construction and operation. Table 3-19 shows the major environmental scaling factors for plant operation.

Refinery emissions are the major source of air pollution for the reference case, even when the average emission rates for the wellcontrolled, relatively low emission refineries of Los Angeles are used in the calculations. Thus, the scaling factors in Table 3-19 reflect well-controlled sources.

Refineries demand more water than any other element in the reference case system.

Refineries also account for about one-third of the necessary employment for the reference case, with crude oil production requiring most of the remaining two-thirds of the employment. Many of the offsite or indirect impacts from population in the reference case result from refinery employment.

2. Environmental Impacts

a. Onshore Production

The environmental impacts from tertiary recovery which will be the major source of new impacts onshore are shown in Table 3-20. These impacts will be the drilling activity necessary to begin tertiary recovery, * the growth of a chemical industry to produce the necessary chemicals for micellar flooding, and the air pollutant emissions from oil combustion to produce steam for injection.

We have assumed a relative recovery rate for tertiary recovery by various methods of: Thermal: 29%, Micellar: 58%, CO₂: 8%,

Hydrocarbon miscible: 5%

Table 3-19

IMPACT SCALING FACTORS FOR 10 6-B/D REFINERY CAPACITY

		Scaling Factor
Impact	Quantity	* Units*
Disturbed land or land removed from alternative uses	4400	Acres 10
Solid waste production (sludge)	80	Cubic yards per day
Wastewater production	420	10 gallons per day
Water pollution 10		
BOD	15	Tons/day
COD	55	Tons/day
Oil	4.0	Tons/day
Phenols	1.0	Tons/day
Suspended solids	10	Tons/day
Dissolved solids	250	Tons/day
Sulfides	1.5	Tons/day
Phosphorus	0.5	Tons/day
Nitrogen	2.0	Tons/day
Air pollution		•
Particulates	5,5	Tons/day
SO ₂	76	Tons/day
Hydrocarbons	69	Tons/day
NO _x	34	Tons/day
co	41	Tons/day
Offsite impacts induced by employ- ment, urbanization, and recrea- tion demands	,	
Permanent employees	9500	People
Total population	32,500	Population multiplier (6.5) times the number of people [†]

Approximate conversion factors: 1 acre = 4000 m^2 , 1 ton = 907 kg, 1 cubic yd = 0.76 m^3 .

[†] Population multipliers are discussed in Chapter 23.

Table 3-20

ENVIRONMENTAL IMPACTS FROM OASHORE OIL PRODUCTION UNDER THE REFERENCE CASE

Inpact St	caling Factor	Inpact Scaling Pactors and Scenario Quantitios		Scenario Quantity which	nario Quentity who	, 	Oventitet	Oneattettve indicator of Environmoptal Impact	of Environmen	ital Impact
Impact	Quantity	Impact Scaling Factor	1975	1985	2000	ni to	1975	1,985	2006	Units
Urbanization and induced population Employees Total population	24. 6. 8.	People/rig People/employee	1,100 25	1,250	1,250	Rigs 10 employees	80° +	29 . 190	061 68 .	10 ³ people
Solid waste produced by drilling	8	rons/10 ³ ft	ī	9.6		10 ⁸ ft of exploratory well		1975 - 2000		10 tons
Land ares disruption by drilling	vel	Acre/exploratory well		1975 - 2000		10 ³ wells		1975 - 2000 190		10 acres
Urhanization and Induced population Employaes Yotal population Wastewater production	13,600 6.5 210	People/amployed g/wnter/B oil	8.8 116. 9.9	91. 6.2 6.2	5,0 65 5,0	10 8/D 10 amployees 10 E/D oil	116 750 1.9	81 520 1.6	65 420 1,1	10 ³ employees 10 ³ people 10 ⁶ g/O
	88.0	Total tertiory recovery		. g	0.4	16 ⁶ B/D Tertiary recovory	C 0	ю. О 	⊕. 6 . 6	10 ⁶ B/D 10 ⁶ B/D
Chemical production Biopolymer and Polymerylanide Surfacturia (Hydrocarbon Sulfor-	1-8	T.bs/H all		2.0	ស ស	10 ⁶ u/11 ′ 10 ⁶ v/D	o •	0,7 - 5.8 5.1 - 11	0,8 - 6,7	10 ⁹ 168/yr 10 ^{\$} 168/yr
ates) Co-surfactants (Isopropanol)	4-10	Lba/8 u11	o ′	¢. 8	6,	10 ⁵ B/D	•	2.9 - 7.3	3,4 - 8,4	. z&/sql ₆ 0ī

