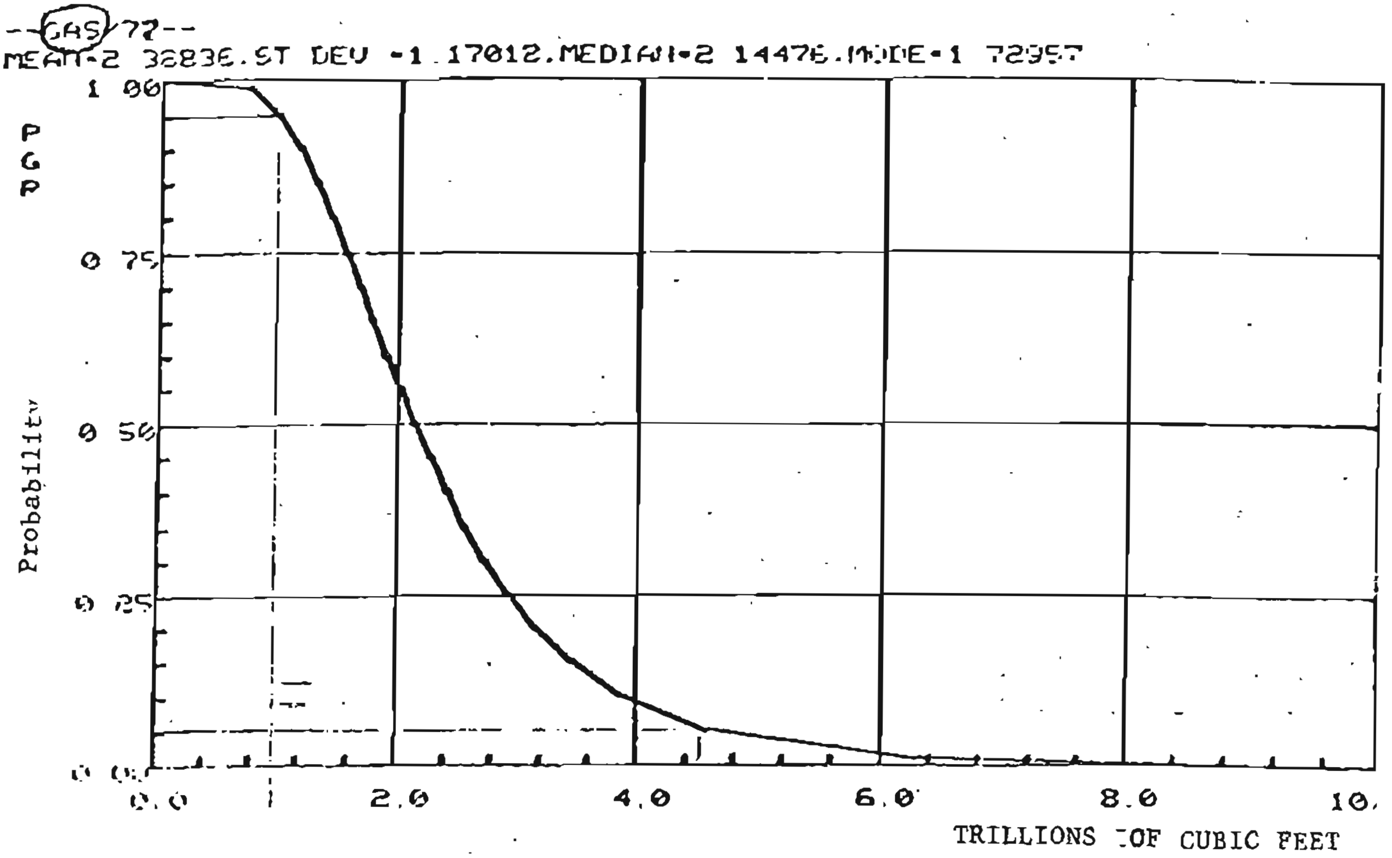


Figure 4.--Lognormal distribution curve showing probability values for natural gas in total offshore Cook Inlet province.

Proposed Lease Sale Area Appraisal

The proposed Federal OCS lease sale area comprises about 5,600 square km and contains about 64,400 cubic km of prospective sedimentary rock above 10,000 m depth. The proposed OCS lease sale area has about 60 percent of the rock volume of the total Cook Inlet province offshore (Upper and Lower Cook Inlet State and Federal waters). Undiscovered recoverable resources of the total Cook Inlet Province offshore were estimated to be:

Total Cook Inlet Province Offshore
Undiscovered Recoverable Resources

	95%	5%	Statistical mean
Oil (billions of barrels)	0.5	2.4	1.2
Gas (trillion cubic feet)	1.0	4.5	2.4

Extrapolation of the volumetric-yield data derived from the above total Cook Inlet offshore figures to the proposed OCS lease sale area, indicates the resource estimates for the Lower Cook Inlet lease area to be:

Proposed OCS Lease Sale Area, Lower Cook Inlet
Undiscovered Recoverable Resources

	95%	5%	Statistical mean
Oil (billions of barrels)	0.3	1.4	0.7
Gas (trillion cubic feet)	0.6	2.7	1.4

Additional hydrocarbons, occurring as natural gas liquids (NGL), might be anticipated in Lower Cook Inlet if large quantities of natural gas are present. Data do not permit direct estimation of these liquids in Lower Cook Inlet, however the NGL/gas production ratio in the Upper Cook Inlet is approximately 0.4 barrels of NGL for each million cubic feet of gas produced.

The appraisals made for the Cook Inlet Province in the recent U.S. Geological Survey study considered the prospective rocks in the province to be of Jurassic and Tertiary ages only. However, an additional 1600 m of prospective Cretaceous rocks is probably present under Cook Inlet (L.B. Magoon, Unpublished data 1975). The Cretaceous rocks, about which little is known at this time, are thought to comprise considerably less volume than the Jurassic and Tertiary rocks, but may have significant unassessed potential.

In calculating the appraisal figures used in this report, the volumetric yield factors for the entire offshore Cook Inlet area derived during the recent study were used, but were applied to rock volumes which included the Cretaceous section.

REFERENCES CITED

Miller, B.M., Thomsen, H.L., Dolton, G.L., Coury, A.B., Hendricks, T.A., Lennartz, F.E., Powers, R.B., Sab.e, E.G., and Varnes, K.L., 1975, Geological estimates of undiscovered recoverable oil and gas resources in the United States: U.S. Geol. Survey Circ. 725, 78 p.

Kaufman, G.M., 1962, Statistical decision and related techniques in oil and gas exploration: Harvard Univ., Ph.d. diss.

Raiffa, Howard, 1968, Decision analysis--introductory lectures on choices under uncertainty: Addison-Wesley, Reading, Mass., 300 p.

1975 FEA REPORT

FORM #3

ALL IS < 200 M WATER

Region 1 OFFSHORE
RAG No.

PROVINCE SUMMARY SHEET

PROVINCE COOK INLET PROVINCE - TERTIARY (MAGOON)

*Stage of Exploration: Early ✓ Intermediate SOME ✓ Late
*Area (MI^2)-----Total Sed. Province: (6728) 12641 % Productive .005 (41%
Areas by Depth Units: 5000' 2654 5000-10,000' 957
10,000'-15,000' 1301 15,000-20,000' 1029
20,000'-30,000' 787 30,000'

*Thickness of sediments (Ft.): Avg. 10,058' (1.905) Max. 25,000'

*Volume of sediments (MI.^{3})
Total Province: (12,817 mi.^{3} -T) 24,239 mi^3 TOTAL
% Drilled. 25% } J & T
% Explored 40%

Stratigraphic Age Range: From PERMO-TRIAS Through HOLOCENE

*Producing and/or Prospective Horizons (oil) (oil)
Age: a. Oligo-Mio (gas) b. Mio-Plio c. Pliocene d.
Gross Thickness: 500 6000 6000 Total: 12,500
HEMLOCK TYONEK BELUGA-STERLING

*Dominant Lithology (Total Province)
Type Ss/Silt. Coal Carb. Ss
% of Volume 70% 10% 20%
Ratio, Marine/non-marine 3:5

Types of Traps
Stratigraphic NONE.
Structural CLOSED ANTICLINES w/ SOME FAULTS (ILIAMNA)

*Structural Aspects
Type Basin INTERMONTANE WITHIN UNSTABLE COASTAL MARGIN
Geometry SYNCLINAL, GENTLE SLOPES

Indications of Hydrocarbons ✓
Producing Trends 2 GAS 2 OIL TRENDS.
Seeps, Tar Sands, etc. OIL SEEPS, MANY. O & G SHOWS IN SECTION

Probable Source Beds (Age and Lithology) M-LATE JURASSIC SILTSTONE W/SS.

