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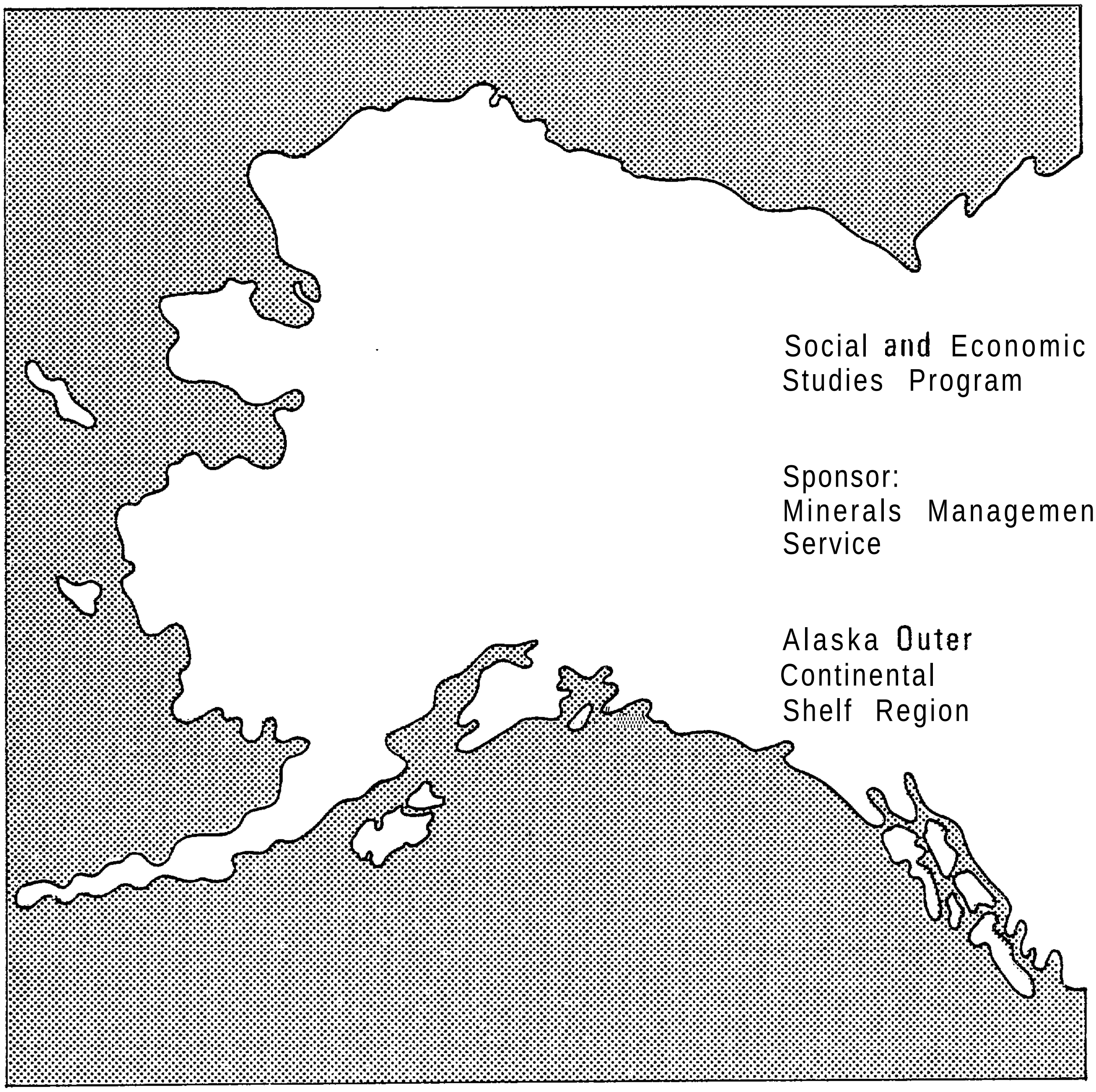

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Alaska Outer Continental Shelf Region

Evaluation Of Bering Sea Crude Oil Transportation Systems: Appendices

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APPENDIX A

NORTH SEA CRUDE OIL TRANSPORTATION EXPERIENCE

APPENDIX A

NORTH SEA CRUDE OIL TRANSPORTATION SYSTEM

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A.1 INTRODUCTION

The environment of the Bering Sea is unique and consequently there is no existing offshore crude oil development and operating experience that can be directly applied to Bering Sea development. Of all offshore crude oil development that has taken place around the world, the development in the North Sea has taken place under conditions that most closely resemble conditions in the Bering Sea. Approximately ten years of operating experience in the North Sea is available and this experience can provide valuable insight and a realistic basis for evaluating potential offshore loading systems and pipeline systems in the Bering Sea. However, it is extremely important to bear in mind that North Sea experience is not directly applicable to the Bering Sea because a number of major factors affecting oil field development are quite different.

One major difference is the fact that Bering Sea oil fields will be much further from refining centers than are oil fields in the North Sea. Pipeline systems for North Sea oil fields deliver the produced crude oil either directly to a refinery or to a large tanker loading terminal with a throughput on the order of 500,000 barrels per day. Thus, many North Sea oil fields that utilize pipelines for transporting the crude oil do not require tanker terminals or tankers and for those that do require terminals and tankers, the cost is shared among several oil field developments. All pipeline systems in the Bering Sea considered in this study will deliver the crude oil to a relatively low volume tanker terminal where it will be loaded aboard a tanker for ultimate delivery to a refinery located more than 3,000 km (1,800 mi) away. Thus, all Bering Sea oil field developments must include some type of tanker terminal and a tanker fleet and, for purposes of this study, it has been assumed that each oil field development must stand alone so terminal costs cannot be shared.

Artother major difference between the Bering Sea and the North Sea is the environment. Obviously, the environment in which an offshore loading system or pipeline system must be installed and function will have a great effect on both construction and operating costs. The most important environmental difference between the Bering Sea and the North Sea is the presence of ice floes and large ice features. These ice conditions make North Sea type offshore loading systems unsuitable for use in the Bering Sea without significant modifications. Ice forces on an offshore loading system in the Bering Sea will be considerably higher than environmental forces acting on a North Sea system.

In spite of the differences between the two regions, North Sea experience can provide much useful information. The following sections provide particular documentation for North Sea oil fields that utilize either offshore loading systems or pipeline systems for transporting the produced crude oil.

A.2 NORTH SEA OIL FIELD DEVELOPMENT

The North Sea province, situated in a politically stable region close to main consumer markets, is one of the most important petroleum regions in the world today. The first offshore drilling took place in Dutch waters in 1961, while the first application for permission to explore for oil and gas in Norwegian and United Kingdom waters was received in 1962. In 1965, the first hydrocarbon was found in U.K. waters with a gas discovery, and in 1969 the first major oil field was struck in the Norwegian part of the Continental Shelf. With the rise in price of Middle East oil in the mid-1970s, the cost of North Sea oil became very competitive; thus triggering a tremendous development in the North Sea area during the past decade.

Twenty-six active North Sea oil fields have been selected for analysis to provide a basis for evaluation of crude oil transportation system alternatives in the Bering Sea. These oil fields include almost all of the oil fields presently producing in the United Kingdom and Norwegian sectors of the North Sea. The location of the twenty-six fields is indicated on Figure A-1. Of these, eight presently utilize an offshore loading system as the long term method for transporting the produced crude oil, six utilize a pipeline directly to an onshore terminal and the remaining twelve utilize interfield pipelines to connect with a pipeline to an onshore terminal. Three of the fields utilizing pipelines initially utilized an offshore loading system to achieve early production and to serve

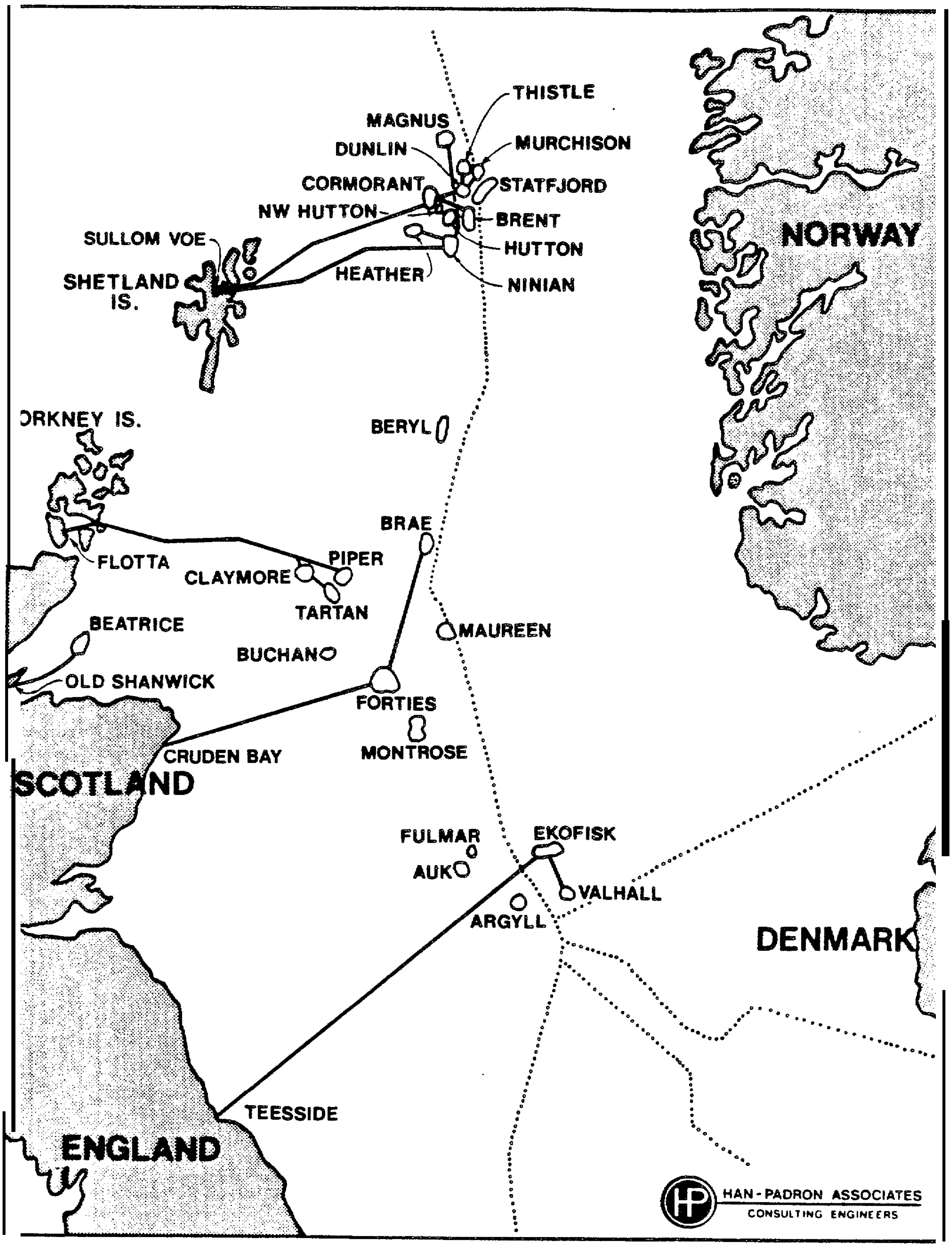


Figure A-1. North Sea oil fields selected for analysis.

until a pipeline could be installed. One of the fields with an offshore loading system will have a pipeline completed in 1984 to replace the OLS. Table A-1 lists the twenty-six fields and the type of transportation system utilized for each. For a description of the characteristics of each type of offshore loading system indicated in the table, refer to Section A-3.

TABLE A-1

NORTH SEA OIL FIELDS - CRUDE OIL TRANSPORTATION SYSTEMS

(U.K. & NORWAY SECTORS ONLY)

FIELD	PIPELINE	OFFSHORE LOADING SYSTEM
Argyll		CALM
Auk		ELSBM
Beatrice	16″ to Old Shanwick Terminal	
Beryl		2-AC
Brae	30″ to Forties	
Brent	16″ to Cormorant	*SPAR & *CALM
Buchan		CALM
Claymore	30″ to Piper	
Cormorant	36″ to Sullom Voe Terminal	
Dunlin	24″ to Cormorant	
Ekofisk	34″ to Teesside Terminal	*2-CALM
Forties	32″ to Cruden Bay Terminal	
Fulmar		SALM w/Storage Tanker
Heather	16" to Ninian	
Hutton	12″ to NW Hutton	
Magnus	24″ to Ninian	
Maureen		AC
Montrose		**2-CALM
Murchison	16″ to Dunlin	
Ninian	36″ to Sullom Voe Terminal	
NW Hutton	20″ to Cormorant	
Piper	30″ to Flotta Terminal	
Statfjord		3-AC
Tarton	24″ to Claymore	
Thistle	16″ to Dunlin	*SALM
Valhall	20″ to Ekofisk	

*Utilized temporarily until pipeline available.
**To be replaced by ‘a pipeline”.

At the present time (last quarter of 1983) there are a total of seventeen offshore loading systems installed in the U.K. and Norwegian sectors of the North Sea and three more are in the firm planning stage. Table A-2 summarizes the number and status of the North Sea offshore loading systems. Table A-3 lists the type of OLS utilized at. each field, the operator of the field and the present status of the OLS.

TABLE A-2

NUMBER AND STATUS OF NORTH SEA OFFSHORE LOADING SYSTEMS

(U.K. & NORWAY SECTORS ONLY)

TYPE OF OLS	NO. OPERATING	NO. ON STANDBY
CALM	4	3
SALM	1	1
AC	6	0
ELSBM	1	0
SPAR	0	1
Total	12	5

TABLE A-3

SUMMARY OF NORTH SEA OFFSHORE LOADING SYSTEMS

(U.K. & NORWAY SECTORS ONLY)

FIELD	OPERATOR	OLS	STATUS
Argyll	Hamilton Bros.	CALM	Operating
Auk	Shell	ELSBM	Operating
Beryl	Mobil	2-AC	Operating
Brent	Shell.	SPAR & CALM	Standby
Buchan	BP	CALM	Operating
Ekofisk	Phillips	2-CALM	Standby
Fulmar	Shell	SALM w/Storage Tanker	Operating
Maureen	Phillips	AC	Operating
Montrose	Amoco	2-CALM	*Operating
Statfjord	Mobil	3-AC	Operating
Thistle	BNOC	SALM	Standby

*To be replaced by a pipeline.

A.3 TYPES OF NORTH SEA OFFSHORE LOADING SYSTEMS

A number of different types, and variations within a type, of offshore loading systems have been utilized in the North Sea. They have been designed to accommodate shuttle tankers up to 150,000 DWT and one is designed to permanently moor a 210,000 DWT storage vessel. The basic types of OLS used in the North Sea include:

A.3.1 Catenary Anchor Leg Mooring (CALM)

The basic features of the catenary anchor leg mooring (CALM) are illustrated in Figure A-2. The main component of the CALM is the mooring buoy. It is circular in plan and, for large vessel moorings, generally 12 m (39 ft) or more in diameter. The buoy is anchored to the seabed by a number of catenary anchor chains. This anchoring system permits the buoy to float freely on the surface of the sea, even in severe wave action.

Fitted on top of the buoy is a fully rotating turntable consisting of three distinct sectors, a mooring bracket sector, a piping manifold sector, and a counterweight sector. The turntable is equipped with navigation aids. The fluid swivel assembly, located at the center of the buoy, connects the piping manifold on the turntable with the internal piping of the buoy leading to flanged connections at the bottom of the buoy for the underbuoy hoses. The outboard end of the piping on the buoy turntable is connected to the floating hose

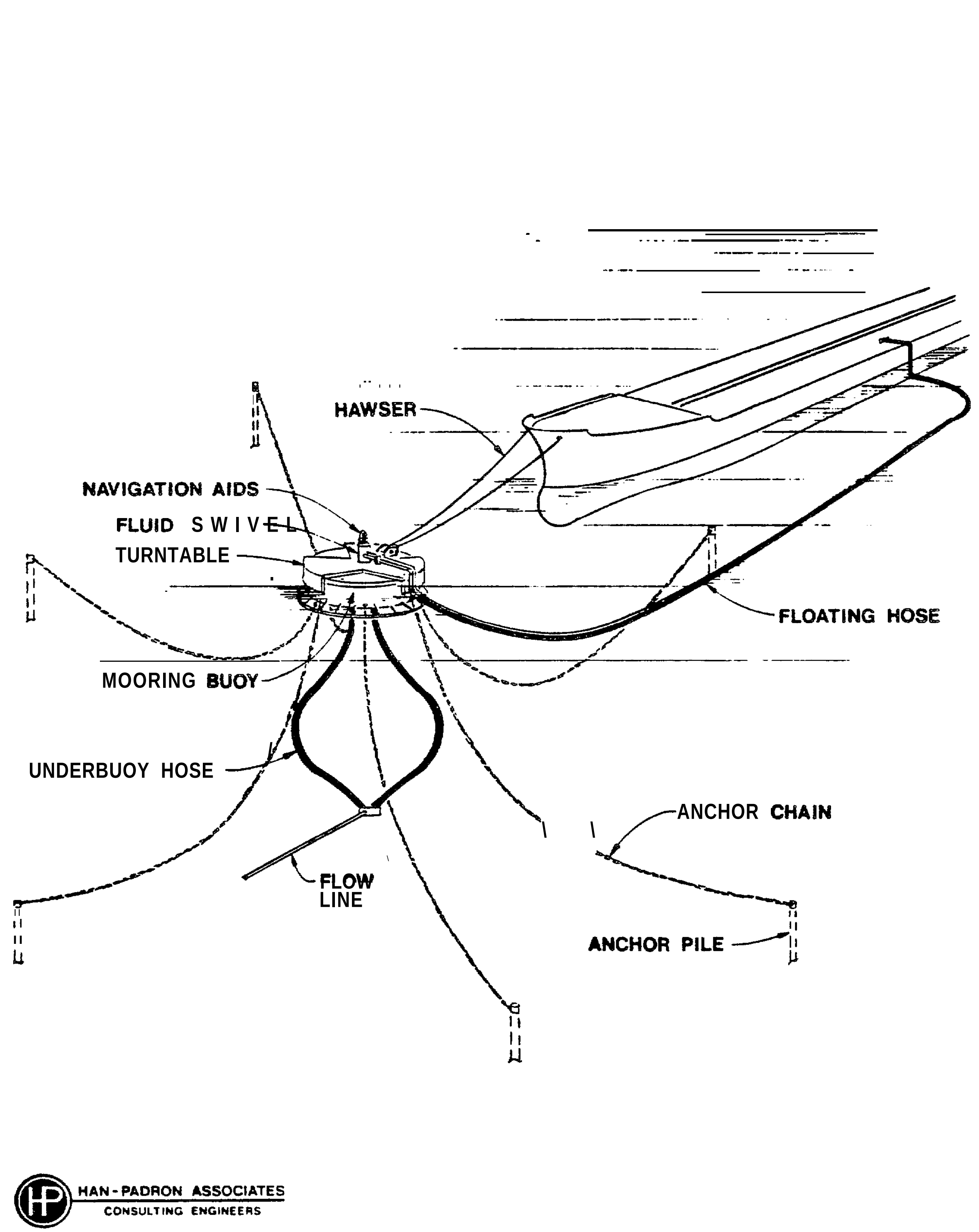


Figure A-2. **Catenary** anchor leg mooring (CALM).

system. The hose is of sufficient length to reach the midship manifold of the largest tanker to use the mooring, with adequate slack to allow for the relative movement of the ship and buoy. The underbuoy hose system transfers the cargo between the buoy and the submarine pipeline end manifold.