Major Seals (Age and Lithology) EOCENE-PLIOCENE SILTSTONE

Field Size Distribution: ONSHORE + OFFSHORE

	Avg.	R.Min.	R.Max.
Oil (mill.bbls):	540 million	372 mill.	647 mill.
Gas (bcf):	210 Billion	20 Bill.	2,400 Bill.

Nature of Hydrocarbons:	Avg.	R.Min.	R. Max.
API Gravity	35.7°	29.7°	44°
Sulfur Content	0.08 WT.%	0.02 WT.%	0.15 WT.%
*Recovery Factor	36%	30%	40%

*Production, Reserves, & Resources:	Crude Oil	NGL	Nat. Gas
Cum. Production (bill.bbls.; tcf)	0.394 Bo	0.003 Bbls	0.3931
Measured Reserves "	0.2120 "	—	1.561
Indicated Reserves "	0.0288 "	—	—
Inferred Reserves (.61 × .2120) =	0.1310 "	—	(.46 × 1.561) = 0.722

*Wells Drilled to Date: Date: 11/1/74
Exploratory Wells 165
Development Wells 296

*Resource Estimates (Undiscovered--In Billion BBLS ~~or~~ AND Trillion Cu.Ft.)
Recovered: 46% = 5,300 IP. | 9.734 × 10^{12} IP (Recoverable (In Place)
Outside Sources NPC-15: 7.9 × 10^9 oil 14.6 × 10^{12} gas (ALASKA SD) 2/1 × 10^9 OIL NO GAS FIG.
U.S.G.S. Evaluator 1.05 × 10^9 BO - NO GAS EVALUATION
Analogs VENTURA BASIN, UINTA BASIN
RAG Estimate

*Province Qualitative Rating: Oil Gas

Posted by: POWERS Date 3/12/75 Approved ✓ Date 3/13

---

* Data most pertinent to resource appraisals. 2/4/75

FORM # 4-A T.

#1 ALL < 200 M

19[illegible] RESOURCE APPRAISAL REPORT — PROVINCE ESTIMATE

Region ONE, OFFSHORE (66%) RAC No. /

Province COOK INLET - TERTIARY

Province Area 12,641 {6728 = TERTIARY
5913 = JURASSIC} (mi²) Province Volume: 26,239 {12,817 = TERT
13,422 = J} (mi³)

* J ESTIMATES ARE WRITTEN ON THIS SHEET

PRODUCTION AND RESERVES	OIL (Bill. BBLS)	NGL (Bill. BBLS)	GAS (TCF)
Cumulative Production:	0.3940	0.003	0.3931
Identified Reserves:		—	
Measured Reserves	0. 2120	—	1.561
Indicated Reserves	0. 0288	—	—
Inferred Reserves	0. 731 (used .618 Petrol)	—	0.722 (Used .463 Fac)
Total (Cumulative & Identified):	0. 766	0. 009	2.676

UNDISCOVERED RESOURCES Resource Appraisal Methods		OIL (Billion Barrels)			NGL (Billion Barrels)			GAS (Trillion Cubic Feet)		
		In-Place	Total Rec. Resource	Undiscovered Rec. Resource	In-Place	Total Rec. Resource	Undiscovered Rec. Resource	In-Place	Total Rec. Resource	Undiscovered Rec. Resource
METHOD I--VOLUMETRIC-ANALOG Analog 1: McALESTER / Analog 2: VENTURA Yield Factors: Oil: 80,000 B/mi³ / 176,000 B/mi³ Gas: 275,000 mil cf/mi³ / 170.200 mil cf/mi³	1.		2.099	1.339					7.215	4.539
Rec. Factors:	2.		4.618	3.882					4.482	1.806
METHOD IV: HENDRICKS' CATEGORIES Dis.-Rec. Factors: 20/40/40	Category #: 2	9.390	1.578	1.112	0.751	0.300	0.297	28.170	11.268	2.592
	Category #: 3	2.347	0.469	- 0 -	0.187	0.075	0.072	4.695	1.878	- 0 -
METHOD: ( ) Yield Factors: Oil: Gas: Prod.Area/Unexpl.Area:										
DOCUMENTED RESOURCE APPRAISAL ESTIMATES:			USE .96 Rec.						Using .80 Recov	
AAPG, Memoir 15, 1971 PRORATED 66% of 7900		5.292	1.906	1.139				9.773	7.818	5.142
KLEIN, ALASKA #50 (1974) PRORATED (36% REC.)				2.301						NO DATA
National Petroleum Council Estimates, 1973 PRORATED		4.257	1.533	0.767						
ANOCRE Estimates										
OTHER MAGOON —				1.05						NO DATA

Posted by POWERS Date 3/15/75 Approved ✓ Date 3/17/75

DOCUMENTATION FOR RESOURCE APPRAISAL METHODS USED ON FORM 4-A

METHOD I
Volumetric - Analog

Analog I

Basin or Province Name: McAlester

Yield factors used:
OIL 50,000 GAS 275 pca

Recovery factors used:
70/40/40

Analog II

Basin or Province Name: Va

Yield factors used:
OIL 17,000 GAS 170,800 NGL

Recovery factors used:
70/40/40

METHOD II
Explored Area - Recovery Procedures

Areas Explored:
1.
2.
3.

Areas Unexplored:
1.
2.
3.

Yield per mi^2 of explored areas:
1.
2.
3.

METHOD III
Productive Area - Recovery Procedure

Areas Productive (proved areas):
1.
2.
3.

Areas Unexplored:
1.
2.
3.

Yield per mi^2 of productive areas:
1.
2.
3.

METHOD IV
Hendricks' Categories

Category # 2

Discovery-Recovery Factors:
30/90/90

Modifications:

Category # 3

Discovery-Recovery Factors:
30/90/90

Modifications:

AAPG, Memoir 15, 1971: Tables: Pages:
NPC Estimates, 1973: Tables: Pages:
ANCORE Estimates:
Other Published Sources: Date: Pages:
Other Procedures:

1975 FEA REPORT

DEFINITIONS FOR RESOURCE APPRAISAL METHODS USED ON FORM 4-B

REASONABLE MINIMUM -- That quantity which the estimator associates with a 95% probability that there is at least this amount.

MOST LIKELY -- That quantity which the estimator associates with the highest probability (of occurrence) that there will be this amount.

REASONABLE MAXIMUM -- That quantity which the estimator associates with a 5% probability that there is at least this amount.

EXPECTATION --Also called "EXPECTED VALUE" or "BEST ESTIMATE" -- A mathematical term. It is the only value we are entitled to add if we combine estimates of similar quantities in other provinces.

$$E = \frac{R.\ Min. + M.\ L. + R.\ Max.}{3} = \frac{50 + 300 + 850}{3} = 400$$

MARGINAL PROBABILITY -- That probability which the estimator would assign to his basic assumptions that oil and gas accumulations are actually present in the province to be evaluated.

FORM # 4-B

Region Q
Province Cook Inlet {6724±T
Province Area 12641 }5913±5 (mi²)
Province Volume: 26239 }12,4122 T (mi³)
{17422-0

RAG No.

RESOURCE APPRAISAL --PROVINCE ESTIMATE

1975 FEA REPORT

PRODUCTION AND RESERVES	OIL (Bill. BBLS)	NGL (Bill. BBLS)	GAS (TCF)
Total (Cumulative & Identified)	0.766	0.003	2.676

REGIONAL REPRESENTATIVE Resource Appraisal	OIL (Billion Barrels) In-Place	OIL Total Rec. Resource	OIL Undiscovered Rec. Resource	NGL (Billion Barrels) In-Place	NGL Total Rec. Resource	NGL Undiscovered Rec. Resource	GAS (Trillion Cubic Feet) In-Place	GAS Total Rec. Resource	GAS Undiscovered Rec. Resource
a. Reasonable Min. (95% "at least")			0.500						2.5
b. Reasonable Max. (5% "at least")			3.5						6.5
c. Most Likely			2.0						4.0
d. Expectation: (a + b + c)/3			2.0						4.3
Method:									
Rec.--Yield Factors:									
Classify: Hypothetical __ Speculative X									

Posted by Powers Date 3/18/75

RESOURCE APPRAISAL GROUP Recommended Appraisal:	OIL In-Place	OIL Total Rec. Resource	OIL Undiscovered Rec. Resource	NGL In-Place	NGL Total Rec. Resource	NGL Undiscovered Rec. Resource	GAS In-Place	GAS Total Rec. Resource	GAS Undiscovered Rec. Resource
a. Reasonable Min. (95% "at least")	6.3	1.266	0.5				9.19	3.676	1.0
b. Reasonable Max. (5% "at least")	15.33	3.066	2.3				18.19	7.276	4.6
c. Most Likely	8.83	1.766	1.0				11.69	4.676	2.0
d. Expectation: (a + b + c)/3	10.33	2.066	1.3				12.94	5.176	2.5
Method:									
Rec.--Yield Factors: 20/40									
Marginal Probability:									

Posted by Powers Date 3/18/75 Approved ✓ Date
KC 7/9/75

FORM #3

1976 FEA REPORT

Region 1 OFFSHORE,
RAG No.

PROVINCE SUMMARY SHEET

PROVINCE COOK INLET PROVINCE - JURASSIC

*Stage of Exploration: Early ✓ Intermediate Late
*Area (MI^2)-----Total Sed. Province: 5913 % Productive - 0 -
Areas by Depth Units: 5000' 5000-10,000'
10,000'-15,000' NO 15,000-20,000' DATA
20,000'-30,000' 30,000'

*Thickness of sediments (Ft.): Avg. 12,000' Max. 20,000+

*Volume of sediments ($MI.^3$)
Total Province: 13,422
% Drilled - 0 -
% Explored - 0 -

Stratigraphic Age Range: From M. JURASSIC Through LOWER CRETACEOUS

*Producing and/or Prospective Horizons
Age: a. U. JURAS b. c. d.
Gross Thickness: 12,000+ Total: 12,000'

*Dominant Lithology (Total Province)
Type SS/SILT CONGLOM.
% of Volume 90% 10%
Ratio, Marine/non-marine 1:0

Types of Traps
Stratigraphic N. DATA
Structural "

*Structural Aspects
Type Basin UNSTABLE COASTAL (ONOCLINE)
Geometry SYNCLIN.

Indications of Hydrocarbons
Producing Trends - 0 -
Seeps, Tar Sands, etc. IN CRET. & JURAS ROX OUTCROPPING ONSHORE - SEEPS -

Probable Source Beds (Age and Lithology) SILT-SS M-U JURASSIC

Major Seals (Age and Lithology) UNKNOWN

Field Size Distribution: Avg. R.Min. R.Max.
Oil (mill.bbls): NONE
Gas (bcf):

Nature of Hydrocarbons: Avg. R.Min. R. Max.
API Gravity
Sulfur Content
*Recovery Factor NONE

*Production, Reserves, & Resources: Crude Oil NGL Nat. Gas
Cum. Production (bill.bbls.;tcf)
Measured Reserves "
Indicated Reserves " NONE
Inferred Reserves "

*Wells Drilled to Date: NONE Date: 1/1/74
Exploratory Wells
Development Wells

*Resource Estimates (Undiscovered--In Billion BBLS or Trillion Cu.Ft.)
Recoverable In Place
Outside Sources NONE
U.S.G.S. Evaluator NONE
Analogs BIG SNOWY TROUGH, C. MONTANA
RAG Estimate

*Province Qualitative Rating: Oil FAIR Gas FAIR

Posted by: Powers Date 3/12/75 Approved ✓ Date 3/12

* Data most pertinent to resource appraisals. 2/4/75

FORM # 4-A J. *(#2) ALL < 200M

Region ONE. OFFSHORE RAC No.
Province COOK INLET-JURASSIC

RESOURCE APPRAISAL --PROVINCE ESTIMATE 1975 FEA REPORT Province Area 5,913 (mi²) Province Volume: 13,422 (mi³)

PRODUCTION AND RESERVES	OIL (Bill. BBLS)	NGL (Bill. BBLS)	GAS (TCF)
Cumulative Production:			
Identified Reserves:			
Measured Reserves			
Indicated Reserves		None	
Inferred Reserves			
Total (Cumulative & Identified):			

UNDISCOVERED RESOURCES Resource Appraisal Methods	OIL (Billion Barrels)			NGL (Billion Barrels)			GAS (Trillion Cubic Feet)		
	In-Place	Total Rec. Resource	Undiscovered Rec. Resource	In-Place	Total Rec. Resource	Undiscovered Rec. Resource	In-Place	Total Rec. Resource	Undiscovered Rec. Resource
METHOD I--VOLUMETRIC-ANALOG Analog 1: Analog 2:									
Yield Factors: Oil: 1.									
Gas:									
Rec. Factors: 2.									
METHOD IV: HENDRICKS' CATEGORIES Dis.-Rec. Factors: Category #: 3									
Category #: 4									
METHOD: ( ) Yield Factors: Oil: Gas: Prod.Area/Unexpl.Area:									
DOCUMENTED RESOURCE APPRAISAL ESTIMATES: AAPG, Memoir 15, 1971									
National Petroleum Council Estimates,1973									
ANOGRE Estimates									
OTHER									

Posted by ______ Date ______ Approved ______ Date ______

41

DOCUMENTATION FOR RESOURCE APPRAISAL METHODS USED ON FORM 4-A

METHOD I Volumetric - Analog	METHOD II Explored Area - Recovery Procedures	METHOD III Productive Area - Recovery Procedure	METHOD IV Hendricks' Categories
Analog I Basin or Province Name: ____ Yield factors used: OIL ____ GAS ____ NGL ____ Recovery factors used: ____ Analog II Basin or Province Name: ____ Yield factors used: OIL ____ GAS ____ NGL ____ Recovery factors used: ____	Areas Explored: 1. ____ 2. ____ 3. ____ Areas Unexplored: 1. ____ 2. ____ 3. ____ Yield per mi^2 of explored areas: 1. ____ 2. ____ 3. ____	Areas Productive (proved areas): 1. ____ 2. ____ 3. ____ Areas Unexplored: 1. ____ 2. ____ 3. ____ Yield per mi^2 of productive areas: 1. ____ 2. ____ 3. ____	Category # ____ Discovery-Recovery Factors: ____ Modifications: ____ Category # ____ Discovery-Recovery Factors: ____ Modifications: ____

AAPG, Memoir 15, 1971: Tables: ____ Pages: ____

NPC Estimates, 1973: Tables: ____ Pages: ____

ANOGRE Estimates: ____

Other Published Sources: Date: ____ Pages: ____

Other Procedures: ____

1975 FEA REPORT

DEFINITIONS FOR RESOURCE APPRAISAL METHODS USED ON FORM 4-B

REASONABLE MINIMUM -- That quantity which the estimator associates with a 95% probability that there is at least this amount.

MOST LIKELY -- That quantity which the estimator associates with the highest probability (of occurrence) that there will be this amount.

REASONABLE MAXIMUM -- That quantity which the estimator associates with a 5% probability that there is at least this amount.

EXPECTATION --Also called "EXPECTED VALUE" or "BEST ESTIMATE" -- A mathematical term. It is the only value we are entitled to add if we combine estimates of similar quantities in other provinces.

$$E = \frac{\text{R. Min.} + \text{M. L.} + \text{R. Max.}}{3} = \frac{50 + 300 + 850}{3} = 400$$

MARGINAL PROBABILITY -- That probability which the estimator would assign to his basic assumptions that oil and gas accumulations are actually present in the province to be evaluated.

FORM # 4-B

1975 FEA REPORT

1975 FEA REPORT

RESOURCE APPRAISAL --PROVINCE ESTIMATE

Region ______________________ RAG No. ______________
Province ______________________
Province Area ______________________ (mi^2)
Province Volume: ______________________ (mi^3)

PRODUCTION AND RESERVES	OIL (Bill. BBLS)	NGL (Bill. BBLS)	GAS (TCF)
Total (Cumulative & Identified)			

REGIONAL REPRESENTATIVE Resource Appraisal	OIL (Billion Barrels)			NGL (Billion Barrels)			GAS (Trillion Cubic Feet)		
	In-Place	Total Rec. Resource	Undiscovered Rec. Resource	In-Place	Total Rec. Resource	Undiscovered Rec. Resource	In-Place	Total Rec. Resource	Undiscovered Rec. Resource
a. Reasonable Min. (95% "at least")									
b. Reasonable Max. (5% "at least")									
c. Most Likely									
d. Expectation: $\frac{(a+b+c)}{3}$									
Method:									
Rec.--Yield Factors:									
Classify: Hypothetical ___ Speculative ___									

Posted by ______________________ Date ______________

RESOURCE APPRAISAL GROUP Recommended Appraisal:									
a. Reasonable Min. (95% "at least")									
b. Reasonable Max. (5% "at least")									
c. Most Likely									
d. Expectation: $\frac{(a+b+c)}{3}$									
Method:									
Rec.--Yield Factors:									
Marginal Probability: ______									

Posted by ______________________ Date ______________ Approved ______________________ Date ______________

GEOLOGIC HAZARDS

General Statement

The Lower Cook Inlet is in an area with a number of geologic hazards that pose potential problems to future installations within the Inlet and along the adjacent coastline. However, oil and gas exploration, development and production activities have been conducted safely for a number of years in the nearby Upper Cook Inlet, which shares the same general coastal and marine environments. Technology developed for oil and gas activities in Upper Cook Inlet should be applicable to potential geologic hazards of equal, or lesser, severity in the proposed lease sale area. Many of the hazards affecting coastal areas have been well defined by previous studies, but the inaccessibility of the sea floor, within the Inlet itself, has resulted in less detailed knowledge about the problems to be encountered there. Detailed marine geologic studies will be conducted in the Lower Cook Inlet prior to the lease sale to provide a detailed understanding of the potential hazards described below.