The mooring hawser system transfers the mooring forces from the ship's mooring fittings to the mooring bracket sector of the turntable. The force is then transferred through the mooring buoy and into the anchor chains.

A.3.2 Single Anchor Leg Mooring (SALM)

The single anchor leg mooring (SALM) system was developed to improve the performance of the catenary anchor leg mooring system. Two SALM'S have been installed in the North Sea and they are quite different in appearance and function.

The Thistle Field single anchor leg mooring, illustrated in Figure A-3, is the deepest SALM installed to date. It was installed in 163 m (535 ft) of water, about 210 kilometers (130 miles) northeast of the Shetland Islands. The system was intended to serve as a temporary loading facility until a pipeline to shore could be commissioned. The Thistle SALM was designed to survive 30 m (98 ft) waves and 50 meters per second (97 knots) winds. Dedicated 80,000 DWT tankers, specially modified for bow loading and self-service

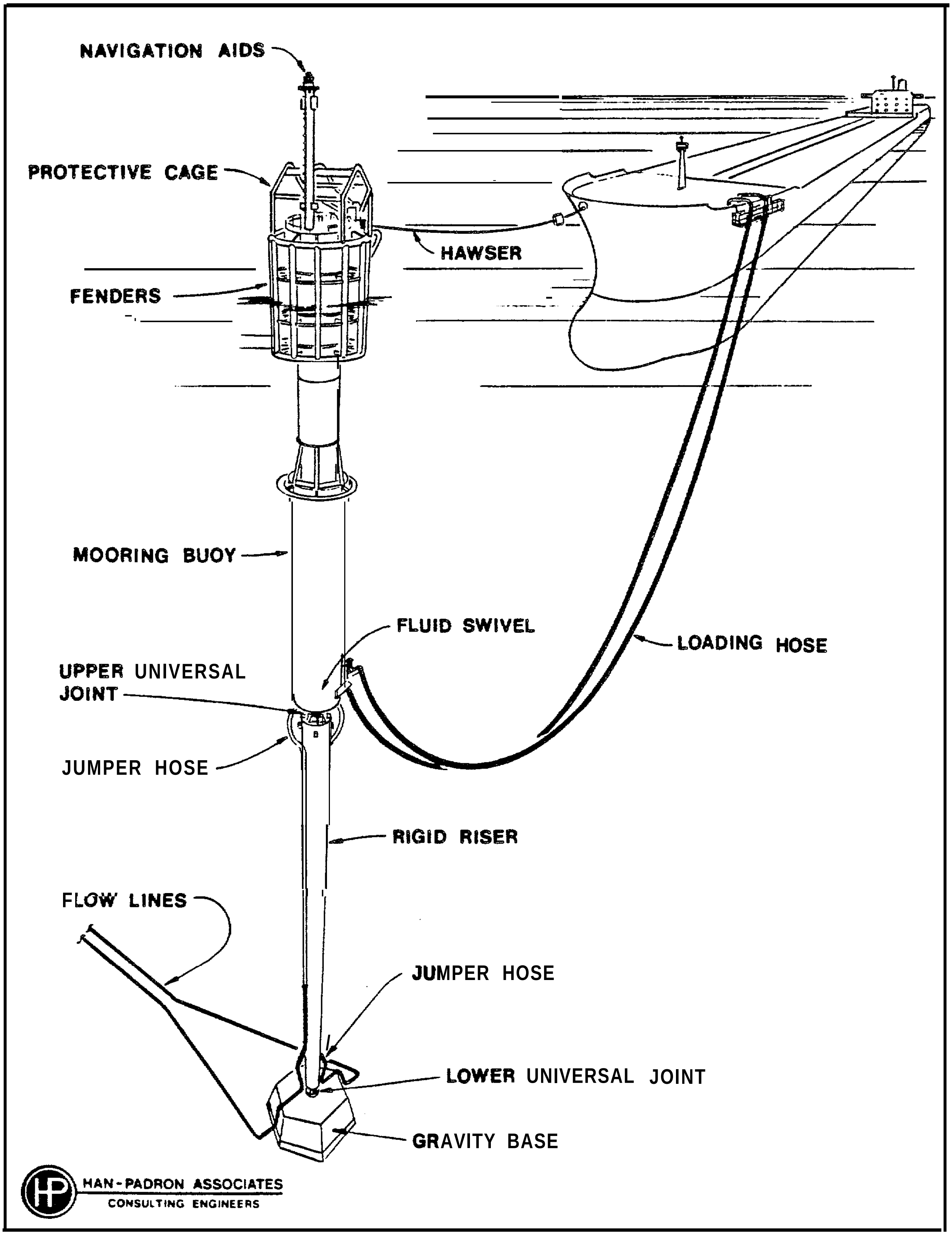


Figure A-3. Thistle Field single anchor leg mooring (SALM).

mooring, can remain moored in significant wave heights up to 4.5 m (15 ft) (Miller et al. 1979).

The Thistle SALM consists of a relatively small diameter buoy connected to a rigid riser by means of a universal joint. The riser is connected to a mooring base by a second universal joint. Mooring brackets are fixed to the buoy deck for attachment of the mooring hawsers and navigational aid features are also provided on the buoy deck. The Thistle buoy is 4 m (13 ft) in diameter and 56 m (184 ft) in length. The top 16 m (52 ft) of the buoy is reduced to 2.5 m (8 ft) in diameter to minimize wave forces. The riser is 2.5 m (8 ft) in diameter and 101 m (331 ft) in length. The fluid swivel assembly is located inside the mooring buoy at the bottom. This allows the fluid swivel assembly to be independent of the load-carrying members and readily available for inspection and maintenance by non-diver personnel. The cargo hoses are connected to a platform attached to the bottom of the buoy.

The Fulmar Field SALM is illustrated in Figure A-4. This SALM is utilized to permanently moor a 210,000 DWT storage vessel to which a 110,000 DWT shuttle tanker is moored in tandem. The primary components of the Fulmar SALM are the buoy, rigid arm, base and mechanical articulations that connect them. The buoy serves also as the rigid anchor leg, attached to both the rigid arm and the base. The outside diameter of the buoy ranges from 8 m (26 ft) at the lower end to 15.9 m (52 ft) at the maximum diameter and down to 5.5 m (18

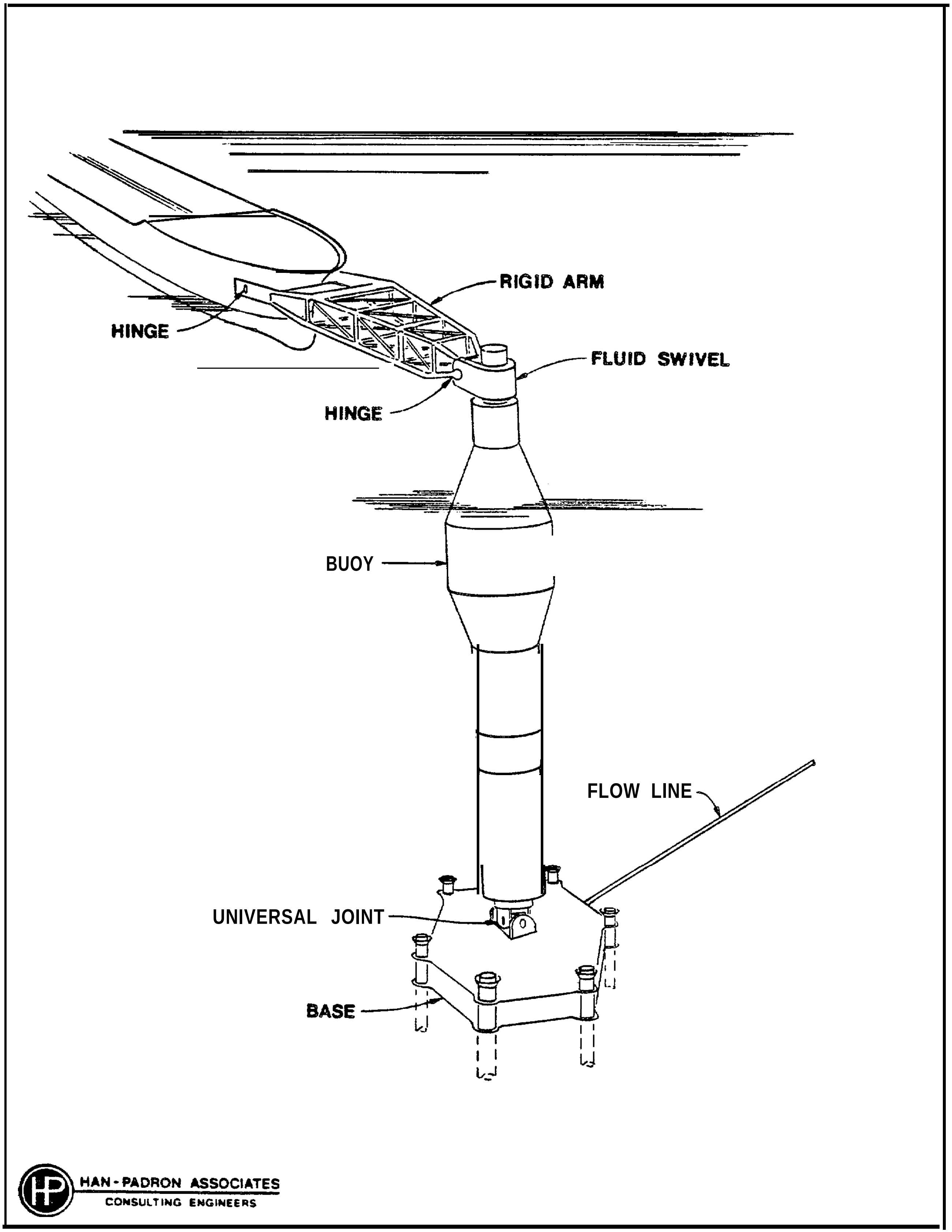


Figure A-4. Fulmar Field single anchor leg mooring (SALM) with floating storage unit (FSU).

ft) at the top (Mack et al. 1981, Ocean Industry 1981).

A.3.3 Articulated Column (AC)

The articulated column (AC) type offshore loading system was specifically developed for North Sea operations. As illustrated in Figure A-5, it consists of a gravity or piled base, a riser connected to the base by a universal joint and extending above the water level, and a revolving head. The riser may be a solid cylindrical hull or an open truss arrangement as shown in Figure A-5. The bottom of the riser is ballasted to reduce forces on the articulation.

The revolving head can be either a simple turntable, similar to that of the CALM, or a more sophisticated unit including living quarters, a helideck, a boom supporting the loading hose, several power generators, a tension limiting device for the mooring hawser, etc.

A.3.4 Exposed Location Single Buoy Mooring (ELSBM)

The only exposed location single buoy mooring (ELSBM), illustrated in Figure A-6, was installed in the Auk Field in 1974. The main hull of the ELSBM is submerged and is composed of two cylinders of different diameters. The buoy is anchored to the seabed in 85 m (280 ft) water depth by means of eight anchor chains. The portion of the buoy extending above the water is relative"ly small in diameter

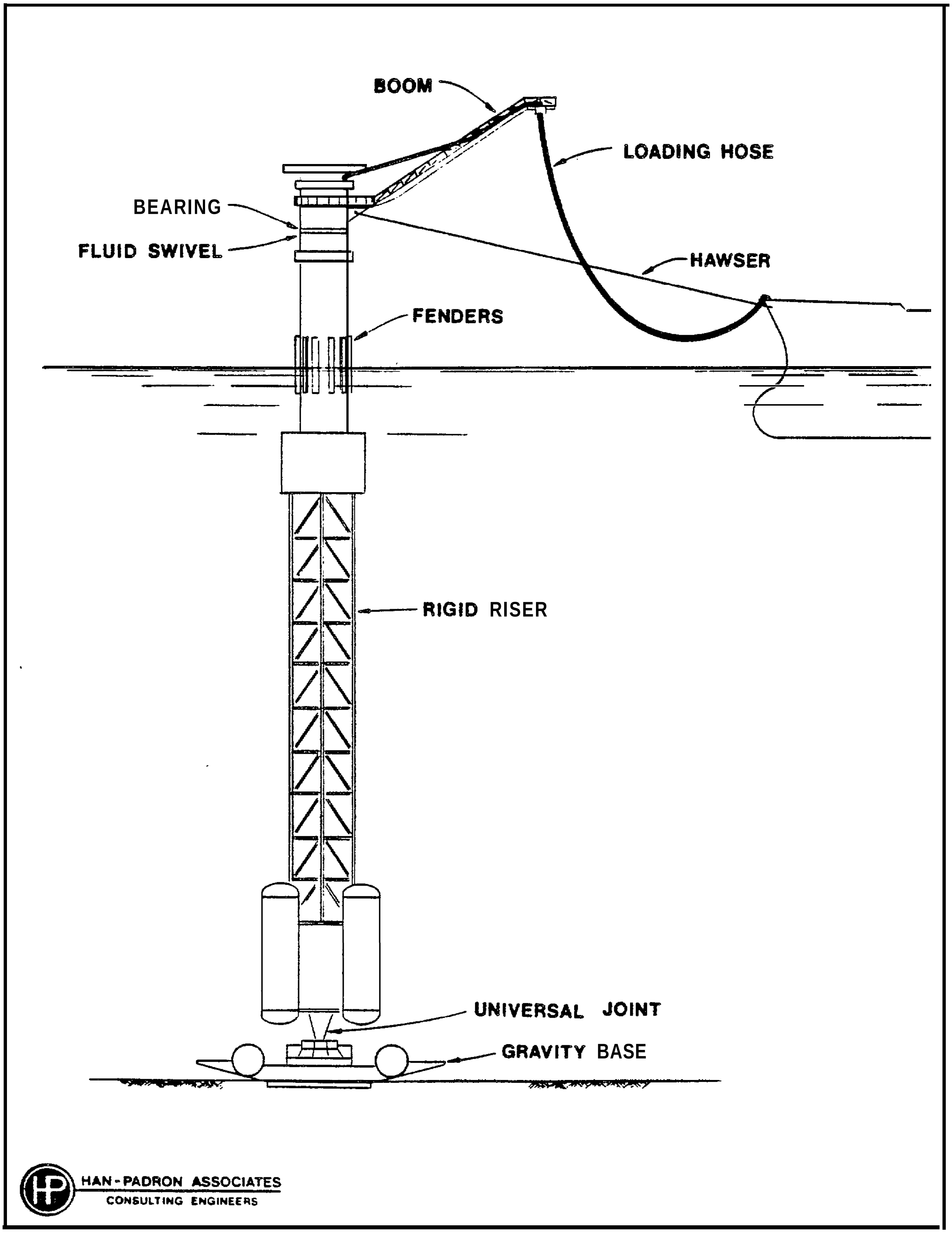
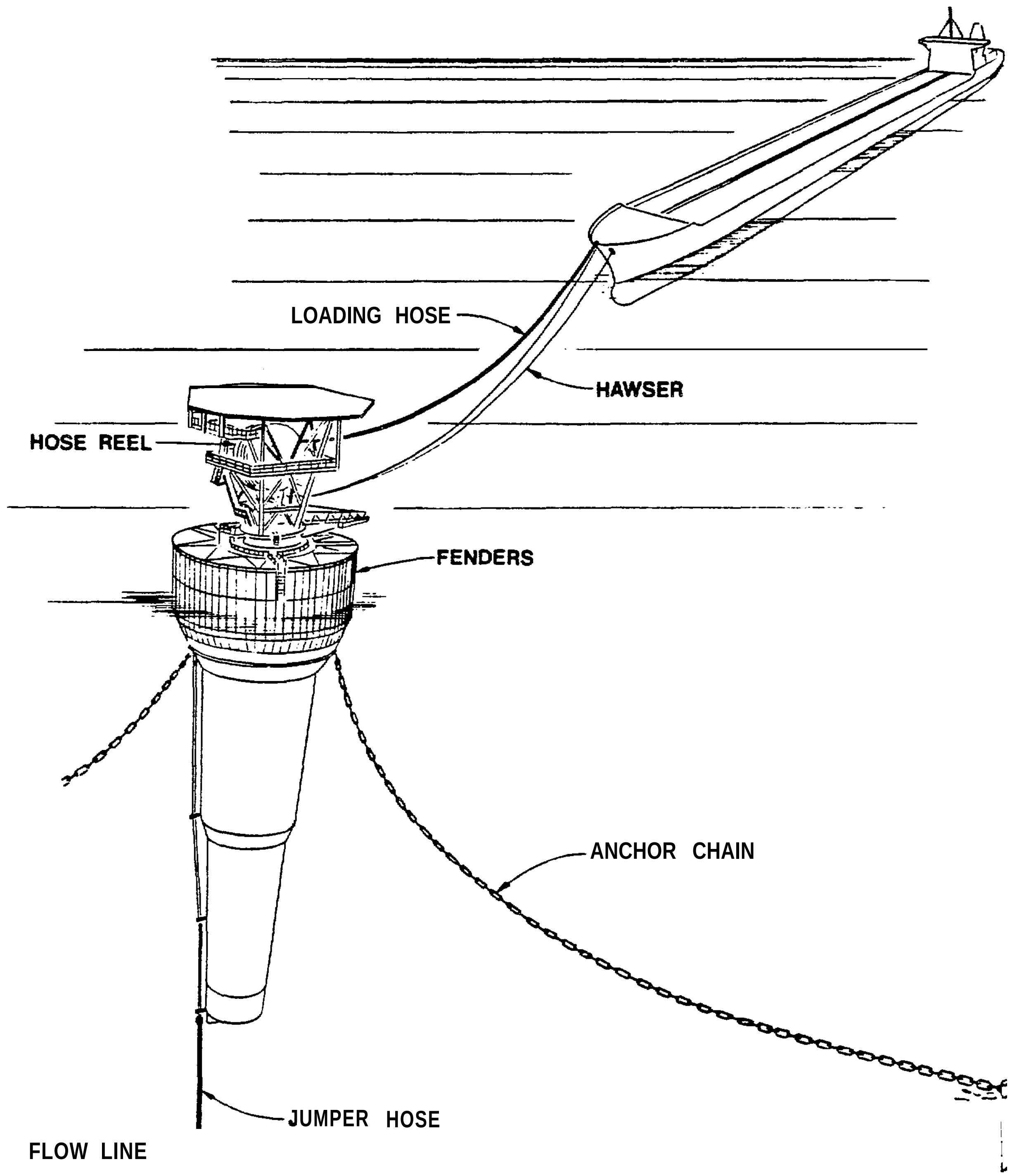