Hazards Associated With Seismic Activity

The Gulf of Alaska - The Aleutian region, one of the most seismically active on earth, accounts for about 7% of the world-wide release of seismic energy annually. In the past 65 years, 13 earthquakes of magnitude 6 or greater have occurred within the general lower Cook Inlet area (Table 2). Earthquakes of this size typically produce major structural damage, either directly by ground shaking, fault displacement, and surface warping or indirectly by seismic sea waves (tsunamis), ground failure, and consolidation of sediments.

TABLE 2

Earthquakes in the vicinity of the lower Cook Inlet, 1912 through 1973. Includes earthquakes greater than magnitude 6, whose epicenters lie between 59.00° and 60.50° north latitude and 151.00° and 153.00° west longitude. (Data courtesy of John Lahr and Robert Page, U.S. Geological Survey).

Date Day	Month	Year	Origin Time Hr/Min Gmt.	Latitude (Degrees N.)	Longitude (Degrees W.)	Depth Kilometers	Magnitude
07	06	12	0955	59.00	153.00	0	6.40
10	06	12	1606	59.00	153.00	0	7.00
24	12	31	0340	60.00	152.00	100	6.25
18	06	34	0913	60.50	151.00	80	6.75
11	10	40	0753	59.50	152.00	0	6.00
05	12	42	1428	59.50	152.00	100	6.50
03	10	54	1118	60.50	151.00	100	6.70
24	01	58	2317	60.00	152.00	60	6.38
19	04	59	1503	59.00	152.50	0	6.25
26	12	59	1519	59.74	151.38	0	6.25
24	06	63	0426	59.50	151.70	52	6.80
17	12	68	1202	60.17	152.84	86	6.50
16	01	70	0850	60.31	152.72	91	6.00

Ground Shaking-- Damage from ground shaking is likely to be greatest in areas underlain by thick accumulations of saturated, unconsolidated sediments, rather than in areas underlain by solid bedrock. This is especially true if the frequency of seismic waves is equal to the resonant frequency of the sediment. Within Cook Inlet, Anchorage and Homer experienced major damage due to ground shaking during the 1964 earthquake.

Surface faulting-- The distribution of active surface faults within the Lower Cook Inlet is poorly known. Closely spaced high resolution seismic reflection lines are needed to determine this distribution because structures located across active faults are almost certain to sustain some deformation or damage during major movement.

Surface Warping:--Surface uplift associated with earthquakes can put docks and facilities out of the reach of water, as occurred at Cordova during the 1964 earthquake. Subsidence of coastal areas can cause flooding of land previously above high-tide line. It also makes coastal areas more susceptible to damage by tsunamis than if they had been uplifted or undeformed.

Tsunamis: Seismic sea waves (tsunamis) are generated when large volumes of sea water are displaced, either by tectonic displacement of the sea floor (regional tsunamis) or by large rockfalls or landslides (local tsunamis). Regional tsunamis occur as a train of long-period waves that radiate energy in a pattern that is controlled by the geometry of the source disturbance. They are seldom detectable in the open ocean and build up to significant, destructive heights only close to and along the shoreline.

The narrow, elongate geometry of the Cook Inlet reduces the chances that a tsunamis generated outside the Inlet will propagate significant destructive energy into it. The tsunamis generated by the 1964 earthquake produced damage in the Lower Cook Inlet area at Rocky Bay and Seldovia. It hit most of the west coast of the Lower Inlet, but caused no damage. If a regional tsunamis should be generated within the Inlet, it probably would have little effect in open waters but could produce significant damage along the Inlet Coastline.

Local tsunamis are a particularly dangerous seismic hazard because they strike without warning, during or shortly after an earthquake. They are likely to occur along steep, indented coastlines such as exist along some parts of the Lower Cook Inlet, when unstable rock masses are shaken loose from steep slopes or when submarine landslides occur on unconsolidated alluvial deltas. Local tsunamis can be exceptionally large; a surge wave ran 1740 feet (vertically) up the slopes during the 1958 southeastern Alaska earthquake. Local tsunamis accounted for more loss of life than any other factor in the 1964 earthquake.

Ground failure—Various types of ground failure, both on land and under water, are a major cause of destruction associated with large earthquakes, especially in areas underlain by thick, unconsolidated sediments. Many deltas are especially prone to earthquake-induced liquefaction and sliding because of their loose, water-saturated nature. Local submarine slides during and after the 1964 earthquake caused damage at Homer, Valdez, Seward, Whittier, and other places.

Underwater dispersal of slide sediments can cause physical damage or burial to installations on the sea floor. Burial and breakage of submarine cables has been reported for slides at Valdez and for many large-scale, deep-water submarine slope failures.

Other types of ground failure include rockfalls in steep, precipitous areas, translatory block sliding such as occurred at Anchorage in 1964, nearly horizontal movement of vibration-mobilized soil, and ground fissuring and associated sand extrusions typical of areas where the ground surface is frozen. Extensive subaerial occurrence of all these phenomena has been documented for large earthquakes and are potential problems along the Cook Inlet coastline. Too little is known of the geotechnical properties of bottom sediments to predict the occurrence of ground movement on the floor of the Lower Cook Inlet.

Consolidation--Consolidation of sediments and the resulting ground subsidence, without actual sliding, is another expectable seismic hazard; this heightens the likelihood of extensive flooding along coastal areas and, of course, could possibly cause submergence of affected marine installations. Consolidation of sediments was a significant cause of subsidence along Homer Spit and near the head of Turnagain Arm during the 1964 earthquake.

Hazards Associated With Volcanic Activity

Five active volcanoes are located in the Lower Cook Inlet area, along the southeast margin of the Alaska Peninsula and the Cook Inlet itself. They are: Augustine, Iliamna, Mt. Douglas, Redoubt, and Mt. Spurr (fig. 1). All but Mt. Douglas have erupted in historic time, and all five can be considered likely to erupt in the future. The

Alaskan volcanoes are andesitic and involve relatively violent eruption compared to the basaltic volcanoes of oceanic basins. Augustine is the most active of the group, last erupting in 1964. It is presently building a lava dome in its crater and could erupt at any time.

Some of the potential hazards associated with Alaskan volcanoes are local in their effects, but ash can cause damage up to 100 miles away from the main eruptive center. Eruptive phenomena that could affect Anchorage and the Cook Inlet are eruptions (ejecta, gases, and ash) and lava flows. Secondary phenomena associated with eruptions that could be hazardous are volcanic mudflows and landslides, flash floods, lightening discharges, corrosive rains, earthquakes, and seawaves. All of these phenomena have occurred in Alaska in historic times.

TECHNOLOGY

Requirements

Technology and operational activities for offshore oil and gas exploration and development in the Lower Cook Inlet OCS area will be influenced by the physical and environmental conditions of the area. Some of the more important physical and environmental conditions which will affect design, location of facilities, and operating procedures are briefly described below.

1. Climate, weather and sea conditions will be major factors in the design, emplacement and operation of offshore exploration, production and transportation equipment and facilities.

   The Cook Inlet is in the transitional zone of Alaska and is characterized by pronounced temperature variations throughout the day and year, and frequent cloudiness and medium humidity, precipitation and wind levels (Evans and others, 1972). Table 3 summarizes meteorological data from two stations in the lower part of the Inlet. Climatic conditions and weather expremes will necessitate design for adequate working conditions (heated, insulated, enclosed areas) and will require careful scheduling of such critical activities as emplacement of platforms and pipelines to avoid the extreme conditions of the winter season.