Figure A-5. Articulated **column** (AC).



HAN-PADRON ASSOCIATES
CONSULTING ENGINEERS

Figure A-6. Exposed location single buoy mooring (ELSBM).

and supports a turntable. The turntable contains a power supply unit, living quarters for three people, a helideck and winches for hauling floating hoses and hawsers.

Crude oil is transported to a flexible hose on the turntable through a hose from the seabed pipeline manifold to the bottom of the buoy, a pipeline along the outside of the buoy hull and a central swivel at the turntable. When not in use, the loading hose is coiled on a hose reel. During loading, the hose is partly unrolled and freely suspended from the reel to the tanker. A counterweight on the hose reel keeps the loading hose in equilibrium and serves to coil up the hose automatically after the loading operation has been completed.

A.3.5 SPAR

The SPAR is similar to the ELSBM but incorporates oil storage capacity within the buoy. Figure A-7 illustrates the Brent Field SPAR, the only one installed to date. It consists of three cylindrical sections placed one on top of the other with an overall height of 137 m (450 ft). The lowest section, the storage facility, is 93 m (305 ft) high with a diameter of 29.3 m (96 ft). Located above this is a 17 m (56 ft) diameter cylinder some 32 m (105 ft) high containing pumping and other equipment, A 12 m (39 ft) high by 26 m (85 ft) diameter cylindrical superstructure forming the top end of the SPAR houses power-generating equipment, control equipment, and

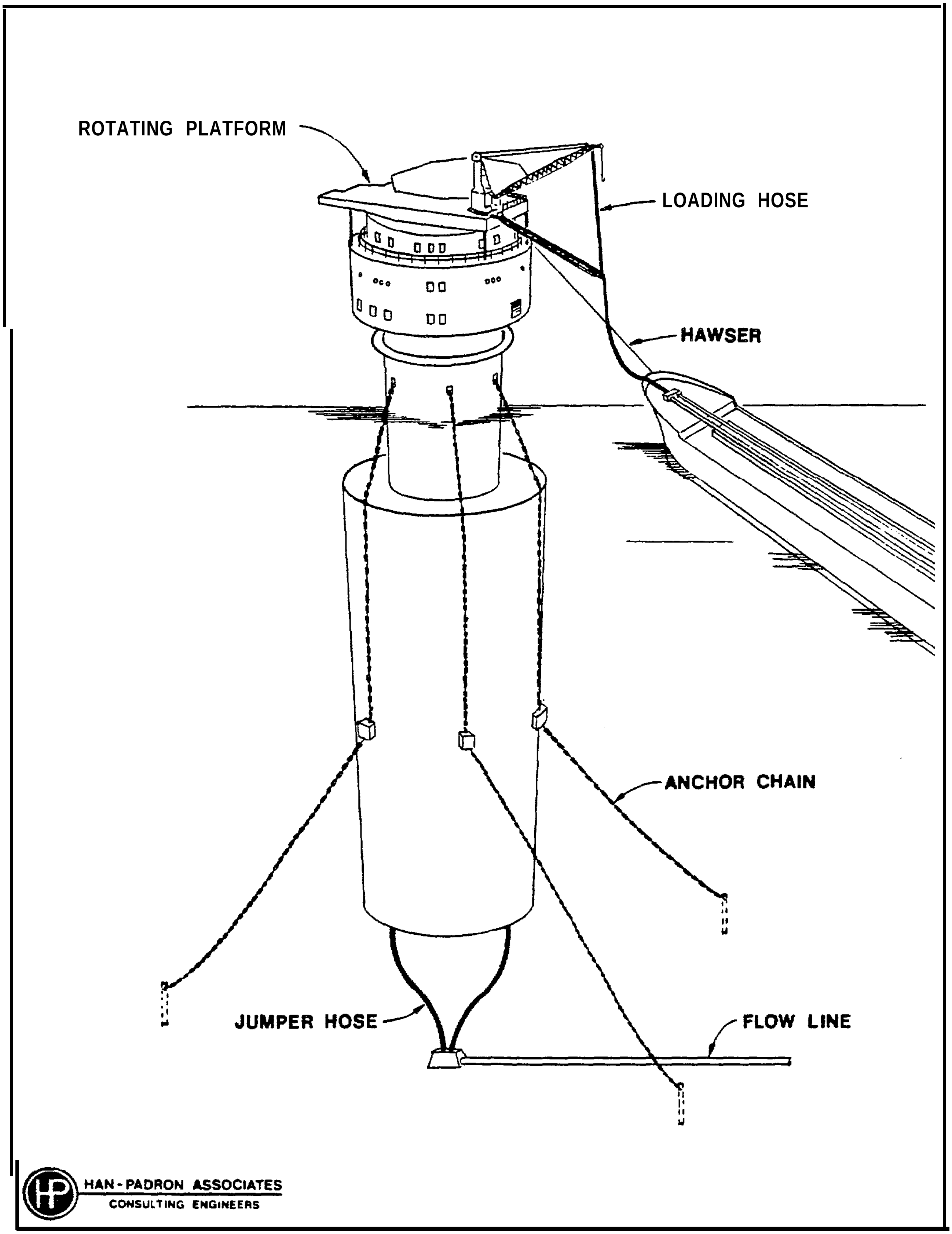


Figure A-7. SPAR.

crew quarters. Mooring and offloading facilities, together with a helipad, are incorporated in the turntable located on top of the superstructure (Bax 1974).

The SPAR has been designed to maintain a constant. draft in both the loaded and ballasted conditions, utilizing a seawater displacement system. Since there is a difference between the specific gravities of oil and seawater, not all of the storage compartments are filled with water when the unit is in ballast.

A.4 CHARACTERISTICS OF NORTH SEA OIL FIELDS UTILIZING OFFSHORE LOADING SYSTEMS

Considerable information is available concerning the characteristics of North Sea oil fields that utilize offshore loading systems for transporting crude oil and the characteristics of the offshore loading systems. This information is categorized and documented in Tables A-4 through A-19 for each of the eleven fields in the U.K. and Norwegian sectors that presently have an OLS installed. Where a field has more than one OLS, a separate table is provided for each OLS if they are not identical. Where information was not available, "N.A." appears in the tables. The construction cost listed for each is the cost in the year the OLS was installed.

In addition to the characteristics of the offshore loading systems and the oil fields, the tables contain a brief statement regarding the operator's philosophy with regard to the selection of the crude oil transportation system. This information is not available for every field.

TABLE A-4

ARGYLL FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Hamilton Bros.
Recoverable Reserves, MMbbl	78
Production Rate, bbl/day	Initial = 35,000; Current = 20,000; Design = 37,000
Distance to:	
nearest field, km (mi)	Auk, Ekofisk - 40 (25)
land base, km (mi)	Aberdeen - 305 (190)
Type of OLS	CALM
Vendor	SBM, Inc.
Year Installed	1974
Maximum Vessel, DWT	100,000 (only 45,000 used)
Hose System, no. x dia	1 x 12" [length = 90 m)
Piping System to OLS, no. x dia	1 x 10" (length = 2250 m)
Loading Rate, bbl/hr	2900
Water Depth, m (ft)	77 (252)
OLS Physical Characteristics	Weight - 392 tonnes
Auxiliary Systems	None
Construction Cost, $MM	1.8 (Replacement: 4.8; see Remarks)
Production Platform	Converted semi-submersible
Offshore Storage, bbl	None
Operator's Philosophy Re System Selection	Field is small and was to be developed at minimum capital investment.
Remarks	-To be replaced by larger CALM (560 t) serving Argyll and Duncan fields. -No storage; production stops when there is no tanker or tanker is unable to load. -Argyll production system is first floating (semi-submersible) system in North Sea. -Reserves include Duncan Field.

TABLE A-5

AUK FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Shel 1
Recoverable Reserves, MMbbl	66
Production Rate, bbl/day	Initial = 40,000; Current = 12,000; Design = 80,000
Distance to:	
nearest field, km (mi)	Fulmar - 16 (10)
land base, km (mi)	Aberdeen - 113 (70)
Type of 01S	ELSBM
Vendor	SBM, Inc.
Year Installed	1974
Maximum Vessel, DWT	42,000
Hose System, no. x dia	2 x 10" (length = 50 m)
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	12,500
Water Depth, m (ft)	85 (280)
OLS Physical Characteristics	Buoy: 11 m (36 ft) dia, 95 m (310 ft) lg; Weight: Buoy = 900 t; Column = 360 t; Head = 270 t; Fendering = 90 t; Solid Ballast = 1360 t
Auxiliary Systems	HeIi, Spare reel and hose, Ballast system
Construction Cost, $MM	12
Production Platform	Steel
Offshore Storage, bbl	None
Operator's Philosophy Re System Selection	-Low reserves could not justify pipeline or storage. -ELSBM rated by Shell as equal reliability to 2 CALM's but better accessibility.
Remarks	-Fabrication by IHC, Holland. -Catenary anchored, 8 chains. -Includes reel to maintain hoses out of water. -Reel, hydraulic brake, mooring system modified after installation.

TABLE A-6

BERYL A FIELD OFFSHORE LOADING SYSTEMC HARACTERISTICS

Operator	Mobil "
Recoverable Reserves, MMbbl	500
Production Rate, bbl/day	Actual = 92,000; Design = 200,000
Distance to:	
nearest field, km (mi)	Frigg - 56 (35)
land base, km (mi)	Orkney - 274 (170)
Type of OLS	AC
Vendor	EMH
Year Installed	1976
Maximum Vessel, DWT	80,000
Hose System, no. x dia	1 x 16"
Piping System to OLS, no. x dia	1 x 32" (length = 1600 m)
Loading Rate, bbl/hr	40,000
Water Depth, m (ft)	120 (395)
OLS Physical Characteristics	Column: 7 m (23 ft) dia, 165 m (540 ft) lg; Boom: 37 m (120 ft.) lg; Weight: Column = 2000 t, Head = 180 t
Auxiliary Systems	Living quarters, Generator, Heli, Surge tank
Construction Cost, $MM	20
Production Platform	Concrete
Offshore Storage, bbl	900,000
Operator's Philosophy Re System Selection	-Reserves too small for 170 km pipeline. -Desire to minimize submarine and floating hose exposure to seawater.
Remarks	-300 tanker loadings in 4-1/2 years. -Gravity base includes iron ballast. -First field with AC.

TABLE A-7

BERYL B FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Mobil
Recoverable Reserves, MMbbl	300
Production Rate, bbl/day	Design = 100,000
Distance to: nearest field, km (mi) land base, km (mi)	 Frigg - 56 (35) Orkney - 274 (170)
Type of OLS	AC
Vendor	EMH
Year Installed	1982
Maximum Vessel, DWT	80,000
Hose System, no. x dia	1 x 20"
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	50,000
Water Depth, m (ft)	120 (395)
OLS Physical Characteristics	N.A.
Auxiliary Systems	Shelter, Winch-down heli (See Remarks)
Construction Cost, $MM	61
Production Platform	Steel
Offshore Storage, bbl	Uses Beryl A storage.
Operator's Philosophy Re System Selection	Consistent with Beryl A.
Remarks	-Mobil minimized auxiliaries on Beryl B as a result of high capital and operating costs at Statfjord. Hose and hawser handling simplified. Hose is dropped into water after loading and replaced annually.

TABLE A-8

BRENT (1) FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Shell
Recoverable Reserves, MMbbl	2000
Production Rate, bbl/day	Actual = 382,000; Design = 550,000
Distance to:	
nearest field, km (mi)	Statfjord - 24 (15)
land base, km (mi)	Shetland Is. - 177 (110)
Type of OLS	SPAR
Vendor	SBM, Inc.
Year Installed	1976
Maximum Vessel, DWT	108,000
Hose System, no. x dia	2 x 12" plus 2 x 8" subsea
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	40,000 (Receives 100,000 bbl/day)
Water Depth, m (f't)	140 (460)
OLS Physical Characteristics	Buoy: 29 m (95 ft) dia; 137 m (450 ft) lg.
Auxiliary Systems	Living quarters, Generator, Heli, Storage, Boom, Loading pumps, Related controls
Construction Cost, $MM	25
Production Platform	1 steel, 3 concrete
Offshore Storage, bbl	2,750,000
Operator's Philosophy Re System Selection	-Required early production prior to pipeline. -Considered crude oil storage necessary.
Remarks	-SPAR includes 300,000 bbl storage. -Catenary anchored, 6 chains. -Water ballast system maintains draft. -Now on standby service.

TABLE A-9

BRENT (2) FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Shell
Recoverable Reserves, MMbbl	2000
Production Rate, bbl/day	Actual = 382,000; Design = 550,000
Distance to:	
nearest field, km (mi)	Statfjord - 24 (15)
land base, km (mi)	Shetland Is. - 177 (110)
Type of OLS	CALM
Vendor	SBM, Inc.
Year Installed	1977
Maximum Vessel, DWT	80,000
Hose System, no. x dia	1 X 16"
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	N.A.
Water Depth, m (ft)	140 (460)
OLS Physical Characteristics	Weight: 400 tonnes
Auxiliary Systems	None
Construction Cost, $MM	3
Production Platform	1 steel, 3 concrete
Offshore Storage, bbl	2,750,000
Operator's Philosophy Re System Selection	Required early production prior to pipeline.
Remarks	Now on standby service.

TABLE A-10

BUCHAN FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	BP
Recoverable Reserves, MMbbl	60
Production Rate, bbl/day	Actual = 32,000; Design = 72,000
Distance to:	
nearest field, km (mi)	Forties - 48 (30)
land base, km (mi)	Aberdeen - 161 (100)
Type of OLS	CALM
Vendor	IMODCO
Year Installed	1979
Maximum Vessel, DWT	115,000
Hose System, no. x dia	1 x 12"
Piping System to OLS, no. x dia	1 x 12" (length = 1,800 m)
Loading Rate, bbl/hr	3,000
Water Depth, m (ft)	112 (369)
OLS Physical Characteristics	Buoy: 15 m (50 ft) dia; Weight: 240 tonnes
Auxiliary Systems	None
Construction Cost, $MM	12
Production Platform	Converted semi-submersible
Offshore Storage, bbl	3,500
Operator's Philosophy Re System Selection	This small field development was initiated by a small oil company (Transworld). The philosophy of low capital investment development was maintained by BP.
Remarks	-Floating (semi-submersible) production system. -Piggable with receiver on tanker.