Table 3

METEOROLOGICAL DATA - COOK INLET

	JANUARY					JULY					YEAR							
Station	Temp1/ Min. Avg.	Temp Mean Av.	Temp Max. Avg.	Total2/ Precip.	Snow2/	Temp Min. Avg.	Temp Mean Avg.	Temp Max. Avg.	Total Precip.	Snow	Temp Min. Avg.	Temp Mean Avg.	Temp. Max. Avg.	Total Precip.	Snow	Elev. Feet	Prev. Wind Direct.	Mean Hourly Wind Speed
Homer 1943-1971	14.0	20.7	27.3	1.73	10.4	44.6	52.4	60.2	1.69	0.0	29.2	36.4	43.6	23.08	55.4	67	NE	6.5 mph
Seldovia*	18.1	23.2	28.2	2.3	10.2	48.6	55.8	57.7	1.40	0.0	33.7	41.0	48.2	26.3	50.8	0-30	N	11.5 - 17.5 mph

*Unofficial local records
1/ °F
2/ Inches

Source: Evans et al., 1972

Mean hourly wind speed is moderate, but under extreme conditions, winds of 75 to 100 knots can occur over open water, and storms with 50 to 75 knot winds are experienced nearly every winter (Evans and others, 1972). Waves and sea conditions must be considered, but available information indicates only moderate maximum wave heights compared with other offshore areas undergoing oil and gas development.

The Cook Inlet is noted for its extreme diurnal tidal ranges up to 9.1 m at Anchorage and the resulting high currents reaching a mean maximum velocity of 3.8 knots with peak maximum velocities exceeding 6.5 knots in the Forelands region (Evans and others, 1972). Tidal ranges and accompanying currents are less extreme in the Lower Cook Inlet with a diurnal range of 5.4 m at Seldovia and 4.2 m at the mouth of the Inlet. Table 4 shows the tidal statistics for Seldovia. The turbulence caused by high tides and currents increases difficulty of offshore operations and requires added time and equipment for certain activities, such as anchoring and maintaining position of drilling vessels, laying of pipelines, diving operations, etc.

2. Ice forms in Upper Cook Inlet in the winter months and may cause damage to vessels and structures, and interference with marine traffic and other marine operational activities. Ice Thicknesses of nearly 1 m can be expected during a "normal" year. (Hutcheon, 1972).

Table 4

Tidal Statistics for Seldovia

	Feet
Highest Tide	23.0
Mean High High Water	17.8
Mean High Water	17.0
Mean Tide Level	9.3
Mean Low Water	1.6
Mean Low Low Water	0.0
Lowest Tide	- 5.5
Mean Range	15.4
Diurnal Range	17.8
Extreme Range	28.5

Source: Evans et al., 1972.

Design analysis of oil platforms for the Upper Cook Inlet shows that ice loading is by far the largest force that would be exerted on such a platform and that the forces of wind, waves, and even earthquakes are relatively samll compared with the ice forces (Vissar, 1972).

Generally, ice conditions in the Lower Cook Inlet are considerably less severe than in the upper parts. This is attributable in part to high salinities, input from warm ocean waters and less land-runoff influence in the Lower Cook Inlet. The Lower Cook Inlet is generally free from ice with only protected embayments becoming ice bound. However, under extreme conditions (the winter of 1970-71), ice has been found as far south as Cape Douglas on the west side and Anchor Point on the east side. At this time, sea ice attached to the shore (fast ice) extended up to three miles off the northern shore of Kachemak Bay. (Hutcheon, 1972).

While design requirements for ice loading by floe ice are recognized as the major design factor for Upper Cook Inlet facilities, the less severe ice conditions in the Lower Cook Inlet may reduce or eliminate the necessity for ice-load design depending upon the location within Cook Inlet area.

Ice loading due to surface or superstructure icing (freezing spray) may occur under certain wind and weather conditions during the coldest winter months and must be taken into account throughout the Alaska offshore areas.

3. Potential seismic loading and earthquake effects must be considered in combination with other design criteria for all offshore and onshore structures and facilities since the Lower Cook Inlet area is located in an active seismic zone and may be subject to severe earthquake activity. Earthquake design criteria and site location must consider potential damage and hazards from direct and indirect causes including ground shaking (vibration), fault displacement, surface warping (uplift or subsidence), sea waves (tsunamis) and ground failure (onshore and submarine landslides).

Tsunamis associated with large submarine earthquakes have occurred in various areas of the Pacific Ocean and must be considered in connection with operations and facilities on the Gulf of Alaska margin. Local tsunamis or sea waves, as a result of earthquake caused land slides, are particularly hazardous to onshore facilities in low lying areas and to near shore facilities and must be considered in their location and design.

4. As with other areas of Alaska, the Lower Cook Inlet is isolated and remote from major population centers, industrial areas and oil supply centers, with no significant industrial complex closer than Seattle, Washington. The Lower Cook Inlet area is more or less undeveloped and would require development of local onshore supply bases, transportation facilities,

living areas for workers and families in addition to onshore terminals, storage facilities, and other industrial complexes. The deep water port at Kodiak and the Homer docking facilities, which are primarily involved in support of the fishing industry, would likely be utilized for oil exploration and development in the proposed lease sale area.

The oil and gas supply and service facilities at Kenai and Anchorage would likely be utilized for Lower Cook Inlet development in addition to local sites that may be developed. It is also possible that existing marine terminals, refineries and other facilities in the Upper Cook Inlet might be used for handling oil from parts of the Lower Cook Inlet within reasonable proximity to those facilities.

5. Potential offshore drilling and producing operations in the Lower Cook Inlet could be as near as 5.6 km and as far as 74 km from the shores of the Cook Inlet in water depths of less than 16.4 m to more than 150 m. It is estimated that over three-fourths of the Lower Cook Inlet area is less than 100 m deep. Figure 5 is a map of the bathymetry of the Cook Inlet.

6. Active volcanoes are located along the west margin of the Lower Cook Inlet and one, Augustine Island, rises out of the Lower Cook Inlet.

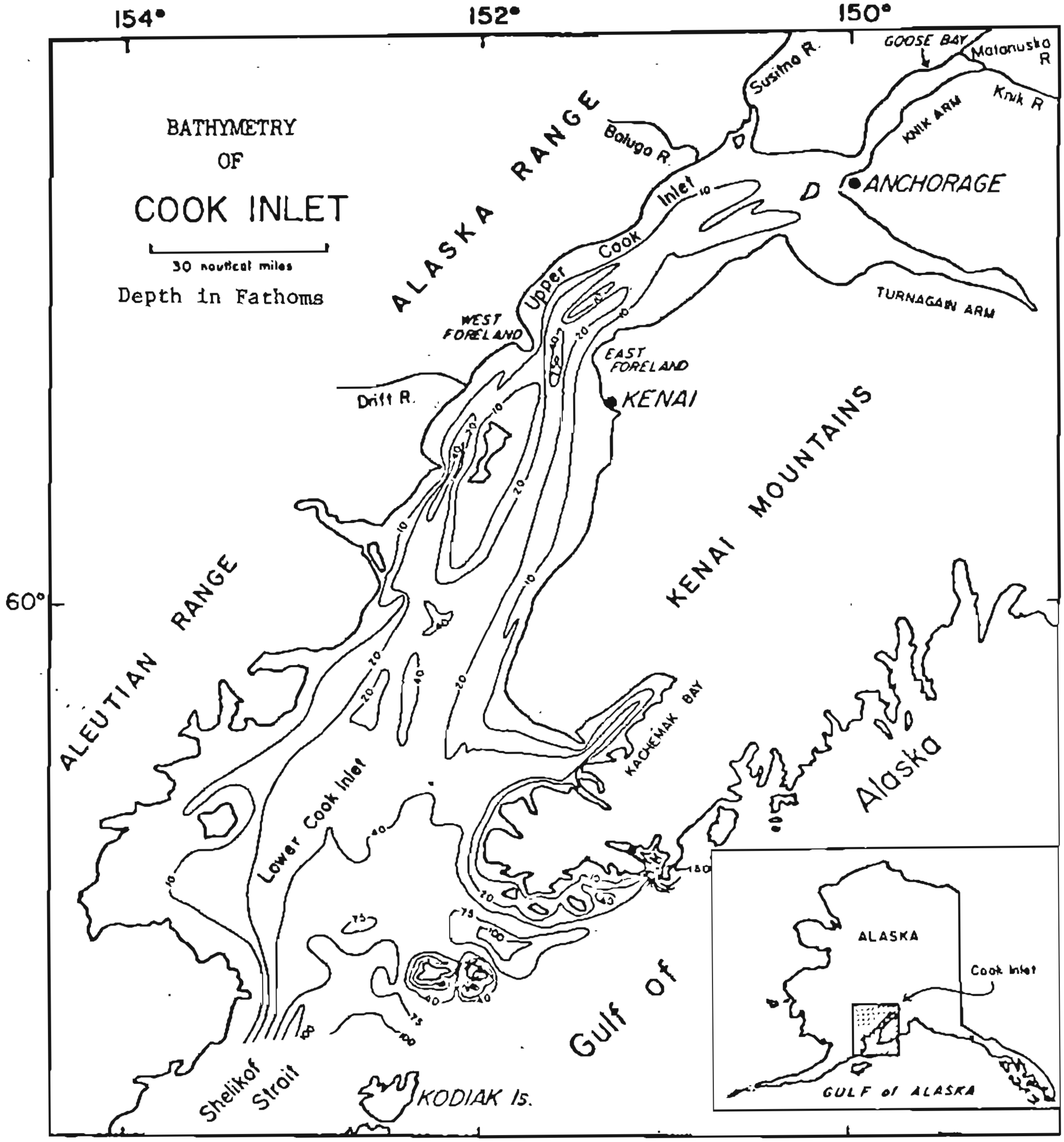


Figure 5

Source: Sharma and Burrell, 1970.

7. Potential hazards from volcanic activity are mainly local to the area of the volcano. Any oil and gas activities in the area of Augustine Island and on the west side of the Lower Cook Inlet should consider the various potential hazards from volcanic activity.

8. The Lower Cook Inlet is a prolific habitat for fish, shellfish, sea mammals and sea birds. Various species of finfish and shellfish are important to the economy of the Lower Cook Inlet. Because of the active fishery in Lower Cook Inlet area, special operating procedures and special equipment may be necessary to assure protection of the marine habitat and compatible multiple use of the area.

Availability

Technology for offshore oil and gas exploration and production has evolved from shallow water, near shore operations in moderate climates, into deeper water and more hostile environments. Figure 6 shows the present water depth capability for mobile drilling and underwater well completion systems, underwater production and manifold systems, and fixed platforms with an industry capability projection of drilling and production systems into deeper water in the short term. Industry has demonstrated the ability to extend its operational capabilities at a rapid rate (National Petroleum Council, 1975). Recent projections by the National Petroleum Council on industry capability for exploration drilling and production for Alaska offshore areas are shown on Table 5.

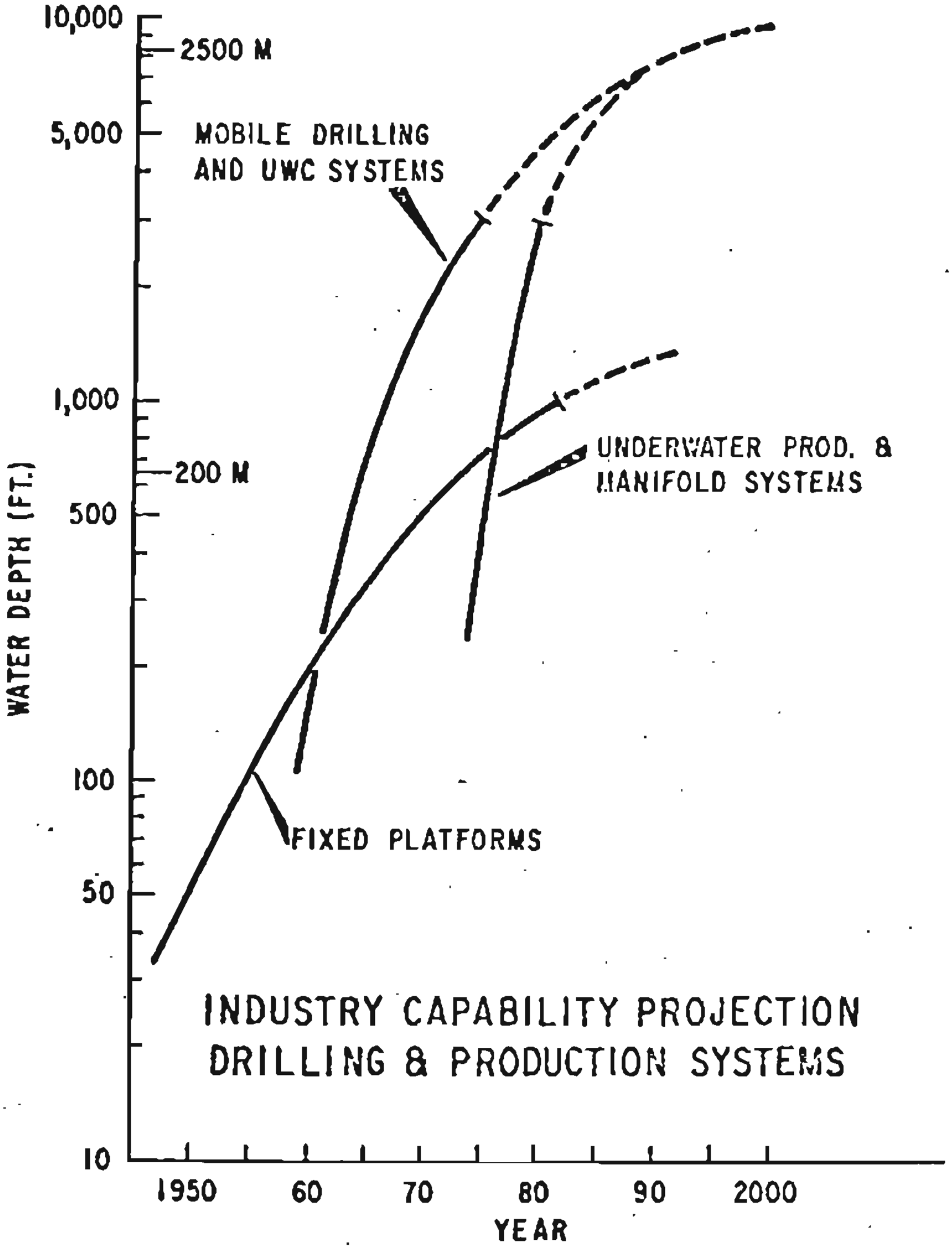


Figure 6

Source: Geer, 1973

Table 5

PRESENT AND FUTURE WATER DEPTH CAPABILITIES AND EARLIEST DATES FOR EXPLORATION DRILLING AND PRODUCTION FOR UNITED STATES OUTER CONTINENTAL SHELF AREAS

	Maximum Water Depth Capabilities		Earliest Date	
Area Province	Exploration Drilling	Production	Exploration Drilling	Production
Cook Inlet Southern Aleutian Shelf Gulf of Alaska Bristol Bay S. of 55° Lat.	Jack-ups 300-350 feet. Drillships and semi-submersibles 1,200 - 1,500 feet.	Platforms 600 feet for ice-free areas. For seasonal ice areas such as Bristol Bay and Lower Cook Inlet, platforms to 200 feet feasible.	Now	At present fixed 24 well platform for ice-free areas in 600 feet ready for production 4½ to 6 years after field discovery and delineation, in 200 feet ready for production 4 to 5 years. Earthquake zones require special surveys and engineering considerations that could cause delays. Satellite UWC could extend depth 100-200 feet in most areas. In the future, production in ice-free areas in 1,500 feet feasible 1980-1985. Production in seasonal ice areas beyond 200 feet feasible 1980-1985.

Source: National Petroleum Council, 1975.

The technology for oil and gas development and operational capability in the Cook Inlet has been demonstrated by the development and production of offshore fields in the Upper Cook Inlet.

After discovery of the first offshore oil and gas in the Upper Cook Inlet in 1963, rapid exploration followed and resulted in the discovery of four major offshore oil fields and one offshore gas field. Development of these fields began with installation of the first fixed platform in 1964 and first production in 1965. These fields are being developed and produced by 14 self-contained fixed platforms which have been in place for 7-10 years. More than 150 miles of offshore pipelines have been installed in the Upper Cook Inlet. Oil production is transported to the Nikiski marine terminal on the east side of the Inlet or to the Drift River marine terminal on the west side of the Inlet for movement by tankers to West Coast refineries. Gas from the North Cook Inlet field is transported to a liquefication plant at Nikiski and is transported to Japan in LNG tankers. Figure 4 is a map of the Cook Inlet showing the oil and gas fields, pipelines, and related facilities in the Upper Cook Inlet.