TABLE A-11

EKOFISK (1) FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Phillips
Recoverable Reserves, MMbbl	3,800 (All fields in Ekofisk area)
Production Rate, bbl/day	Actual = 314,000; Design = 800,000
Distance to:	
nearest field, km (mi)	Fulmar - 56 (35)
land base, km (mi)	Stavinger - 305 (190)
Type of OLS	CALM
Vendor	SBM, Inc.
Year Installed	1971
Maximum Vessel, DWT	60,000
Hose System, no. x dia	1 x 12" (increased to 20") (length = 100 m)
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	N.A.
Water Depth, m (ft)	71 (232)
OLS Physical Characteristics	Weight: 360 tonnes
Auxiliary Systems	None
Construction Cost, $MM	2.5
Production Platform	15 steel, 1 concrete
Offshore Storage, bbl	1,000,000
Operator's Philosophy Re System Selection	To be used until pipeline installed.
Remarks	Now on standby service.

TABLE A-12

EKOFISK (2) FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Phillips
Recoverable Reserves, MMbbl	3,800 (All fields in Ekofisk area)
Production Rate, bbl/day	Actual = 314,(.)00; Design = 800,000
Distance to: nearest field, km (mi) land base, km (mi)	 Fulmar - 56 (35) Stavinger - 305 (190)
Type of OLS	CALM
Vendor	SBM, Inc.
Year Installed	1971
Maximum Vessel, DWT	150,000
Hose System, no. x dia	1 x 12" (increased to 20") (length = 100 m)
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	N.A.
Water Depth, m (ft)	63 (208)
OLS Physical Characteristics	Weight: 360 tonnes
Auxiliary Systems	None
Construction Cost, $MM	2.5
Production Platform	15 steel, 1 concrete
Offshore Storage, bbl	1,000,000
Operator's Philosophy Re System Selection	To be used until pipeline installed.
Remarks	Now on standby service.

TABLE A-13

FULMAR FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Shell
Recoverable Reserves, MMbbl	500
Production Rate, bbl/day	Actual = 150,000; Design = 180,000
Distance to: nearest field, km (mi) land base, km (mi)	 Auk - 56 (35) Aberdeen - 274 (170)
Type of OLS	SALM
Vendor	Shell/Exxon with Ocean Resources
Year Installed	1981
Maximum Vessel, DWT	210,000 (Permanent); 110,000 (Transport)
Hose System, no. x dia	2 X 16″
Piping System to OLS, no. x dia	1 X 16″ (length = 2200 m)
Loading Rate, bbl/hr	36,500
Water Depth, m (ft)	85 (280)
OLS Physical Characteristics	Buoy: 3-8-16 m (10-26-52 ft) dia, 96 m (315 ft) lg; Arm: 61 m (200 ft) lg, 30 m (100 ft) width; Weight: Arm = 815 t, Articulation = 360 t, Buoy = 1830 t, Base = 800 t
Auxiliary Systems	SALM connected to storage tanker
Construction Cost, $MM	40, plus 60 for tanker conversion
Production Platform	2 Steel
Offshore Storage, bbl	1,300,000
Operator's Philosophy Re System Selection	-Rejected pipeline due to cost and lack of spare capacity. -Shallow water favored SALM over SPAR.
Remarks	-Permanently yoke-moored storage tanker. -Transport tanker loaded in tandem. -Heaviest North Sea lift to that time. -Combination gravity and piled base.

TABLE A-14

MAUREEN FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Phillips
Recoverable Reserves, MMbbl	150
Production Rate, bbl/day	Design = 80,000
Distance to: nearest field, km (mi) land base, km (mi)	 Forties - 64 (40) Aberdeen - 258 (160)
Type of OLS	AC
Vendor	EMH
Year Installed	1982
Maximum Vessel, DWT	85,000
Hose System, no. x dia	2 X 16"
Piping System to OLS, no. x dia	1 x 24" (length = 2200 m)
Loading Rate, bbl/hr	20,000
Water Depth, m (ft)	93 (305)
OLS Physical Characteristics	Column: 9m (30 ft) dia, 101 m (331 ft) lg; Weight: Column = 3070 t conc, 155 t steel, Articulation = 258 t, Head = 240t, Base = 4160 t, Ballast = 1900 t
Auxiliary Systems	Surge tank, Winch-down heli
Construction Cost, $MM	40
Production Platform	Steel gravity
Offshore Storage, bbl	650,000
Operator's Philosophy Re System Selection	-Marginal field, no pipeline intended. -Phillips analysis indicated AC cost 2 x CALM and 1.25 x SALM. AC selected based on estimated 92% availability and reduced maint.
Remarks	-Only existing concrete AC. -Structure economical in U.K. waters but does not meet Norwegian criteria which would require double concrete ringed column.

TABLE A-15

MONTROSE FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Amoco
Recoverable Reserves, MMbbl	100
Production Rate, bbl/day	Actual = 15,000; Design = 60,000
Distance to: nearest field, km (mi) land base, km (mi)	 Forties - 47 (29) Aberdeen - 241 (150)
Type of OLS	2 CALM's
Vendor	SBM, Inc.
Year Installed	1975
Maximum Vessel, DWT	72,000
Hose System, no. x dia	1 x 10" plus 1 x 10" underbuoy
Piping System to OLS, no. x dia	1 x 10" (length = 1600 m)
Loading Rate, bbl/hr	2,000
Water Depth, m (ft)	93 (304)
OLS Physical Characteristics	Weight: 385 tonnes each
Auxiliary Systems	None
Construction Cost, $MM	2.5 each
Production Platform	Steel
Offshore Storage, bbl	None
Operator's Philosophy Re System Selection	-Installed 2 CALM's to improve availability. -Regrets not connecting to Forties pipeline.
Remarks	-No storage; production stops when no tanker is available or tanker is unable to load. -Two buoys allow second tanker to moor in good weather while first tanker loads. -To be replaced by pipeline to Forties Field in 1985.

TABLE A-16

STATFJORD A FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Mobil
Recoverable Reserves, MMbbl	3,000 (all fields)
Production Rate, bbl/day	Actual = 310,000; Design = 300,000
Distance to:	
nearest field, km (mi)	Brent - 24 (15)
land base, km (mi)	Bergen - 241 (150)
Type of OLS	AC
Vendor	EMH
Year Installed	1978
Maximum Vessel, DWT	125,000
Hose System, no. x dia	2 x 20″
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	60,000
Water Depth, m (ft)	146 (480)
OLS Physical Characteristics	Weight of Head: 410 tonnes
Auxiliary Systems	Living quarters, 3 Generators, Heli, Surge tank
Construction Cost, $MM	60
Production Platform	Concrete
Offshore Storage, bbl	1,300,000
Operator's Philosophy Re System Selection	Pipeline would require crossing deep, Norwegian Trench.
Remarks	-250 tanker loadings in 3-1/2 years. -Statfjord ACs considered by Mobil as excessively outfitted with auxiliary systems. Design simplified for Beryl B.

TABLE A-17

STATFJORD B FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Mobil
Recoverable Reserves, MMbbl	3,000 (all fields)
Production Rate, bbl/day	Actual = 140,000; Design = 180,000
Distance to: nearest field, km (mi) land base, km (mi)	 Brent - 24 (15) Bergen - 241 (150)
Type of OLS	AC
Vendor	SBM, Inc.
Year Installed	1982
Maximum Vessel, DWT	150,000
Hose System, no. x dia	1 x 20"
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	60,000
Water Depth, m (ft)	146 (480)
OLS Physical Characteristics	Column: 9 m (30 ft) dia, 181 m (595 ft) lg; Weight: Column = 2720 t, Articulation = 250 t, Base = 860 t
Auxiliary Systems	Living quarters, 3 Generators, Heli, Surge Tank
Construction Cost, $MM	110
Production Platform	Concrete
Offshore Storage, bbl	1,900,000
Operator's Philosophy Re System Selection	Pipeline would require crossing deep, Norwegian Trench.
Remarks	Incurred high costs due to replacement of defective steel.

TABLE A-18

STATFJORD C FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	Mobil
Recoverable Reserves, MMbbl	3,000 (all fields)
Production Rate, bbl/day	Design = 210,000
Distance to: nearest field, km (mi) land base, km (mi)	 Brent - 24 (15) Bergen - 241 (150)
Type of OLS	AC
Vendor	SBM, Inc.
Year Installed	Due 1984
Maximum Vessel, DWT	150,000
Hose System, no. x dia	1 x 20"
Piping System to OLS, no. x dia	N.A.
Loading Rate, bbl/hr	60,000
Water Depth, m (ft)	146 (480)
OLS Physical Characteristics	Weight: Column = 3630 t, Head = 450 t, Articulation = 270 t, Base = 900 t
Auxiliary Systems	Living quarters, 3 Generators, Heli, Surge tank
Construction Cost, $MM	100
Production Platform	Concrete
Offshore Storage, bbl	1,900,000
Operator's Philosophy Re System Selection	Pipeline would require crossing deep, Norwegian Trench.
Remarks	Under construction.

TABLE A-19

THISTLE FIELD OFFSHORE LOADING SYSTEM CHARACTERISTICS

Operator	BNOC
Recoverable Reserves, MMbbl	500
Production Rate, bbl/day	Actual = 115,000 (has achieved 180,000); Design = 260,000
Distance to:	
nearest field, km (mi)	Murchison - 16 (10)
land base, km (mi)	Shetland Is. - 200 (125)
Type of OLS	SALM
Vendor	SBM, Inc.
Year Installed	1976
Maximum Vessel, DWT	120,000
Hose System, no. x dia	2 x 16" (attached at 46 m (150 ft) depth)
Piping System to OLS, no. x dia	1 x 16" (length = 2400 m)
Loading Rate, bbl/hr	20,000
Water Depth, m (ft)	163 (535)
OLS Physical Characteristics	Riser: 2.5 m (8 ft) dia, 101 m (331 ft) lg; Buoy: 4 m (13 ft) dia, 56 m (185 ft) lg; Base: 15 m (48 ft) wide, 7 m (22 ft) high
Auxiliary Systems	Batteries, Hydraulic/pneumatic control system
Construction Cost, $MM	18.5
Production Platform	Steel
Offshore Storage, bbl	70,000
Operator's Philosophy Re System Selection	-Installed to achieve early revenue until Brent pipeline available. -To improve availability, design improved with respect to instrumentation and accessibility.
Remarks	-Now on standby service. -Tubular riser. -Includes 2 U-joints (1 at base/riser, and 1 at 46 m (150 ft) water depth).

A.5 PERFORMANCE OF NORTH SEA OFFSHORE LOADING SYSTEMS

There are a number of different types of offshore loading systems operating in the North Sea and within each general type there is a wide range of variations. Therefore, a comparison of the performance of the various systems is extremely difficult and must be kept. fairly general. The actual performance of a particular system depends on a great many factors including:

- sea conditions,
- water depth,
- throughput,
- maintenance,
- operational procedures,
- initial capital investment.

There are no locations in the North Sea that have more than one type of offshore loading system. Since no two systems are subjected to the same conditions, comparisons between different systems at different locations can only be on a qualitative basis.

Where information on weather downtime, downtime due to buoy repairs, weather limitations for mooring and loading, etc., is available, it is still difficult to make a reliable comparison between the performance of different loading systems because:

- data collection is not uniform,
- often wave data are based on imprecise visual observations ,

- some locations include storage facilities which have a significant influence on OLS performance,
- the availability of a second OLS influences the loading performance.

A summary of the performance of North Sea offshore loading systems by types is presented in Table A-20. The specified operating limitations and reported performance of each of the offshore loading systems evaluated are presented in Tables A-21 through A-36. Operating history is presented in the form of reported availability of the OLS, with an indication of the cause of the non-availability or downtime.

Note that the availability and downtime indicated in Tables A-20 through A-36 are based on operators' reports of the occasions when a tanker was required to standby due to severe weather or maintenance operations. Thus, periods of time when the OLS was unavailable due to severe weather or maintenance operations but no tanker was standing by are not recorded as downtime. This is different than the definition of availability and downtime used in the body of this report. For the optimization analyses, weather downtime is defined as those periods of time when the weather is too severe to permit mooring or loading operations, regardless of whether or not a tanker is required to wait. For maintenance downtime estimates, it has been assumed in the body of this report that most maintenance operations can be performed during periods of time when no tanker is scheduled to call and unplanned maintenance has only a small effect on overall availability to OLS.

An evaluation of the data in Tables A-20 through A-36 leads to the following general conclusions regarding North Sea offshore loading system performance:

1. All offshore loading systems require substantial maintenance.
2. Where offshore storage is provided, the offshore loading systems can be preventively maintained to virtually eliminate loss of production due to maintenance downtime.
3. As the size and cost of the offshore loading system increases, its availability increases.

TABLE A-20

SUMMARY OF NORTH SEA OFFSHORE LOADING SYSTEM PERFORMANCE

PERFORMANCE CRITERIA	TYPE OF OFFSHORE LOADING SYSTEM: CALM	SALM	ELSBM & SPAR	AC
Operating Wave (Significant), m (ft)				
Mooring	2 (6.5)	3 (10)	3 (10)	4 (13)
Loading	4 (13)	4.5 (15)	5 (16)	5.5 (18)
Overall Availability, %	70	80	85	97
Weather Downtime, %	20	10	10	2
Maintenance Downtime, %	10	10	5	1

There is no disclosure of reservoir damage due to offshore loading system downtime. If reservoir damage were to occur the prime candidates would be those fields with long OLS history and no storage to compensate for OLS unavailability. These fields are Argyll, Auk, Buchan and Montrose. All have experienced about 25 percent downtime due to OLS unavailability for reasons of maintenance and weather and all have current production rates substantially below initial. Since these fields are generally marginal, to what degree downtime due to OLS unavailability is related to poor reservoir performance is unknown. However, Amoco has recently reported that they expect the installation of a pipeline at the Montrose Field, replacing the existing OLS, to improve reservoir performance by increasing recoverable reserves approximately 1.5 million barrels or approximately 1.5 percent.

TABLE A-21

ARGYLL FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	CALM
Water Depth, m (ft)	77 (252)
Operating Wave (Significant), m (ft)	
Mooring	4.5 (15)
Loading	N.A.
Survival Wave (Maximum), m (ft)	N.A.*
Operating Wind, m/s (knots)	13 (25)
Survival Wind, m/s (knots)	N.A.
Overall Availability, %	77
Weather Downtime, %	13
Maintenance Downtime, %	10

Remarks: *Could not be designed for 100-year (maximum) wave.

TABLE A-22

AUK FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	ELSBM
Water Depth, m (ft)	85 (280)
Operating Wave (Significant), m (ft)	
Mooring	3 (10)
Loading	5 (16)
Survival Wave (Maximum), m (ft)	23 (75)
Operating Wind, m/s (knots)	25 (50)
Survival Wind, m/s (knots)	43 (85)
Overall Availability, %	78
Weather Downtime, %	15
Maintenance Downtime, %	7

TABLE A-23

BERYL A FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	AC
Water Depth, m (ft)	120 (395)
OperatingWave (Significant), m (ft)	
Mooring	4 (14)
Loading	5.5 (18)
Survival Wave (Maximum), m (ft)	29 (96)
Operating Wind, m/s (knots)	N.A.
Survival Wind, m/s (knots)	56 (110)
Overall Availability, %	99.5
Weather Downtime, %	
Maintenance Downtime, %	

TABLE A-24

BERYL B FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	AC
Water Depth, m (ft)	120 (395)
Operating Wave (Significant), m (ft)	
Mooring	4 (14)
Loading	5.5 (18)
Survival Wave (Maximum), m (ft)	28 (92)
Operating Wind, m/s (knots)	31 (61)
Survival Wind, m/s (knots)	51 (loo)
Overall Availability, %	1983 Startup
Weather Downtime, %	
Maintenance Downtime, %	

TABLE A-25

BRENT (1) FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	SPAR
Water Depth, m (ft)	140 (460)
Operating Wave (Significant), m (ft)	
Mooring	3 (10)
Loading	5 (16)
Survival Wave (Maximum), m (ft)	32 (105)
Operating Wind, m/s (knots)	21 (40)
Survival Wind, m/s (knots)	68 (133)
Overall Availability, %	88
Weather Downtime, %	10
Maintenance Downtime, %	2

Remarks: Now on standby service.

TABLE A-26

BRENT (2) FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	CALM
Water Depth, m (ft)	140 (460)
Operating Wave (Significant), m (ft)	
Mooring	N.A.
Loading	N.A.
Survival Wave (Maximum), m (ft)	N.A.
Operating Wind, m/s (knots)	N.A.
Survival Wind, m/s (knots)	N.A.
Overall Availability, %	N.A.
Weather Downtime, %	N.A.
Maintenance Downtime, %	N.A.

Remarks: Now on standby service.

TABLE A-27

BUCHAN FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	CALM
Water Depth, m (ft)	112 (369)
Operating Wave (Significant), m (ft)	
Mooring	3.5 (11.5)
Loading	5 (18)
Survival Wave (Maximum), m (ft)	N.A.*
Operating Wind, m/s (knots)	N.A.
Survival Wind, m/s (knots)	N.A.
Overall Availability, %	72
Weather Downtime, %	N.A.
Maintenance Downtime, %	N.A.

Remarks: *Could not be designed for 100-year (maximum) wave.

TABLE A-28

EKOFISK (1) FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	CALM
Water Depth, m (ft)	71 (232)
Operating Wave (Significant), m (ft)	
Mooring	N.A.
Loading	N.A.
Survival Wave (Maximum), m (ft)	N.A.*
Operating Wind, m/s (knots)	N.A.
Survival Wind, m/s (knots)	N.A.
Overall Availability, %	60
Weather Downtime, %	N.A.
Maintenance Downtime, %	N.A.

Remarks: *Could not be designed for 100-year (maximum) wave.

Now on standby service.

TABLE A-29

EKOFISK (2) FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	CALM
Water Depth, m (ft)	63 (208)
Operating Wave (Significant), m (ft)	
Mooring	N.A.
Loading	N.A.
Survival Wave (Maximum), m (ft)	N.A.*
Operating Wind, m/s (knots)	N.A.
Survival Wind, m/s (knots)	N.A.
Overall Availability, %	60
Weather Downtime, %	N.A.
Maintenance Downtime, %	N.A.

Remarks: *Could not be designed for 100-year (maximum) wave.

Now on standby service.

TABLE A-30

FULMAR FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	SALM
Water Depth, m (ft)	85 (280)
Operating Wave (Significant), m (ft)	
Mooring	3 (10)
Loading	4.5 (15)
Survival Wave (Maximum), m (ft)	27 (88)
Operating Wind, m/s (knots)	20 (39)
Survival Wind, m/s (knots)	44 (86)
Overall Availability, %	N.A.
Weather Downtime, %	N.A.
Maintenance Downtime, %	N.A.

Remarks: Permanently moored storage tanker moored by yoke to SALM. Transport tanker moored in tandem.

TABLE A-31

MAUREEN FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	AC
Water Depth, m (ft)	93 (305)
Operating Wave (Significant), m (ft)	
Mooring	N.A.
Loading	5.5 (18)
Survival Wave (Maximum), m (ft)	N.A.
Operating Wind, m/s (knots)	25 (49)
Survival Wind, m/s (knots)	45 (88)
Overall Availability, %	92
Weather Downtime, %	N.A.
Maintenance Downtime, %	N.A.

TABLE A-32

MONTROSE FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of 01S	(2) CALM's
Water Depth, m (ft)	93 (304)
Operating Wave (Significant), m (ft)	
Mooring	1.5 (5)
Loading	4 (13)
Survival Wave (Maximum), m (ft)	N.A.*
Operating Wind, m/s (knots)	25 (49)
Survival Wind, m/s (knots)	45 (88)
Overall Availability, %	76
Weather Downtime, %	18
Maintenance Downtime, %	6

Remarks: *Could not be designed for 100-year (maximum) wave.

To be replaced by pipeline to Forties Field in 1985.

TABLE A-33

STATFJORD A FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	AC
Water Depth, m (ft)	146 (480)
Operating Wave (Significant), m (ft)	
Mooring	N.A.
Loading	5.5 (18)
Survival Wave (Maximum), m (ft)	28 (92)
Operating Wind, m/s (knots)	31 (61)
Survival Wind, m/s (knots)	51 (100)
Overall Availability, %	99
Weather Downtime, %	
Maintenance Downtime, %	

Remarks: Maintained daily by crew of four on twelve hour shift. Loading carried out around-the-clock.

TABLE A-34

STATFJORD B FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	AC
Mater Depth, m (ft)	146 (480)
Operating Wave (Significant), m (ft)	
Mooring	N.A.
Loading	5.5 (18)
Survival Wave (Maximum), m (ft)	30 (loo)
Operating Wind, m/s (knots)	21 (41)
Survival Wind, m/s (knots)	63 (124)
Overall Availability, %	99
Weather Downtime, %	
Maintenance Downtime, %	

TABLE A--35

STATFJORD C FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	AC
Water Depth, m (ft)	146 (480)
Operating Wave (Significant.), m (ft)	
Mooring	N.A.
Loading	5.5 (18)
Survival Wave (Maximum), m (ft)	30 (100)
Operating Wind, m/s (knots)	21 (41)
Survival Wind, m/s (knots)	63 (124)
Overall Availability, %	1984 Start-up
Weather Downtime, %	
Maintenance Downtime, %	

Remarks: Under construction.

TABLE A-36

THISTLE FIELD OFFSHORE LOADING SYSTEM

OPERATING LIMITATIONS AND PERFORMANCE

Type of OLS	SALM
Water Depth, m (ft)	163 (535)
Operating Wave (Significant), m (ft.)	
Mooring	3 (10)
Loading	4.5 (15)
Survival Wave (Maximum), m (ft)	30 (98)
Operating Wind, m/s (knots)	25 (49)
Survival Wind, m/s (knots)	50 (98)
Overall Availability, %	80.5
Weather Downtime, %	10
Maintenance Downtime, %	9.5

Remarks: Now on standby service.

A.5.1 General Offshore Loading System Maintenance Problems

In general, North Sea offshore loading system operating and maintenance problems can be characterized, from the sea floor upward, as follows:

a) PLEM/Riser Connection

Leaks have occurred where the pipeline end manifold (PLEM) connects with the riser to the offshore loading system, particularly where the subsea product line from the production facility has been hard piped to the fluid riser at the universal joint of articulated columns. Failing successful seal repairs, bypass hoses have been installed successfully.

b) Underbuoy and Floating Hoses

One of the most common offshore loading system problems is associated with the hoses, both underbuoy and floating hoses. Due to wave action, improper handling and inadequate materials, the hoses have kinked, twisted, deteriorated and failed at the connections. As a result, many operating companies have advanced their maintenance programs to replace the hoses at regular periods, regardless of condition, rather than risk failure with consequent interrupted loading operations. Also, hose technology has advanced considerably. Concerned oil companies have formed a user's organization which, in association with regulatory agencies, has established standards for hose materials, construction, manufacturing, and quality control.

Operators of large, costly facilities have chosen to avoid most of the floating hose problems associated with long term hose residence in the sea by using the articulated column and the ELSBM. One operator has concluded that hose life can be extended by allowing it to simply hang about 9 m (30 ft) into the water from the articulated column boom rather than transfer it from the boom to the loading tanker and back after each loading. Designers of the Thistle Field SALM chose to keep the hose totally submerged to avoid wave action. The hose is connected to the buoy at a depth of 52 m (170 ft), hangs to 107 m (350 ft) deep and, when not loading, terminates 15 m (50 ft) below the surface.

c) Bearings

The proper selection, design and maintenance of bearings for offshore loading systems is critical to the successful operation of these systems. In most systems that incorporate large bearings, a bearing failure can lead to long shutdown periods and extremely costly repairs. Preventing seawater access to roller bearings is an extremely important consideration in the design of bearings and their' supporting structures. This is normally achieved by providing water barriers on the structure, by providing the bearings with integral seals or by a combination of these methods.

Proper maintenance is essential in order for roller bearings to have a reasonable service life in the marine environment. Maintenance generally consists of lubricating the bearings on a regular basis. The recommended interval between lubrications varies depending on the manufacturer, operator and degree of exposure. Typically, the interval used is between one week and one month.

d) Fluid Swivels

All single point mooring systems contain fluid swivels to permit the tanker to rotate about the mooring and all fluid swivels require maintenance and occasional overhaul. The location, arrangement and details of the fluid swivel assembly in the different types of mooring systems varies considerably. CALM's and some types of articulated column moorings utilize non-submerged fluid swivels while SALM's and some other types of articulated column moorings utilize submerged fluid swivels.

The main difference between the submerged and non-submerged swivels is that the submerged swivels normally have two external seawater seals and two internal crude oil or product seals while the non-submerged swivels have only one external seal and two internal seals. Problems that do occur with fluid swivels usually involve the seals.

e) Hawsers

The SPM hawser consists of a synthetic rope spliced to form an endless strop or with splices at each end. Hawsers are a particularly vulnerable portion of most offshore loading facilities because they usually float free when not in use and are subjected to extremely high loading when a ship is moored. Consequently, the two main problems are abrasion and fatigue. At present, these problems cannot be eliminated but they can be minimized by proper selection of hawser materials, proper design of hawser connection and support details, and proper operation of the OLS to eliminate overloading of the hawser.

There are no established rules for hawser replacement. Research is being carried out to develop a relationship among number of load cycles, magnitude of load and remaining useful life of hawsers. Of course, for such a development to be useful it would be necessary to install load-monitoring equipment on the OLS. In addition to predicting hawser useful life, the use of a load-monitoring system will decrease the probability of overloading the hawser and of a hawser failure by keeping the vessel's master aware of the load level in the hawser. There are several load-monitoring systems available and in use in the North Sea but their use is by no means universal. The present practice of OLS terminal operators regarding hawser replacement varies greatly. Some North Sea terminals retire hawsers after only one month of service while other terminals utilize a hawser for three months or more.

A.5.2 Specific Instances of Offshore Loading System Problem

The following discussion of North Sea offshore loading system problems is based on interviews with representatives of manufacturers of offshore loading systems and oil companies, published articles and the authors' experience. It is by no means a complete evaluation of all problems that have occurred but is provided to illustrate the diversity of problems that can occur. No conclusions should be drawn regarding the quality of a particular type of mooring or of the mooring of a particular manufacturer. The number of OLSS designed and installed by each manufacturer varies greatly so the absolute number of specific problems discussed below provides no information regarding the percentage of successful versus unsuccessful systems of a particular manufacturer. Also, and more importantly, the philosophy of the various manufacturers and oil companies regarding publicizing problems which their systems have encountered varies greatly. Some are quite willing to volunteer this type of information while others will only provide limited replies to specific questions.

a) Argyll Field

The Argyll Field CALM experienced problems with the buoy turntable. The mooring was taken out of service and the buoy was taken to shore for repair of the main bearing.

b) Auk Field

The Auk Field's Exposed Location Single Buoy Mooring (ELSBM) started tanker loading operations in January 1976. During the first year of operation the downtime due to buoy repairs was high. These breakdowns were mainly due to mooring rope failures, which also caused damage to the counterweight arrangements and to reel hoses.

To improve operational efficiency some minor modifications to the original ELSBM concept were introduced (Versluis 1980). The hydraulic brakes of ropes and hose reel are now activated after the tanker mooring operation is finished. In the case of a mooring rope failure the counterweight system is no longer subject to failure. The introduction of a weak link in the reel hose eliminated damage to the reel hose in the case of a mooring rope failure. Also, to minimize mooring rope failures, the mooring hawser is changed every four weeks.

Although the buoy has been designed for a maximum mooring load of 180 tonnes, loading is stopped and the hose is disconnected if the hawser tension, which is constantly monitored and recorded, reaches 70 tonnes. If hawser tension reaches 90 tonnes, the tanker departs from the buoy.

Downtime due to buoy repairs have been nearly eliminated by the above measures. However, due to limitations in the allowable mooring load, the yearly weather downtime is approximately 15 percent (Versluis 1980).

c) Beryl Field

The Beryl "A" articulated column had an initial design provision for the hose to be stored in a catenary configuration suspended between the boom tip and t-he hawser fairlead with the hawser in the retrieved position. The hose strings required extremely frequent replacement, probably because the arrangement of storing the loading hose in the catenary configuration created severe fatigue loadings on the hose string. The problem was solved by allowing the hose string to hang vertically from the boom tip, with the lower end submerged in the sea, thus damping the hose movement. The boom had to be reinforced to accommodate this new hose configuration.

d) Buchan Field

In its first year of operation the Buchan CALM experienced premature wear of the mooring hawser chafe chain links where the chain rubs on the tanker bow apron. Also, the weak link bolts in the loading hose end stretched. At about the same time a failure of the weak link shackle on the mooring hawser occurred due to fatigue cracking at a load of 30 tonnes (design breaking load was 270 tonnes). This resulted in the parting of the weak link bolts in the loading hose end unit. Pollution was minimized by automatic shutdown of the system.

Following another crack in the weak link shackle, the shackle was redesigned and has not failed since. However, the hawser parted at 110 tonnes versus its upgraded design breaking load of 490 tonnes. Two weeks later the hawser parted again at about 120 tonnes. The hawser became entangled with a CALM mooring chain and had to be cut free. For reinstallation a stellite coated chafe chain was used to obtain longer wear. Chafe chain life was doubled but it was still susceptible to wearing against the tanker bow. The weak link bolts in the hose end unit were replaced with bolts of a different material and stretching has not recurred.

Recurring maintenance problems with the buoy, including a jammed turntable, have also been reported.

e) Maureen Field

The Maureen Field articulated column has reportedly had trouble retrieving hoses due to the angle of the tanker bow slot. The configuration was revised to solve the problem.

f) Montrose Field

During the first three years of operations with the Montrose

CALMS, there were a number of problems which resulted in downtime (Fairbrother 1979). The two components requiring major repairs were the floating hose and the mooring hawser. Since there are two buoys, downtime incurred due to repairs is significantly reduced because regular preventive maintenance can be carried out on the vacant. buoy.

A total of approximately eleven mooring ropes are used for the buoys each year. This is, in part, because the rope is provided with small buoy-type floats to keep the rope afloat when no tanker is moored. These are frequently lost, which causes the rope to dip below the surface, where it can become tangled with the anchor chains. Also, during the first three years of operation, three mooring ropes parted.

A common problem with the floating hose string is the tangling of the hose and hawser messenger ropes, which prevents mooring until they are untangled. Since repairs on the hoses and hawsers require work offshore they are very sensitive to weather, and an average 3.5 percent downtime has been incurred due to waiting on weather to effect repairs.

Three major equipment failures have been experienced at Montrose (Fairbrother 1979). First a manhole cover worked loose and a buoyancy tank flooded. A derrick barge levelled the buoy, pumped out the tank and tightened the cover. Then two mooring chains parted, both due to a Kenter link (which is used to join the shots of chain together) coming apart. Both links were in the thrash zone where the chain first contacts the seabed, the chain motion having caused the link to vibrate apart. This was despite the provision of a lead plug and a welded plate over the Kenter link pin to prevent this. The discovery of a fatigue crack in a flange on the vertical product pipe from the buoy turntable, located in the splash zone, put one of the buoys completely out of service.

Early problems were encountered with the expansion joint on the buoy pipework which had a tendency to invert on the vacant buoy due to vacuum formation. This was countered by use of reinforced joints and maintenance of a small positive pressure on the line.

The operator is in the process of installing a pipeline to replace the two CALMS. The pipeline will be operational in 1985.

g) Thistle Field

The Thistle SALM was placed on standby in 1978 when the pipeline to shore was commissioned. While on standby, the buoyancy of the system was reduced enough to remove tension from the upper universal joint. This allowed a joint pin to become loose and disengage, leaving the buoy connected to the riser only by the cargo jumper hoses. While the buoy was being removed for repairs, the riser system was damaged and as a result also had to be removed for repairs. The failure was probably caused by the fact that while on standby service, the SALM was apparently unattended for several months and water leaked into the buoy from a valve at the end of the hose and via a small leak in an expansion joint inside the buoy. Although the Thistle SALM buoy was designed to retain positive buoyancy with any two compartments flooded, valves between compartments were inadvertently left open, allowing three compartments to flood.

A.6 NORTH SEA OFFSHORE LOADING SYSTEM CONSTRUCTION SCHEDULE

The four-year program for the design, fabrication and installation of the Fulmar SALM and Floating Storage Unit (FSU) is shown in Table A-37 (Gunderson et al. 1982). The FSU is a converted VLCC used to store 1.3 million barrels of crude oil from the Fulmar drilling and production platform. In turn, the FSU loads shuttle tankers in tandem. This example is selected because the SALM/FSU is the only system of its type in the North Sea and is a recent project. It required special evaluation, design and model testing by the operator, Shell, and its partner, Exxon. Thus, it is somewhat analagous to an offshore loading system for frontier areas such as the Bering Sea in that the operator had to evaluate the following:

- type of production platform
- storage or non-storage
- type of storage: platform or SPM
- pipeline versus tanker loading
- modification and upgrading of standard OLS, in this case a SALM, for the specific application
- relevant design criteria
- model test program

The project schedule and environmental criteria are shown in Table A-38 (Gundersen et al. 1982).

TABLE A-37

KEY DATES FOR FULMAR PROJECT

ACTIVITY	DATE
Preliminary Design & Model Test	Fall, 1977
Final Design Complete	December, 1978
Request for Tender	December, 1978
Fabrication Contract Signed	April 4, 1979
Contract for Tanker Conversion to FSU	September 9, 1979
16-Inch Pipeline from Platform to SALM Site	June, 1979
Load-Out of Buoy	October, 1980
Load-Out of Base	October, 1980
Load-Out of Rigid Arm	January, 1981
Completion of Buoy/Base Assembly	April, 1981
Installation of Buoy/Base	May 16, 1981
FSU Completed	May, 1981
Rigid Arm Joined to FSU	June, 1981
FSU/Rigid Arm Tow from Verolme Rotterdam	July 1, 1981
FSU/Rigid Arm Mated to SALM Buoy	July 5, 1981
Hook-up Complete	July 22, 1981

TABLE A-38

TIME REQUIREMENTS & SEA CONDITIONS FOR CRITICAL ACTIVITIES FOR FULMAR PROJECT

ACTIVITY	TIME REQUIRED PLANNED days	TIME REQUIRED ACTUAL days	SEA CONDITIONS (SIGNIFICANT WAVE HEIGHT) LIMITING m (ft)	SEA CONDITIONS (SIGNIFICANT WAVE HEIGHT) ACTUAL m (ft)
Buoy Loaded Onto Cargo Barge	1	1	--	Protected Waters
Base Mated to Buoy	1	1	. .	Protected Waters
Tow Buoy & Base to Fulmar	4	3	Summer Storm	3 (10)
Buoy Lift & Uprighting	1	1	1.4 (4.5)	1.2 (4)
Ballast Base & Buoy	3	2	2.4 (8.0)	1.2 (4)
Install & Drive Piles	4	2.5	1.8 (6.0)	1 (3)
Grout Piles	1	0.25	2.4 (8.0)	1 (3)
Install Pipeline Spool Piece	6	4	1.8 (6.0)	1 (3)
Tow FSU, La Ciotat-Rotterdam	15	12	Summer Storm	Good
Connect Arm to FSU	9	7	. .	Protected Waters
Tow FSU, Rotterdam-Fulmar	2.5	2.5	Summer Storm	2 (6.5)
Position FSU & Connect Assist Tugs	0.5	0.5	1.6 (5.2)	1 (3)
Lift Arm & Spindle	0.5	0.5	1.6 (5.2)	1 (3)
Secure Spindle to Buoy	1	1	1.6 (5.2)	1.2 (4)
Complete Hook-Up & Testing	2.5	7	--	--

A.7 NORTH SEA OFFSHORE LOADING SYSTEM CAPITAL AND OPERATING COSTS

The capital cost of North Sea offshore loading systems varies greatly depending on water depth, type of system, size of tankers, throughput, environmental design criteria and ancillary facilities provided. The least expensive type of mooring system, a CALM, in a water depth of 75 m (250 ft) to 100 m (325 ft), suitable for mooring tankers of under 100,000 DWT, would cost less than ten million dollars (all costs are in 1982 dollars). The most expensive offshore loading systems constructed to date, articulated columns, in a water depth of approximately 146 m (480 ft) suitable for mooring 150,000 DWT tankers cost more than one hundred million dollars.