The Cook Inlet is considered a major oil and gas producing province. Oil and gas production for June 1975 and the cumulative production for offshore oil and gas fields follows (State of Alaska, 1975):

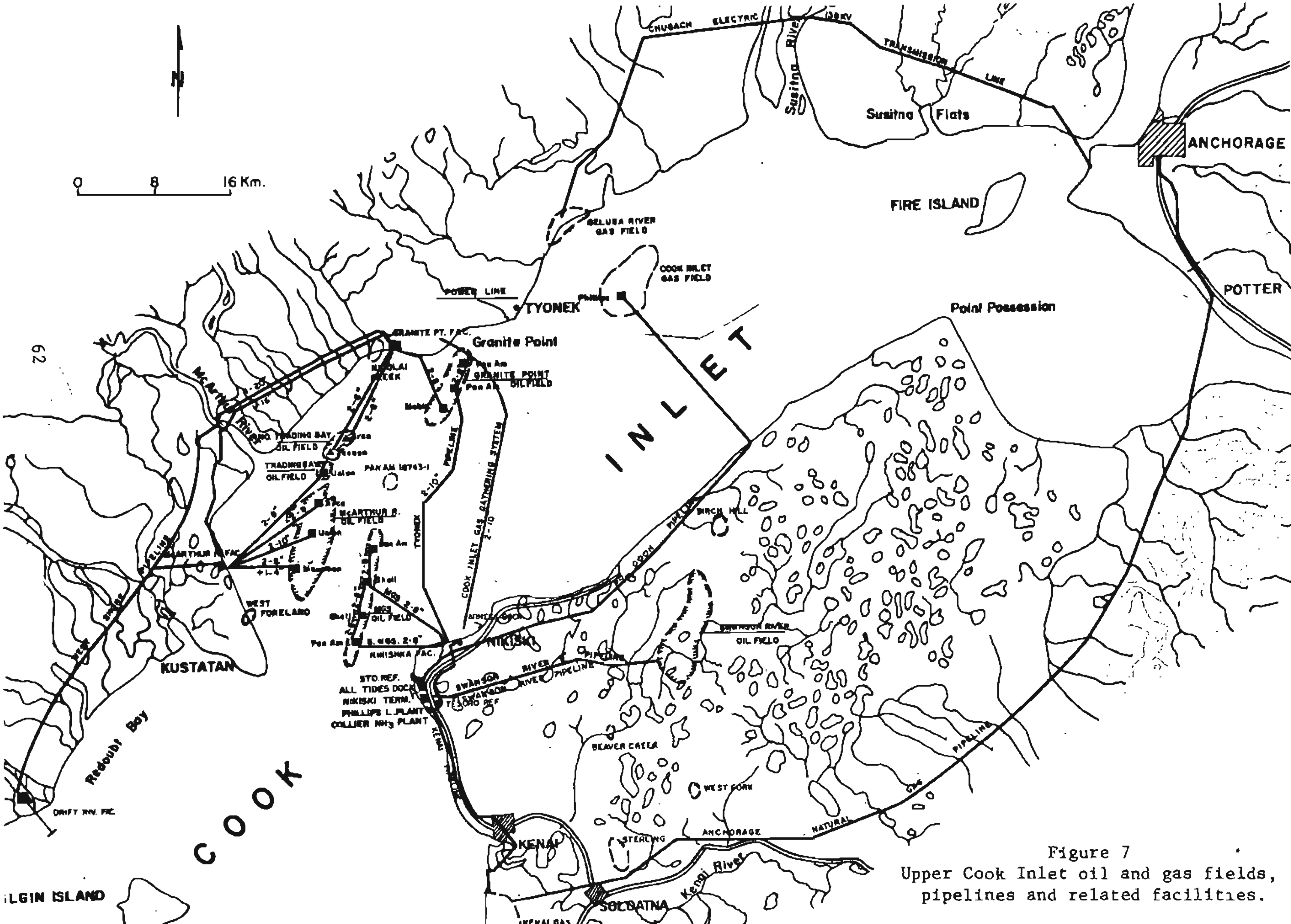


Figure 7
Upper Cook Inlet oil and gas fields, pipelines and related facilities.

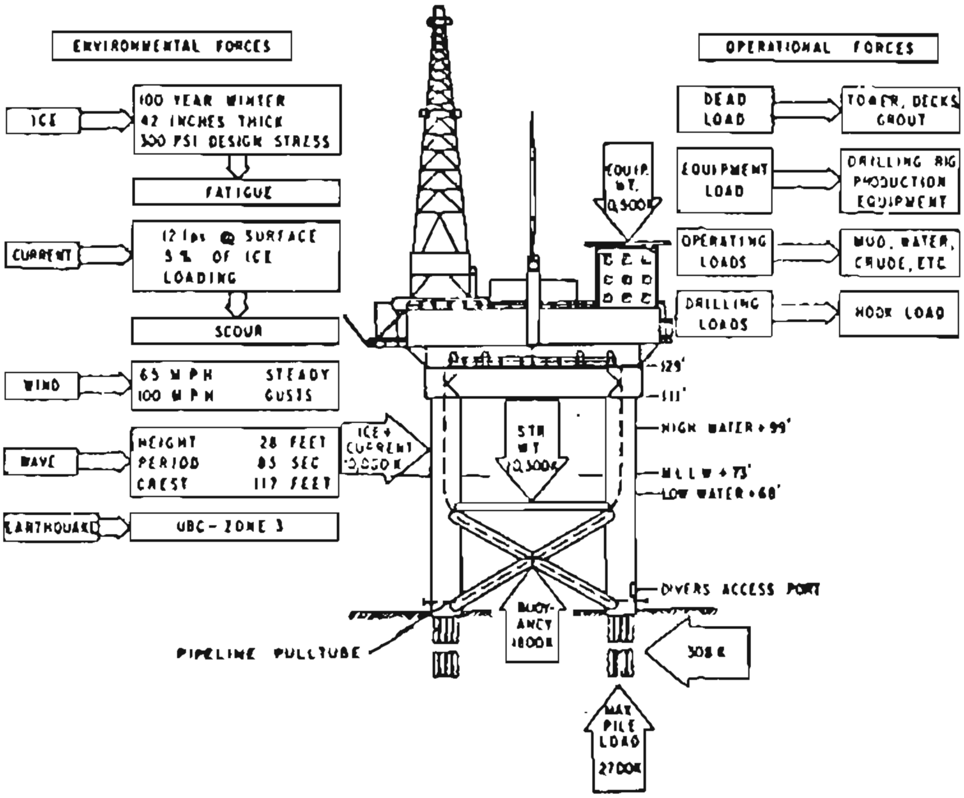
	June 1975		Cumulative (through 6/75)	
Field	Oil (bbls)	Gas (MCF) *	Oil (bbls)	Gas (MCF)
Granite Point	377,004		58,344,635	
McArthur River	3,303,532		273,327,506	
Middle Ground Shoal	715,137		91,814,814	
Trading Bay	523,207		59,743,472	
N. Cook Inlet		2,697,998		220,592,058
Total	4,918,880	2,697,998	483,230,427	220,592,058

* Solution gas from oil fields not shown.

Special design features for the Upper Cook Inlet platforms include one, three and four legged tower-type platforms with minimum surface area at the water level to provide minimum exposed area to the moving ice (Vissar 1969). Wells are drilled through the legs, and the legs are attached to the sea floor by as much as 65 m of grouted piling designed to withstand required stresses and unstable bottom conditions. Figure 5 shows design loads on a tower-type structure in Cook Inlet.

The technology for development of the deep water ports of the Lower Cook Inlet is also available and may be adapted from the North Sea and other offshore areas where oil and gas operations have moved into deeper water utilizing newly developed technology.

In the North Sea area, drilling has been successfully conducted in water depths exceeding 200 m and drilling and production platforms have been placed in 125 m of water. A concrete platform was recently placed in 140 m of water at the Brent Field north of 61° latitude



Design loads on a tower structure in Cook Inlet.

Figure 8

Source: Visser 1972

in the North Sea. Large diameter pipelines, 81 cm, have been installed successfully in water depths of 146 m and new equipment under construction will extend that capability to deeper water (Rainey, 1974). There are several offshore storage and tanker loading facilities in use or planned for North Sea fields. The offshore terminals are designed for permanent use in some fields and for temporary or supplemental use in others until pipelines and shore facilities can be completed. Some typical North Sea offshore terminals are described below:

1. Ekofisk field - A million barrel concrete storage tank combined with an SBM (Single Bouy Mooring, Inc.) tanker facility.
2. Brent field - Concrete production platforms with up to a million barrel storage capacity per platform used in combination with a submersible storage and tanker loading facility (Shell group SPAR system).
3. Argyle field - A semi-submersible production platform with subsea wells used in conjunction with a submersible SBM tanker loading facility.

Between 1960 and 1975, 252 subsea wells were completed worldwide in water depths of 15-114 m in various offshore areas (Ocean Industry, 1975). Several subsea production systems are in the prototype or test stage for use in water depths of 91-456 m and are being developed for use in deep water in conjunction with fixed platforms or in areas where platforms are not feasible. Several advanced subsea production systems are in actual use or in the process of installation in the Gulf of Mexico and the North Sea areas.

The type of development in the Lower Cook Inlet will depend upon the water depth, distance from shore, the type of oil or gas deposit to be developed and the physical and environmental factors at the discovery location. Shallow water development would likely follow conventional use of fixed steel platforms with pipelines to shore, similar to the Upper Cook Inlet fields. Deep water development may involve: 1) conventional fixed steel platforms as in shallow water, 2) a combination of fixed steel or concrete platforms, 3) structures with subsea wells and production systems with pipelines to shore.

Recent developments in marine geophysical technology provide methods for detecting surface and subsurface geologic hazards so that they may be avoided in the selection of locations for wells, fixed platforms or other offshore facilities. These geophysical data, in conjunction with core sample tests, are used in analyzing soil characteristics and foundation design for bottom supported structures. High resolution acoustic surveys and the submission of data, along with pertinent geological and engineering studies, will be required prior to permitting wells or the placement of a platform or structure.

Procedures for analyzing seismic forces and for designing offshore structures to withstand earthquakes are available (API, 1974). New techniques for evaluating and predicting maximum earthquake probability and seismic risk; new techniques for measuring, predicting and analyzing structural behavior; and new procedures for investigating, testing, evaluating and analyzing soil characteristics and bearing capacity for foundation designs have improved overall capability and reliability for design of offshore structures in earthquake prone areas.

DRILLING UNIT AVAILABILITY

At present, there are two offshore drill vessels in Alaskan waters. The CLOMAR CONCEPTION, a ship-shaped drill vessel belonging to Global Marine, Inc., is presently drilling in OCS waters approximately 29 miles southwest of Yakataga in the Gulf of Alaska. The GEORGE FERRIS, a jack-up rig owned by Sun Marine Drilling Co., is not drilling at the present and is located in State submerged lands in Kachemak Bay.

There are only two other mobile drilling vessels in the Pacific Coast area; the CUSS No. 1, owned by Global Marine Inc., and the WODECO I, owned by Western Offshore. Both are small floating barge type vessels not designed for long term operations in the Gulf of Alaska.

The relatively shallow water depths and the moderate sea conditions of the Lower Cook Inlet will allow exploratory drilling by jack-up rigs as well as drillships and semi-submersible vessels. However, due to the extreme winter conditions and ice floes in part of the Lower Cook Inlet, drilling may be restricted to the summer season (April through October).

The trend in new drillships and semi-submersible vessels has been toward capability of drilling in deeper water and in more harsh environmental climates. Most drill ships and semi-submersibles constructed in recent years, and nearly all of these under construction or planned, are of the class and type designed for extended operations in rigorous environmental regions such as the North Sea, offshore Eastern Canada, and the Gulf of Alaska. The semi-submersible rigs are designed for stability under adverse sea and weather conditions, whereas the drill ships are designed for maximum mobility and self-sufficiency. Both semi-submersible and drill ships are capable of drilling in water depths of 305 m using chain anchor systems and can be used in deeper water if they are equipped with dynamic positioning equipment. Floating drill vessels are susceptible to delay and down time during extreme weather conditions, and drilling productivity in the Gulf of Alaska will likely be reduced during the stormy fall and winter season even though the newer rigs are designed for year round operations under these conditions.

Mobile offshore drill vessels for the Alaska offshore areas must be obtained from other parts of the world which will require considerable transit time and expense since most offshore mobile drilling units are being constructed or working on the Gulf Coast of the United States or in foreign areas, mainly in the European and Far East areas. Cost of mobilization and moving a drilling unit from the North Sea to the Cook Inlet area is estimated to be between 1.5 - 5 million dollars depending upon the type of rig.

A recent count of offshore mobile rigs showed 298 total units in operation, of which 83 are floating drill ships or barges, 139 are jack-up (bottom supported) and 76 are semi-submersible. An additional 139 units are under construction or planned, including 33 drill ships, 55 jack-ups and 51 semi-submersibles. (Offshore Rig Data Services, 1975).

Table 6 indicates mobile offshore rigs under construction with a breakdown of completion dates through 1977 by rig type.

MANPOWER

As in the case with drilling units, most of the skilled manpower for exploratory drilling will initially have to come from other areas. The reservoir of manpower, in general, needed for the drilling, development and production, including the installation of platforms, pipelines and onshore facilities is relatively small due to 1) the low population density in Alaska and 2) the continued need of qualified people on existing production facilities in the Upper Cook Inlet.

Some of the skilled manpower may be available in Alaska, depending on the stage of construction of the Trans-Alaska or other pipelines and of the Prudhoe Bay oil field. Also, it is expected that replacements will be recruited from the local labor market and trained in the skills required. As the energy shortage continues, many predict that skilled manpower for the oil and gas and related industries will be in short supply.

A large potential supply of manpower, available for training, exists in the Pacific Northwest and California. Its real availability will depend in large part on the relative state of the national economy and in finding a sufficient number of individuals willing to work far from home under harsh climatic conditions for long periods of time.

Table 6

Mobile Rigs Under Construction as of August 1975

Rig Type	Total Number	Completion Date 1975	1976	1977 or later
Semi-submersibles	51	14	33	4
Jackups	55	15	31	9
Drillships	33	9	18	6
	139	38	82	19

Source: Offshore Rig Data Services, 1975.

TIME FRAME FOR DEVELOPMENT

Estimates of a time frame for development and production from a new area are conjectural at best. Speculative factors which can affect development timing include the ready availability of needed equipment and material, water depth, discovery success, reservoir and hydrocarbon character, economic climate and other conditions which can cause unforeseen delays (labor disputes, environmental hearings, etc.)

A review of Upper Cook Inlet development indicates the time from lease sale to first production to vary from 4-7 years with peak production attained 1-2 years later. This would indicate a total time of 5-9 years from lease sale to peak or maximum production. It should be recognized that this time frame applies to relatively shallow water areas, less than 100 feet (20 m), where drilling and development is less difficult and less expensive than in deeper water areas which require additional time for design and construction of special deep water equipment and facilities.

The expensive operating conditions and the expected high cost of equipment for Alaska operations will likely restrict development to the shallow water areas with lower costs. Development in deeper water will be restricted to those fields which have very large recoverable reserves and sufficient potential productivity for economic development.

REFERENCES CITED

American Petroleum Institute, 1975, Recommended practice for planning, designing, and constructing fixed offshore platforms: RP 2A, Sixth Edition, 39 p.

Evans, C. D., Buck, E. H., Buffler, R. T, Fisk, S. G., Forbes, R. B., and Parker, W. B., 1972, The Cook Inlet environment - a background study of available knowledge: Prepared by the University of Alaska Resource and Science Service Center, Alaska Sea Grant Program, Anchorage, Alaska, for the Alaska District Corps of Engineers, Anchorage, Alaska, 446 p.

Geer, R. L., 1973, Offshore drilling and production technology - where do we stand and where are we headed?: Amer. Petroleum Institute meeting, April 9 - 11, 1973, Denver, Paper 362-C.

Hutcheon, R.J., 1972, Sea ice conditions in Cook Inlet, Alaska during the 1970-71 winter: NOAA Tech. Memo. AR7., U.S. Dept. of Commerce, National Weather Service, Anchorage, Alaska, 17 p.

----- 1972, Forecasting ice in Cook Inlet, Alaska: NOAA Tech. Memo. AR5, U.S. Dept. of Commerce, National Weather Service, Anchorage, Alaska, 14 p.

National Petroleum Council, 1975, Ocean petroleum resources: Report of the National Petroleum Council, March, 98 p.

Ocean Industry, 1975, Comparison of 252 subsea completions: July, v. 10, no. 7, p. 42-45.

Offshore Rig Data Services, 1975, The rig locator report: The Sheffer Co., Houston, Texas, August 7.

Rainey, J.M., 1974, The deep wate challenge and the response by a major North Sea contractor: Preprint, 1974 Offshore North Sea Technology Conference, Stavanger, Norway.

Sharma, G. D., and Burrell, D.C., 1970, Sedimentary environment and sediments of Cook Inlet, Alaska: Am. Assoc. Petroleum Geologists Bull., Vol. 54, No 4. p. 647-654.

State of Alaska, 1975, Division of Oil and Gas, Department of Natural Resources, Monthly Bulletin, August 1975.

Visser, R.C., 1969, Platform design and construction in Cook Inlet, Alaska,: Jour. Petroleum Technology, v. XXI, April, p. 411-420.

——— 1972, Offshore oil and gas field development, Cook Inlet, Alaska: Preprint, Northern Canada offshore drilling meeting, December 5 and 6, 1972, Ottawa, Canada.

Acknowledgments

The responsibility for specific subjects is as follows:

Magoon, introduction, framework geology, petroleum geology; Sable, resource appraisal estimate; Hampton, geologic hazards; Smith and Chmelik, technology, drilling unit availability, manpower and time frame for development.

The manuscript was reviewed by R. Q. Foote. C. D. Masters, W. L. Adkison, E. Scott.