Operating and maintenance costs are difficult to determine for each field because operators assign costs differently in terms of services provided to support the direct operating and maintenance manpower and material. However, most operators report that annual operating costs are approximately $4,000,000 to $5,000,000, regardless of the type of offshore loading system utilized.

Bearing in mind the great variation in costs that can exist, typical capital and operating costs for the various types of offshore loading systems used in the North Sea are presented in Table A-39. These costs are based on a water depth of approximately 120 m 400 ft), a tanker size of approximately 100,000 DWT, minimal anti" a ry facilities, and 1982 dollars.

TABLE A-39

NORTH SEA OFFSHORE LOADING SYSTEM

CAPITAL AND OPERATING COSTS

COST ITEM	TYPE OF OFFSHORE LOADING SYSTEM				
	CALM	SALM	ELSBM	SPAR	AC
Capital Cost, $MM	10	25	30	5(3*	65
Annual Operating Cost, $MM	5	5	5	5	5

*The SPAR includes 300,000 bbl of crude oil storage capacity.

A.8 CHARACTERISTICS OF NORTH SEA OIL FIELDS UTILIZING PIPELINE SYSTEMS

Of the twenty-six oil producing fields in the United Kingdom and Norwegian sectors of the North Sea that were analyzed, eighteen transport the crude oil by pipeline. All of these pipelines, including those from the Norwegian fields, ultimately terminate at' U.K. onshore terminals. Three of the fields now serviced by pipeline utilized offshore loading systems initially in order to derive revenue until the installation of pipelines could be completed. These OLS remain installed and are maintained for standby service. One field presently serviced by 01S will be have a pipeline installed in the near future to replace the OLS. Table A-1 lists the transportation systems utilized by the various North Sea oil fields. Information regarding the characteristics of North Sea oil fields that utilize pipeline systems for transporting crude oil to shore, and the characteristics of these pipelines is presented in Table A-40*

TABLE A-40

NORTH SEA PIPELINE SYSTEM CHARACTERISTICS

ROUTE	LENGTH km (mi)	DIA in.	CAPACITY Mb/day	THROUGHPUT Mb/day	OPERATOR	YEAR INSTALL	RECOVERABLE RESERVES MMb	WATER DEPTH m (ft)
Main Pipelines								
Beatrice to Old Shanwick	68 (42)	16	100	45	BNOC	1979	130	45 (148)
Cormorant to Sullom Voe	175 (109)	36	1,000	790	Shell	1976	500	160 (525)
Ekofisk to Teesside	354 (220)	34	1,000	310	Phillips	1974	3,800*	71 (232)
Forties to Cruden Bay	179 (111)	32	600	470	BP	1974	1,800	128 (420)
Ninian to Sullom Voe	169 (105)	36	950	340	BP	1976	1,200	135 (443)
Piper to Flotta	210 (131)	30	560	400	Occidental	1975	620	145 (476)
Interfield Pipelines								
Brae to Forties	116 (72)	30	100	**	Marathon	1983	500	112 (367)
Brent to Cormorant	34 (21)	30	490	322	Shell	1979	2,000	140 (460)
Claymore to Piper	13 (8)	30	100	94	Occidental	1977	400	114 (374)
Dunlin to Cormorant	32 (20)	24	125	82	Shell	1978	400	151 (495)
Heather to Ninian	35 (22)	16	75	34	Union	1978	120	145 (476)
Hutton to NW Hutton	6 (4)	12	105	100	Conoco	1984	250	147 (482)
Magnus to Ninian	92 (57)	24	120	**	BP	1983	500	186 (610)
Montrose to Forties	47 (29)	14	60	***	Amoco	1985	100	93 (304)
Murchison to Dunlin	16 (10)	16	150	92	Conoco	1980	320	156 (512)
NW Hutton to Cormorant	20 (12)	20	205	108	Amoco	1982	300	144 (472)
Tartan to Claymore	23 (14)	24	89	13	Texaco	1980	250	145 (476)
Thistle to Dunlin	11 (7)	16	200	125	BNOC	1978	500	163 (535)
Valhall to Ekofisk	35 (22)	20	90	90	Amoco	1982	370	70 (230)

* All fields in the Ekofisk area.
** Startup at time of publication.
*** Future.

A.9 PERFORMANCE OF NORTH SEA PIPELINE SYSTEMS

A pipeline is generally considered to be a more reliable crude oil transportation method than an offshore loading system since it is not susceptible to weather downtime. Nevertheless, there have been a number of instances of lost production due to North Sea pipeline system downtime, which is usually related to planned or unplanned maintenance and repairs. This section describes some specific incidents of North Sea pipeline system downtime due to a variety of problems. It is not a complete list of all pipeline problems that have occurred but is provided to illustrate the types of problems that can occur.

The 36 inch oil line from Cormorant to Sullom Voe was found to be laying on a rocky bottom with some concrete damage. On one section, the concrete coating was lost progressively due to vibrations caused by high velocity currents. With progressive loss of concrete, the pipe became buoyant and floated to the surface. This occurred over a length of 1.5 km (0.9 mi). A few short segments of the same pipeline suffered concrete damage and some loss and lifted slightly off-bottom when the pipe was empty. Some small concrete losses were occasionally observed related to damage of the concrete due to laydown and pick-up caused by bad weather periods (Starting 1981). An anchor was found lying beside the Ekofisk-Teesside pipeline, 8 km (5 mi) outside Teesside. The 9 tonne anchor was traced back to a 50,000 DWT tanker. The line was bent and buckled locally. The damage was analyzed and the operator established a reduced maximum operating pressure pending repair of the damage. The line was eventually shut down for approximately six weeks to make a hyperbaric weld repair. Other work on the pipeline was carried out simultaneously with the repair. Greater Ekofisk oil production was maintained during the shutdown by reinstalling the original CALM offshore loading system used to load Ekofisk oil to tankers before the pipeline start-up (Kaufman 1978).

Free spans have occurred on the Ekofisk-Teesside pipeline. All spans over 25 m (82 ft) length are sandbagged. Natural backfilling has not been satisfactory and about 50 percent of the line lies exposed in the trench. The situation is more or less stable (Starting 1981).

During operations around the Piper-Claymore-Flotta pipeline, the Claymore spur line spool piece connection to the tee was snagged and ripped free at the Claymore end connection. Although the main oil line from Piper to Flotta was not damaged, it was decided that additional protection should be implemented on pipelines leading away from key areas to guard against snagging, impacts and chain/wire burn type damage to the pipelines. Simple reinforced concrete covers, later known as PPU's (Pipeline Protection Units) were developed to achieve the objective. These units were placed at all key areas on the pipeline.

A.10 NORTH SEA PIPELINE SYSTEM CONSTRUCTION SCHEDULE

The time required to construct an underwater pipeline is very sensitive to the conditions in which the pipeline will be laid. Three different types of pipe-laying vessels have been used in the North Sea: conventional lay barges, large and small ship-shaped vessels, and large and small semi-submersibles. Their approximate operating costs and limitations are shown in Table A-41 (Marsden & Ostby 1977).

TABLE A-41

LAYING VESSEL LIMITATIONS AND COSTS

VESSEL TYPE	SIGNIFICANT WAVE HEIGHT m (ft)	COST M$/day (1982)	LAYING RATE m/day	(ft/day)
Small conventional lay barge	2 (6)	150-175	600-900	(2 ,000-3 ,000)
Large conventional lay barge	2-2.5 (6-8)	175-200	750-1,500	(2,500-4,900)
Small ship-shaped	3-3.5 (10-12)	200-350	1,400-1,800	(4,500-6,000)
Large ship-shaped	4.5-5.5 (15-18)	300-450	1,800-2,100	(6,000-7,000)
Small semi-submersible	3-3.5 (10-12)	200-350	1,400-1,800	(4,500-6,000)
Large semi-submersible	4.5-5.5 (15-18)	300"450	1,800--2,100	(6,000-7,000)

Table A-41 also shows the approximate laying rates of the different types of laying vessels for large pipe of more than 30-inch outside diameter. Laying rate is not a function of water depth for depths down to approximately 300 m (1000 ft). However, a 16 inch pipeline can be laid 20 percent faster than a 36 inch line (Marsden & Ostby 1977).

Pipelines in the North Sea are buried. The rate of trenching or burying depends on the depth of cover, the seabed consistency, obstructions around the pipeline and the type of trenching barge. A large trenching barge can operate in seas up to approximately 1.5 m (5 ft) significant wave height. The rate of travel is approximately 1 to 3 m (3 to 10 ft) per minute in water depths less than 3U0 m (1000 ft). The operating cost of a large trenching barge is approximately $150,000 per day.

A.11 NORTH SEA PIPELINE SYSTEM CAPITAL AND OPERATING COSTS

Other than the cost of a fixed platform, a pipeline is usually the major expense for an offshore oil field development project. Although it is difficult to predict the cost of a pipeline project since total cost is extremely site specific, the major cost parameters include environmental conditions, water depth, and pipe dimensions and length. Representative examples of the cost of crude oil pipelines recently installed in the North Sea are shown in Table A-42. The construction cost listed for each is the actual cost in the year the pipeine was installed.

TABLE A-42

INSTALLED COST OF RECENT NORTH SEA PIPELINES

FROM	TO	DIAMETER in.	LENGTH km (mi)	COST MM$	COST PER MILE MM$/mi	YEAR INSTALL
MontPose	Forties	14	47 (29)	39.5	1.36	1984
Beatrice	Old Shanwick	16	68 (42)	80.0	1.90	1980
Germ	Jutland	20	210 (131)	167.0	1.28	1982

Average construction costs for North Sea pipelines have been developed from several sources. Bearing in mind that the cost for any particular pipeline project may vary considerably from the average depending on its characteristics, the average cost for North

Sea pipelines is presented in Figure A-8, in dollars per **mile.** Since all North Sea pipelines are buried, the cost presented includes the cost of burial.

Pipeline operating costs are more difficult to define than construction costs because different operators have different methods of allocating costs for operation, maintenance and repairs. However, most operators report that pipeline operating costs average between three and five percent of construction cost. Assuming that annual operating costs are four percent of pipeline construction cost, the annual operating cost for North Sea pipelines is indicated in Figure A-8 .

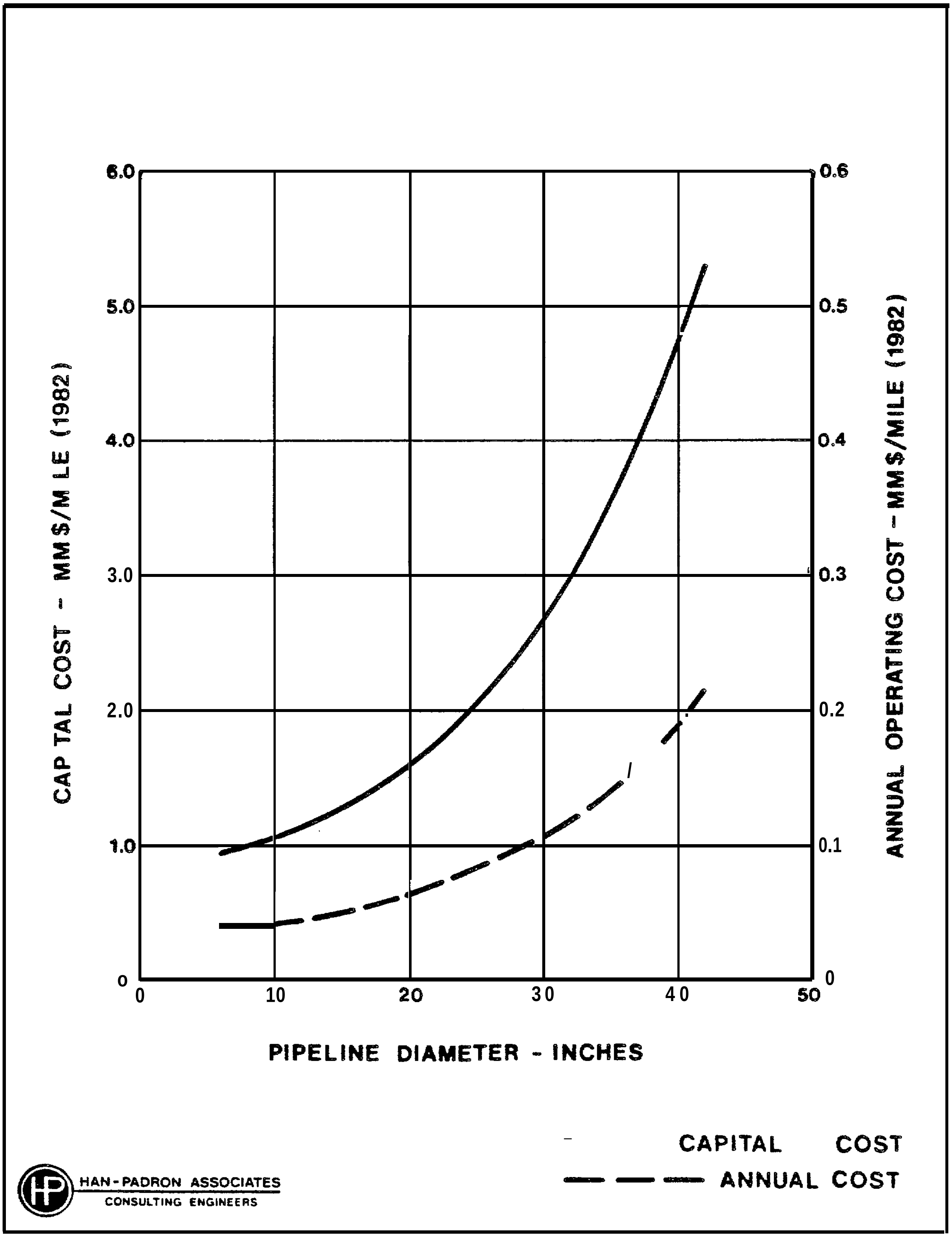


Figure A-8. Average construction and operating costs for North Sea pipelines.

A.12 NORTH SEA CRUDE OIL TRANSPORTATION SYSTEM SELECTION PHILOSOPHY

There is no single, uniform philosophy utilized by the operators of North Sea oil fields regarding the selection of the crude oil transportation system. Of the twenty-six fields evaluated, eight utilize offshore loading systems and eighteen utilize pipeline systems. Three of the eighteen utilized an offshore loading system to achieve early production before the pipeline was completed.

Five of the eight fields that utilize an OLS have quite small recoverable reserves - 150 million barrels or less. The largest field with an OLS, Statfjord, with three billion barrels reserves, is in Norwegian waters and a pipeline from this field to Norway would require crossing the deep Norwegian Trench, making the construction of a pipeline extremely expensive. The operators of the Beryl Field determined that its 800 million barrels of recoverable reserves could not justify the expense of a 274 km (170 mi) pipeline to the Orkney Islands. Similarly, the operators of the 500 million barrel Fulmar Field rejected a pipeline because of the high construction cost required and also because of a lack of spare capacity.

Five main pipelines service seventeen of the eighteen fields with pipeline transportation systems. The Beatrice Field, which is only 68 km (42 mi) from shore, is the only field with an exclusive pipeline. The recoverable reserves connected to each of the remaining five pipelines, each of which is more than 150 km (94 mi) long, ranges from 1.3 billion barrels to 4.2 billion barrels.

The Brent, Ekofisk and Thistle Fields each had offshore loading systems initially with pipelines installed at a later date. The Ekofisk OLS operated for approximately five years, the Brent. OLS for approximately three years and the Thistle OLS for only nine months. The operators of the Thistle Field report that even though the OLS operated for only nine months, loading approximately 18 million barrels of crude oil, it was very valuable to the Thistle Development Plan. It provided early oil flow and consequent revenue and also provided valuable experience in starting up the field so that when the pipeline became available the majority of the preliminary production problems had been overcome.

Thus, it appears that for oil fields located more than approximately 100 km (60 mi) from land, when recoverable reserves exceeded one billion barrels, and a pipeline was technically feasible, a pipeline was selected for the crude oil transportation system for North Sea oil fields. When recoverable reserves were less than one billion barrels, an offshore loading system was selected.

The type of offshore loading system selected also appears to be a function of the size of the reservoir. Fields with recoverable reserves of 150 million barrels or more were provided with the highest capital cost, highest availability articulated columns, except for the Fulmar Field which has a SALM (essentially an articulated column) with a floating storage unit. Fields with 100 million barrels or less of recoverable reserves were provided with lowest cost, lowest availability CALMS. Where an OLS was utilized only on a temporary basis, a CALM was provided except in the extremely deep water of the Thistle Field where a more cost effective SALM was provided and at the Brent Field where a SPAR was installed to provide offshore crude oil storage capacity.

The general philosophy used in the selection of crude oil transportation systems in the North Sea apparently is based on minimizing overall life cycle costs, within the limits of existing technology, although some extrapolation of existing technology was acceptable. The apparent results of this philosophy are presented in the logic diagram shown in Figure A-9.

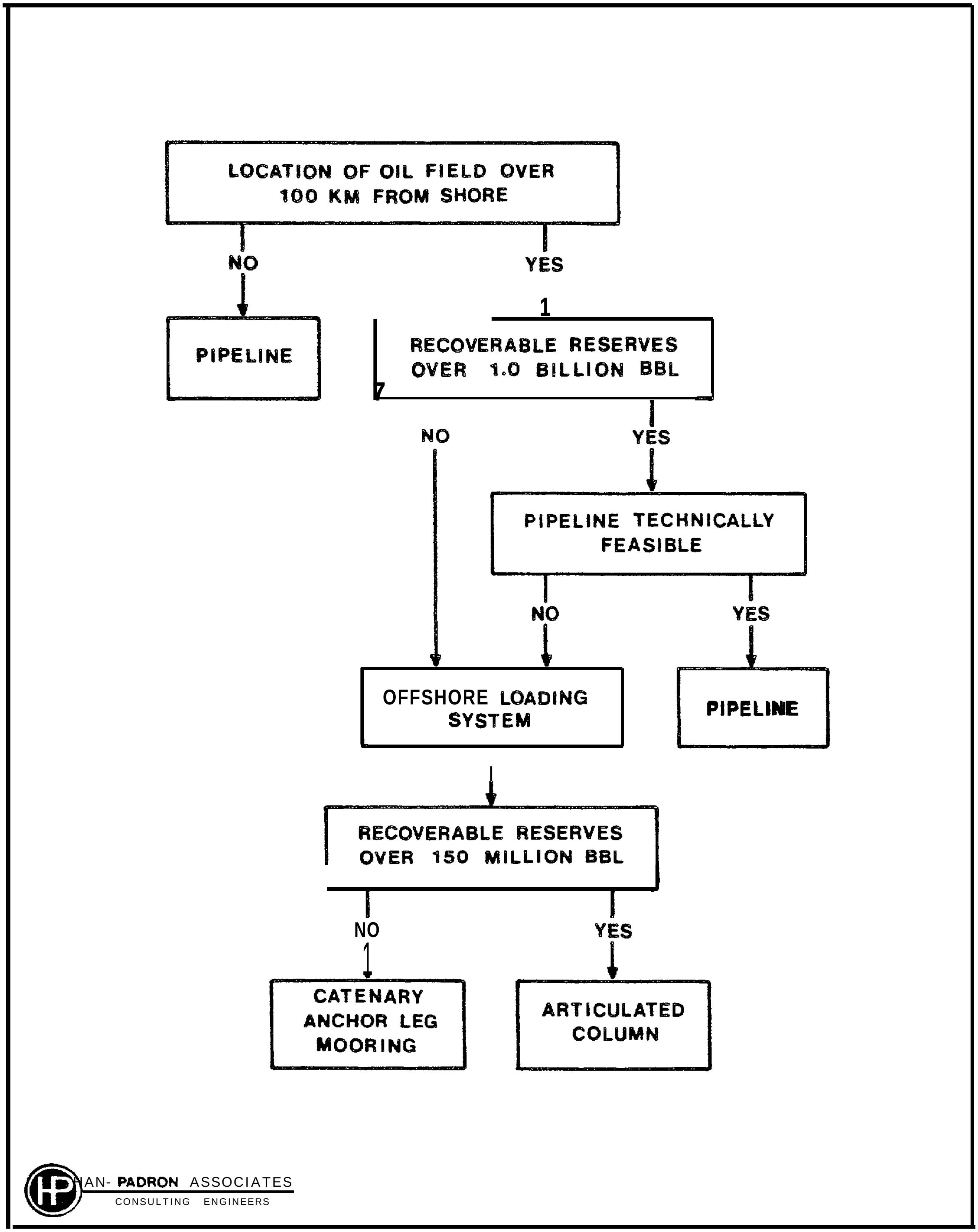


Figure A-9. Logic diagram representing result of North Sea crude oil transportation system selection process.

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APPENDIX B

TRANSPORTATION ALTERNATIVE SENSITIVITY ANALYSES

APPENDIX B

TRANSPORTATION ALTERNATIVE SENSITIVITY ANALYSES

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B.1 INTRODUCTION

All relevant parameters regarding environmental factors, crude oil production parameters and crude oil destinations were defined for each of the three scenarios utilized in the evaluation of crude oil transportation alternatives from the Bering Sea. The parameters are referred to as the "base case" parameters.

In order to evaluate the effect of variations to the base case parameters on the conclusions regarding the optimum transportation alternative, a number of sensitivity analyses have been carried out. The parameters varied for the analyses include:

- o quantity of recoverable reserves (production rate),
- o crude oil properties,
- o distance to shore,
- o water depth, and
- o geotechnical conditions.

The effects of these variations on the individual transportation elements are discussed in the sections of this report in which the elements are described. The tables contained in this Appendix illustrate the effect on the overall transportation system alternative for each scenario.

The base case recoverable reserves has been defined as 500 million barrels and the sensitivity values are 100 million, 200 million, one billion and two billion barrels. All size reservoirs have been assumed to perform in the same manner, as described in Section 3.3.2, with peak production rate equal to 9.1 percent of reserves. Thus, the base case peak production rate is 125 MBPD and the sensitivity values are 25, 50, 250 and 500 MBPD.

The base case crude oil properties are quite suitable for transportation in either long pipelines or tankers. The sensitivity case crude oil" has a relatively high pour point making the cost of alternatives requiring pumping long distances underwater prohibitive. For offshore loading alternatives, loading pipeline diameters and pumping horsepower would increase but the increase in total transportation system cost would be negligible. Therefore, no further economic analysis was conducted for crude oil properties sensitivity.

Variations in the distance of the production platform from shore have virtually no effect on alternatives which have offshore crude oil storage and loading and no distance sensitivity analyses were conducted for these alternatives. Also, where any likely variation in a pipeline or tanker route length was less than ten percent of the base case length, no distance sensitivity analysis was performed.

Variations in water depth only affect alternatives which have offshore crude oil storage and loading and water depth sensitivity analyses were conducted only for these alternatives.

As for water depth, variations of the seabed soil parameters affect only the offshore storage and loading alternatives.

The tables presented in the following section show the capital cost, annual operating cost during a peak production year and manpower required for each major transportation system element, for each alternative, and for each sensitivity parameter variation. The manpower figures presented are the crew size times a "shift factor" and times a "rotation factor." Tanker crews are not included. The tables also list the present value of the total life cycle cost and the average transportation cost (ATC) of the crude oil for each case. They have been developed by fixing all scenario parameters but one at the base case values and setting the one parameter at a non-base case (sensitivity) value.

The present value of the total life cycle cost is based on constant January 1982 dollars and an 8 percent discount rate. The effect of taxes or royalties is not included. To obtain the ATC of the crude oil, on a per barrel basis, the present value of total cost is divided by the total volume of oil produced over the 15 year life of the reservoir.

B.2 SENSITIVITY ANALYSIS TABLES

TABLE B-1

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1A

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-y r
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	274	28	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	330	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	91	3	---
LAND PIPELINE	5089	175	Excl
TOTAL	5784	225	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 7870

AVERAGE TRANSPORTATION COST PER BARREL = $ 18.36

TABLE B-2

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	188	20	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	212	16	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	59	2	---
LAND PIPELINE	4830	168	Excl
TOTAL	5289	206	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 7200

AVERAGE TRANSPORTATION COST PER BARREL = $ 83.95

TABLE B-3

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	208	22	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	231	17	120
TRANSSHIPMENT TERMINAL	...	---	---
MARINE PIPELINE	67	2	---
LAND PIPELINE	4956	175	Excl
TOTAL	5462	216	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 7460

AVERAGE TRANSPORTATION COST PER BARREL = $ 43.50

TABLE B-4

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	459	47	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	400	20	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	123	3	---
LAND PIPELINE	5215	182	Excl
TOTAL	6197	252	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 8520

AVERAGE TRANSPORTATION COST PER BARREL = $ 9.94

TABLE B-5

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	835	84	Excl
OFFSHORE LOADING TERMINAL	---	---	...
NEARSHORE LOADING TERMINAL	493	22	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	185	5	...
LAND PIPELINE	5600	196	Excl
TOTAL	7113	307	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 9940

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.80

TABLE B-6

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1B

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	36	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	336	18	120
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	90	3	---
LAND PIPELINE	---	---	---
TOTAL	1689	132	360

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2880

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.71

TABLE B-7

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	294	28	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	186	211	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	252	16	120
TRANSSHIPMENT TERMINAL	279	20	140
MARINE PIPELINE	59	2	---
LAND PIPELINE	---	...	---
TOTAL	1290	112	360

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2300

AVERAGE TRANSPORTATION COST PER BARREL = $ 26.82

TABLE B-8

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	310	30	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	204	22	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	273	17	120
TRANSSHIPMENT TERMINAL	307	21	140
MARINE PIPELINE	67	2	---
LAND PIPELINE	---	---	---
TOTAL	1381	118	360

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2450

AVERAGE TRANSPORTATION COST PER BARREL = $ 14.28

TABLE B-9

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	460	46	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	429	42	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	459	19	120
TRANSSHIPMENT TERMINAL	473	24	140
MARINE PIPELINE	123	3	---
LAND PIPELINE	---	---	---
TOTAL	2164	160	360

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3610

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.21

TABLE B-10

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	786	78	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	770	80	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	608	22	120
TRANSSHIPMENT TERMINAL	568	25	140
MARINE PIPELINE	185	5	---
LAND PIPELINE	---	---	...
TOTAL	3137	236	360

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 5260

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.07

TABLE B-11

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1B

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	36	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	336	18	120
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	40	1	---
LAND PIPELINE	..-	---	---
TOTAL	1639	130	360

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2810

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.56

TABLE B-12

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1B

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	36	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	336	18	120
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	144	4	---
LAND PIPELINE	---	---	---
TOTAL	1743	133	360

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2940

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.86

TABLE B-13

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1C

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	460	46	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	433	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	90	3	---
LAND PIPELINE	---	---	---
TOTAL	1203	94	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2050

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.78

TABLE B-14

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	310	30	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	267	16	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	59	2	---
LAND PIPELINE	---	---	---
TOTAL	856	74	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1520

AVERAGE TRANSPORTATION COST PER BARREL = $ 17.73

TABLE B-15

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	NANPOWER man-yr
ICE-STRENGTHENED TANKERS	350	34	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	...	---	...
NEARSHORE LOADING TERMINAL	302	17	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	67	2	---
LAND PIPELINE	---	---	---
TOTAL	939	79	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1650

AVERAGE TRANSPORTATION COST PER BARREL = $ 9.62

TABLE B-16

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	786	78	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	533	20	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	123	3	---
LAND PIPELINE	---	---	---
TOTAL	1662	127	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2810

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.28

TABLE. B-17

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE--STRENGTHENED TANKERS	1572	156	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	584	21	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	185	5	---
LAND PIPELINE	---	---	---
TOTAL	2561	208	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 4430

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.58

TABLE B-18

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1C

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	460	46	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	433	19	120
TRANSSHIPMENT TERMINAL	..-	---	---
MARINE PIPELINE	40	1	---
LAND PIPELINE	---	---	---
TOTAL	1153	92	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1980

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.62

TABLE B-19

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1C

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	460	46	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	433	19	120
TRANSSHIPMENT TERMINAL	---	...	---
MARINE PIPELINE	144	4	---
LAND PIPELINE	---	...	---
TOTAL	1257	95	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2120

AVERAGE TRANSPORTATION COST PER BARREL = $ 4*94

TABLE B-20

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1D

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	36	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	323	18	100
NEARSHORE LOADING TERMINAL	---	---	. . .
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1586	129	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2750

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.41

TABLE B-21

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	294	28	Excl
ICEBREAKERS	22(.)	26	100
CONVENTIONAL TANKERS	136	20	Excl
OFFSHORE LOADING TERMINAL	250	18	100
NEARSHORE LOADING TERMINAL	---	. . .	---
TRANSSHIPMENT TERMINAL	289	20	140
MARINE PIPELINE	. . .	---	. . .
LAND PIPELINE	---	---	---
TOTAL	1179	112	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2180

AVERAGE TRANSPORTATION COST PER BARREL = $ 25.45

TABLE B-22

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	310	30	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	204	22	Excl
OFFSHORE LOADING TERMINAL	268	20	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	307	21	140
MARINE PIPELINE	---	...	---
LAND PIPELINE	---	...	---
TOTAL	1309	119	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2380

AVERAGE TRANSPORTATION COST PER BARREL = $ 13.86

TABLE B-23

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	460	46	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	429	42	Excl
OFFSHORE LOADING TERMINAL	407	19	100
NEARSHORE LOADING TERMINAL	---	---	..-
TRANSSHIPMENT TERMINAL	473	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1989	156	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3390

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.95

TABLE B-24

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-y r
ICE-STRENGTHENED TANKERS	786	78	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	770	80	Excl
OFFSHORE LOADING TERMINAL	512	20	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	568	25	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	2856	229	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 4910

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.87

TABLE B-25

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1D

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 18 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-y r
ICE-STRENGTHENED TANKERS	366	36	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	362	19	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	...	---	---
LAND PIPELINE	---	---	---
TOTAL	1625	130	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2790

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.52

TABLE B-26

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1D

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 37 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	36	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	325	18	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	.--	---	---
TOTAL	1588	129	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2750

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.41

TABLE B-27

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1D

PARAMETER VARIED FROM BASE CASE: SOIL TYPE - SILT

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	36	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	331	18	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1594	129	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2750

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.42

TABLE B-28

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1E

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	460	46	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	385	19	120
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	...
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1065	91	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1880

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.39

TABLE B-29

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	310	30	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	268	18	120
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	798	74	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1460

AVERAGE TRANSPORTATION COST PER BARREL = $ 17.04

TABLE B-30

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	350	34	Excl
ICEBREAKERS	220	26	10U
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	300	18	120
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	870	78	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1570

AVERAGE TRANSPORTATION COST PER BARREL = $ 9.15

TABLE B-31

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	786	78	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	443	19	120
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1449	123	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2550

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.98

TABLE B-32

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	1572	156	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	487	19	120
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	2279	201	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 4080

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.38

TABLE B-33

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1E

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 18 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	460	46	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	426	19	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1106	91	200

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1920

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.49

TABLE B-34

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1E

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 37 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	46(I	46	Excl
ICEBREAKERS	220	26	100
CONVENTIONAL TANKERS	...	---	Excl
OFFSHORE LOADING TERMINAL	378	19	100
NEARSHORE LOADING TERMINAL	...	---	...
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1058	91	200

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1870

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.37

TABLE B-35

SENSITIVITY ANALYSIS FOR SCENARIO 1, ALTERNATIVE 1E

PARAMETER VARIED FROM BASE CASE: SOIL TYPE - SILT

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	46(.)	46	Excl
ICEBREAKERS	22(J	26	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	395	19	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	...	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1075	91	200

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1890

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.41

TABLE B-36

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2A

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	292	30	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	320	18	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	321	11	---
LAND PIPELINE	---	---	---
TOTAL	1737	124	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2860

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.66

TABLE B-37

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE = 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	252	26	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	186	20	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	251	16	140
TRANSSHIPMENT TERMINAL	279	20	140
MARINE PIPELINE	219	8	---
LAND PIPELINE	---	---	..-
TOTAL	1314	107	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2270

AVERAGE TRANSPORTATION COST PER BARREL = $ 26.50

TABLE B-38

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	260	28	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	204	22	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	268	17	140
TRANSSHIPMENT TERMINAL	307	21	140
MARINE PIPELINE	259	9	---
LAND PIPELINE	---	..-	---
TOTAL	1425	114	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2440

AVERAGE TRANSPORTATION COST PER BARREL = $ 14.24

TABLE B-39

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	340	36	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	429	42	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	412	19	140
TRANSSHIPMENT TERMINAL	473	24	140
MARINE PIPELINE	499	15	---
LAND PIPELINE	---	---	-e-
TOTAL	2240	153	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3260

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.81

TABLE B-40

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	438	46	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	770	80	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	591	23	140
TRANSSHIPMENT TERMINAL	568	25	140
MARINE PIPELINE	707	22	---
LAND PIPELINE	---	---	---
TOTAL	3201	213	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 5130

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.99

TABLE B-41

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2A

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	292	30	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	320	18	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	242	8	---
LAND PIPELINE	---	---	---
TOTAL	1658	122	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2750

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.41

TABLE B-42

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2A

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	292	30	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	...	...	---
NEARSHORE LOADING TERMINAL	320	18	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	428	15	---
LAND PIPELINE	---	..-	.a-
TOTAL	1844	129	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3010

AVERAGE TRANSPORTATION COST PER BARREL = $ 7.02

TABLE B-43

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2B

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	38	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	396	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	321	10	---
LAND PIPELINE	---	---	---
TOTAL	1210	84	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1980

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.61

TABLE B-44

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	266	28	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	265	16	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	219	8	---
LAND PIPELINE	---	---	---
TOTAL	877	69	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1500

AVERAGE TRANSPORTATION COST PER BARREL = $ 17.47

TABLE B-45

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	294	31	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	295	17	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	259	9	---
LAND PIPELINE	---	---	---
TOTAL	975	74	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1640

AVERAGE TRANSPORTATION COST PER BARREL = $ 9.57

TABLE B-46

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	615	63	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	478	21	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	459	15	---
LAND PIPELINE	---	---	---
TOTAL	1679	116	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2720

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.17

TABLE B-47

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	1100	115	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	594	23	120
TRANSSHIPMENT TERMINAL	---	---	...
MARINE PIPELINE	707	22	...
LAND PIPELINE	---	---	-e-
TOTAL	2528	177	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 4130

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.41

TABLE B-48

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2B

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	38	Excl
ICEBREAKERS	127	27	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	396	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	242	8	---
LAND PIPELINE	---	---	...
TOTAL	1131	82	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1870

AVERAGE TRANSPORTATION COST PER BARREL = $4.36

TABLE B-49

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2B

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	366	38	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	396	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	428	15	---
LAND PIPELINE	---	---	---
TOTAL	1317	89	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2120

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.95

TABLE B-50

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2C

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	264	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	437	22	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	796	28	---
LAND PIPELINE	.--	---	---
TOTAL	2254	139	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3510

AVERAGE TRANSPORTATION COST PER BARREL = $ 8.18

TABLE B-51

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	234	26	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	186	20	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	365	20	140
TRANSSHIPMENT TERMINAL	279	20	140
MARINE PIPELINE	484	17	...
LAND PIPELINE	---	---	---
TOTAL	1628	115	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2670

AVERAGE TRANSPORTATION COST PER BARREL = $ 31.10

TABLE B-52

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	240	26	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	204	22	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	384	21	140
TRANSSHIPMENT TERMINAL	307	21	140
MARINE PIPELINE	581	20	---
LAND PIPELINE	---	---	---
TOTAL	1796	122	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2900

AVERAGE TRANSPORTATION COST PER BARREL = $ 16.91

TABLE B-53

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	300	32	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	429	42	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	522	23	140
TRANSSHIPMENT TERMINAL	473	14	140
MARINE PIPELINE	1136	43	---
LAND PIPELINE	---	---	---
TOTAL	2940	116	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 4010

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.68

TABLE B-54

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	376	38	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	770	80	Excl
OFFSHORE LOADING TERMINAL	---	---	...
NEARSHORE LOADING TERMINAL	698	26	140
TRANSSHIPMENT TERMINAL	568	25	140
MARINE PIPELINE	1926	65	---
LAND PIPELINE	...	---	---
TOTAL	4418	246	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 6690

AVERAGE TRANSPORTATION COST PER BARREL = $ 3*90

TABLE B-55

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2C

PARAMETER VARIED FROM BASE CASE : MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-y r
ICE-STRENGTHENED TANKERS	264	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	..-	---	---
NEARSHORE LOADING TERMINAL	437	22	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	67'1	23	---
LAND PIPELINE	..-	---	---
TOTAL	2129	134	38(J

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3340

AVERAGE TRANSPORTATION COST PER BARREL = $ 7.80

TABLE B-56

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2C

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	264	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	437	22	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	924	32	---
LAND PIPELINE	---	---	---
TOTAL	2382	143	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3680

AVERAGE TRANSPORTATION COST PER BARREL = $ 8.59

TABLE B-57

SENSITIVITY ANALYSIS FOR SCENARIO 2. ALTERNATIVE 2D

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	340	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	386	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	796	28	---
LAND PIPELINE	---	---	---
TOTAL	1602	93	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2450

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.71

TABLE B-58

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	248	26	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	264	17	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	484	17	---
LAND PIPELINE	---	---	---
TOTAL	1076	72	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1730

AVERAGE TRANSPORTATION COST PER BARREL = $ 20.18

TABLE B-59

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	272	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	292	17	120
TRANSSHIPMENT TERMINAL	...	---	...
MARINE PIPELINE	581	20	---
LAND PIPELINE	---	...	---
TOTAL	1225	77	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1920

AVERAGE TRANSPORTATION COST PER BARREL = $ 11.22

TABLE B-60

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	567	57	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	465	20	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	1136	43	---
LAND PIPELINE	---	---	---
TOTAL	2248	132	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3450

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.02

TABLE B-61

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	1020	100	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	739	26	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	1926	65	---
LAND PIPELINE	---	---	---
TOTAL	3765	203	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 5610

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.28

TABLE B-62

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2D

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	340	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	...	---
NEARSHORE LOADING TERMINAL	386	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	271	24	---
LAND PIPELINE	---	...	---
TOTAL	1477	89	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2280

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.32

TABLE B-63

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2D

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	340	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	386	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	924	32	---
LAND PIPELINE	---	---	---
TOTAL	1730	97	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2610

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.10

TABLE B-64

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2E

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	302	32	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	260	15	80
NEARSHORE LOADING TERMINAL.	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1366	113	320

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2380

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.56

TABLE B-65

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	254	28	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	136	20	Excl
OFFSHORE LOADING TERMINAL	221	14	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	279	20	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1017	99	320

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1900

AVERAGE TRANSPORTATION COST PER BARREL = $ 22.20

TABLE B-66

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	264	28	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	204	22	Excl
OFFSHORE LOADING TERMINAL	231	15	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	307	22	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1133	103	320

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2060

AVERAGE TRANSPORTATION COST "PER BARREL = $ 11.99

TABLE B-67

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	358	38	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	429	42	Excl
OFFSHORE LOADING TERMINAL	309	17	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	473	24	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1696	138	320

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2930

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.42

TABLE B-68

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	600	62	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	770	80	Excl
OFFSHORE LOADING TERMINAL	456	19	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	568	25	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	2521	2(I7	320

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 4380

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.56

TABLE B-69

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2E

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 80 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-y r
ICE-STRENGTHENED TANKERS	302	32	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	256	15	80
NEARSHORE LOADING TERMINAL	. . .	---	---
TRANSSHIPMENT TERMINAL	423	23	14(I
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1362	113	320

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2380

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.55

TABLE B-70

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2E

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 200 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	302	32	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	297	17	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1403	115	320

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2440

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.68

TABLE B-71

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2E

PARAMETER VARIED FROM BASE CASE: SOIL TYPE - SILTY SAND

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	302	32	Excl
ICEBREAKERS	127	17	80
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	259	15	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1365	113	320

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2380

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.55

TABLE B-72

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2F

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	368	40	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	288	16	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	783	73	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1440

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.35

TABLE B-73

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2F

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	268	28	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	227	14	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	...	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	...
TOTAL	622	59	180

PRESENT VALUE OF TOTAL COST (@ 8%) ' MM$ 1150

AVERAGE TRANSPORTATION COST PER BARREL = $ 13.42

TABLE B-74

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2F

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	294	31	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	341	15	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	662	63	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1230

AVERAGE TRANSPORTATION COST PER BARREL = $ 7.15

TABLE B-75

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2F

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	621	65	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	327	17	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1075	99	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1960

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.29

TABLE B-76

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2F

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	1242	129	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	479	23	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1868	169	200

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3380

AVERAGE TRANSPORTATION COST PER BARREL = $ 1.97

TABLE B-77

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2F

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 80 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	368	40	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	285	16	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	780	73	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1430

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.34

TABLE B-78

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2F

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 200 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	368	40	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	330	17	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	825	74	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1490

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.47

TABLE B-79

SENSITIVITY ANALYSIS FOR SCENARIO 2, ALTERNATIVE 2F

PARAMETER VARIED FROM BASE CASE: SOIL TYPE - SILTY SAND

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	368	40	Excl
ICEBREAKERS	127	17	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	296	16	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	769	73	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1420

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.32

TABLE B-80

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3A

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	333	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	535	19	---
LAND PIPELINE	276	10	---
TOTAL	1398	74	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2070

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.83

TABLE B-81

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	186	20	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	207	16	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	357	13	---
LAND PIPELINE	262	9	---
TOTAL	1012	58	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1540

AVERAGE TRANSPORTATION COST PER BARREL = $ 17.93

TABLE B-82

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	204	22	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	231	17	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	396	14	---
LAND PIPELINE	269	9	---
TOTAL	1100	62	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1670

AVERAGE TRANSPORTATION COST PER BARREL = $ 9.72

TABLE B-83

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	426	42	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	374	20	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	824	29	---
LAND PIPELINE	283	10	---
TOTAL	1907	101	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2830

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.30

TABLE B-84

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3A

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE = 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	770	80	Excl
OFFSHORE LOADING TERMINAL	...	---	---
NEARSHORE LOADING TERMINAL	568	25	140
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	1334	44	---
LAND PIPELINE	304	11	---
TOTAL	2976	160	140

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 4430

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.59

TABLE B-85

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3A

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	333	19	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	386	13	---
LAND PIPELINE	276	10	---
TOTAL	1249	68	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1870

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.36

TABLE B-86

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3A

PARAMETER VARIED FROM BASE CASE : MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	---	---	Excl
ICEBREAKERS	---	---	---
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	...	---	---
NEARSHORE LOADING TERMINAL	333	19	120
TRANSSHIPMENT TERMINAL	---	---	...
MARINE PIPELINE	699	25	---
LAND PIPELINE	276	10	...
TOTAL	1562	80	120

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2290

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.34

TABLE B-87

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 33

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yf-
ICE-STRENGTHENED TANKERS	260	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	...	---	---
NEARSHORE LOADING TERMINAL	419	21	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	154	5	---
LAND PIPELINE	---	---	---
TOTAL	1590	115	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2630

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.13

TABLE B-88

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 313

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	232	26	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	186	20	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	36u	19	140
TRANSSHIPMENT TERMINAL	279	20	140
MARINE PIPELINE	111	4	---
LAND PIPELINE	---	---	---
TOTAL	1248	101	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2160

AVERAGE TRANSPORTATION COST PER BARREL = $ 25.18

TABLE B-89

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	240	26	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	204	22	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	379	21	140
TRANSSHIPMENT TERMINAL	307	21	140
MARINE PIPELINE	122	4	---
LAND PIPELINE	---	---	---
TOTAL	1332	106	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 228(I

AVERAGE TRANSPORTATION COST PER BARREL = $ 13.31

TABLE B-90

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	294	31	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	429	42	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	485	22	140
TRANSSHIPMENT TERMINAL	473	24	140
MARINE PIPELINE	216	7	---
LAND PIPELINE	---	---	---
TOTAL	1977	138	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3220

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.75

TABLE B-91

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3B

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	364	37	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	770	80	Excl
OFFSHORE LOADING TERMINAL	---	---	...
NEARSHORE LOADING TERMINAL	624	25	140
TRANSSHIPMENT TERMINAL	568	25	140
MARINE PIPELINE	314	9	...
LAND PIPELINE	---	---	---
TOTAL	2720	188	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 4410

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.57

TABLE B--92

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3B

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	260	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	419	21	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	37	1	---
LAND PIPELINE	---	---	---
TOTAL	1473	111	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2470

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.77

TABLE B-93

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 39

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-y r
ICE-STRENGTHENED TANKERS .	260	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	...	---	---
NEARSHORE LOADING TERMINAL	419	21	140
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	290	10	---
LAND PIPELINE	---	...	---
TOTAL	1726	120	380

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2810

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.55

TABLE B-94

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3C

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	336	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	366	18	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	154	5	---
LAND PIPELINE	---	---	---
TOTAL	936	69	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1560

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.63

TABLE B-95

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	250	26	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	259	16	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	111	4	---
LAND PIPELINE	---	---	---
TOTAL	700	58	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1220

AVERAGE TRANSPORTATION COST PER BARREL = $ 14.22

TABLE B-96

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	270	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	284	17	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	122	4	---
LAND PIPELINE	---	---	---
TOTAL	756	61	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1310

AVERAGE TRANSPORTATION COST PER BARREL = $ 7.61

TABLE B-97

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	561	57	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	429	19	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	216	7	---
LAND PIPELINE	---	---	---
TOTAL	1286	95	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2140

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.50

TABLE B-98

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3C

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	1005	100	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	672	25	140
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	314	9	---
LAND PIPELINE	---	---	---
TOTAL	2071	146	240

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3390

AVERAGE TRANSPORTATION COST PER BARREL = $ 1.98

TABLE B-99

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3C

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	336	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	...	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	366	18	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	37	1	...
LAND PIPELINE	---	---	---
TOTAL	819	65	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1400

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.27

TABLE B-100

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3C

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO SHORE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	336	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	---	---	---
NEARSHORE LOADING TERMINAL	366	18	120
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	290	10	---
LAND PIPELINE	---	---	---
TOTAL	1072	74	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1740

AVERAGE TRANSPORTATION COST PER BARREL = $ 4.05

TABLE B-101

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	256	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	266	17	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1279	106	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2230

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.21

TABLE B-102

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	234	25	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	186	20	Excl
OFFSHORE LOADING TERMINAL	229	16	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	279	20	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1008	93	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1840

AVERAGE TRANSPORTATION COST PER BARREL = $ 21.48

TABLE B-103

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	240	26	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	204	22	Excl
OFFSHORE LOADING TERMINAL	238	17	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	307	21	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	..-	---	---
TOTAL	1069	98	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1940

AVERAGE TRANSPORTATION COST PER BARREL = $ 11.33

TABLE B-104

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	290	30	Excl
ICEBREAKERS	80	12	10(.I
CONVENTIONAL TANKERS	429	42	Excl
OFFSHORE LOADING TERMINAL	300	18	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	473	24	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1572	126	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2700

AVERAGE TRANSPORTATION COST PER BARREL = $ 3.15

TABLE B-105

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	354	36	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	770	80	Excl
OFFSHORE LOADING TERMINAL	377	20	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	568	25	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	2149	173	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 3700

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.16

TABLE B-106

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

PARAMETER VARIED FROM BASE CASE: MINIMUM DISTANCE TO TRANSS. TERM.

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	254	27	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	265	17	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1276	105	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2220

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.18

TABLE B-107

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

PARAMETER VARIED FROM BASE CASE: MAXIMUM DISTANCE TO TRANSS. TERM.

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	260	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	267	17	100
NEARSHORE LOADING TERMINAL	---	...	...
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1284	106	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2240

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.22

TABLE B-108

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 100 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	256	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	261	16	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1274	105	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2220

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.17

TABLE B-109

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 30

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 150 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	256	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	254	26	Excl
OFFSHORE LOADING TERMINAL	272	16	100
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	423	23	140
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1285	105	340

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2240

AVERAGE TRANSPORTATION COST PER BARREL = $ 5.22

TABLE B-110

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3D

PARAMETER VARIED FROM BASE CASE: SOIL TYPE - SILTY CLAY

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	SAME		
ICEBREAKERS			
CONVENTIONAL TANKERS	AS		
OFFSHORE LOADING TERMINAL			
NEARSHORE LOADING TERMINAL		BASE	
TRANSSHIPMENT TERMINAL			
MARINE PIPELINE			CASE
LAND PIPELINE			
TOTAL			

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$

AVERAGE TRANSPORTATION COST PER BARREL = $

TABLE B-ill

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3E

BASE CASE

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	332	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	237	14	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	...	---
LAND PIPELINE	---	---	---
TOTAL	649	60	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1190

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.77

TABLE B-112

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 25,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	248	26	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	186	13	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	514	51	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 97(I

AVERAGE TRANSPORTATION COST PER BARREL = $ 11.26

TABLE B-113

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 50,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	270	28	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	204	13	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	...
TOTAL	554	53	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1030

AVERAGE TRANSPORTATION COST PER BARREL = $ 6.00

TABLE B-114

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 250,000 BP(I

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	555	57	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	269	15	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	904	84	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1660

AVERAGE TRANSPORTATION COST PER BARREL = $ 1.93

TABLE B-115

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3E

PARAMETER VARIED FROM BASE CASE: PEAK PRODUCTION RATE - 500,000 BPD

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	995	100	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	409	21	120
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	1484	133	220

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 2680

AVERAGE TRANSPORTATION COST PER BARREL = $ 1.56

TABLE B-116

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3E

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 100 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	332	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	234	14	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	---
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	---
TOTAL	646	60	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1180

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.76

TABLE B-117

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3E

PARAMETER VARIED FROM BASE CASE: WATER DEPTH 150 M

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	332	34	Excl
ICEBREAKERS	80	12	100
CONVENTIONAL TANKERS	---	---	Excl
OFFSHORE LOADING TERMINAL	241	14	80
NEARSHORE LOADING TERMINAL	---	---	---
TRANSSHIPMENT TERMINAL	---	---	...
MARINE PIPELINE	---	---	---
LAND PIPELINE	---	---	...
TOTAL	653	60	180

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$ 1190

AVERAGE TRANSPORTATION COST PER BARREL = $ 2.78

TABLE B-118

SENSITIVITY ANALYSIS FOR SCENARIO 3, ALTERNATIVE 3E

PARAMETER VARIED FROM BASE CASE: SOIL TYPE - SILTY CLAY

TRANSPORTATION ELEMENT	CAPITAL COST MM$	ANNUAL COST MM$	MANPOWER man-yr
ICE-STRENGTHENED TANKERS	SAME		
ICEBREAKERS			
CONVENTIONAL TANKERS	AS		
OFFSHORE LOADING TERMINAL			
NEARSHORE LOADING TERMINAL		BASE	
TRANSSHIPMENT TERMINAL			
MARINE PIPELINE			CASE
LAND PIPELINE			
TOTAL			

PRESENT VALUE OF TOTAL COST (@ 8%) = MM$

AVERAGE TRANSPORTATION COST PER BARREL = $