Page 1 of Table 3-20

rable 3-20

RNVIRONMENTAL LAPPACES FIGM ONSHORE OIL PRODUCTION UNDER THE REPERENCE CASE

	Impact	t Scaling Facto	Scaling Factors and Scenarto Quantities	ries							
Activity	Impact	acm1	Impact Scaling Factor		Scenario Quantity which Determines Impacts	enarto Quantity whi. Determines Impacts	ty which mpacts	Quantita	tive Indicato	Quentitative Indicator of Environmental Impac.	ental Impaci
		quantity	Vnits	1975	1985	2000	Unites*	1975	\$86T	3000	Un 169
Tertiary recovery 40 by thermal mothods		0.20	Total Tortiary	D	8. 5.	4,0	10 ⁶ B/B	0	1,0	1,2	10 ⁶ B/II
	Air pollution Particulates	0.13	10 tons/10 B oil recovered	0	1.0	1.2	10 ⁶ 13.70	0	0.12	0.14	10 ³ tons/D
	30 NO _X CD Hydrocarbans	1 0.2 - 0.4 0.03 0.02	F					***	1 0.2 - 0.4 0.02 0.02	1,2 0,24 - 0,48 0,02 0,02	
Production	Land disruption	-	Acres/development	~ I	1975 ~ 2000 570	01	10 ³ develop- ment well		1975 - 2000 570		10 ³ acres [†]
	Solid waste production		Times the smount of waste produced by exploration	ĤΙ	1975 - 2000 70	D)	10 ⁶ cons [†]		1975 - 2000 210		106 tons

*
Approximate conversion factors: 1 gml = 3.79 x 10^{-3} m, 1 can = 90^7 kg, 1 acre = 4.05 x 10^3 mg, 1 ft = 0.305 m, 16^6 B = 180,000 mg, 1 pound = 0.454 kg, 1 mile = 1.61 km Accumulative for pertod indicated.

Applies to 1980 only, not 1975.

Page 2 of Table 3-20

Tertiary recovery, which requires many new wells in fields already producing under primary and secondary recovery, will bring an influx of drill rigs and well development personnel. This influx of personnel and their families can be expected to produce boom-town conditions in small communities that border large oil fields. For example, West Texas and Rock Springs, Wyoming, currently experience considerable oil-related activity as a result of recent crude oil price increases.

The most significant potential for adverse environmental effect will result from the production and use of large quantities of chemicals necessary for tertiary recovery (up to 10 billion lbs/yr [4.5 x 10 kg/yr] of some of the chemicals). Many of these chemicals are hazardous; polyacrylamide, for example, is carcinogenic. The isopropanol production shown in Table 21 for example, will, in the year 2000, be at about the level of today's methanol production. At present, no large-scale commercial production capacity exists for manufacturing these chemicals.

With onshore production likely to begin a long-term decline sometime in the next few decades, 3,6,41 and with production unlikely to increase significantly up to the onset of long-term decline, little onshore construction directly related to production can be expected. For example, pipeline construction will be confined mainly to that necessary for the transport of oil from tanker ports and from new offshore and Alaskan oil fields.

Total oil industry employment directly related to onshore production should also remain constant or decline with production through the end of the century.

b. Alaska Production

Under the reference case, Alaska undergoes the most substantial increase in oil production since the current production of about 200,000 B/D (32,000 m³/D) is projected to grow to over 3,400,000 B/D (540,000 m³/D) by the year 2000--far greater than any increase projected for other regions. The environmental impacts from this production increase are shown in Table 3-21.

The large projected rise in oil production employment in Alaska, from the current 3,000 to 57,000 by the year 2000, suggests that this state, with a current population of only about 350,000, will experience considerably more population related impacts than any other region under the reference case. This is particularly true if the 6.5 employment multiplier can be used to estimate the total increase in population of over 370,000 people. These impacts will be concentrated along the coastline of the Gulf of Alaska, along the North Slope, and in the Fairbanks region since it is the only large city close to the North Slope.

With the largest area of unspoiled wilderness in the nation and the second largest volume of crude oil reserves of all the states (Texas has more), Alaska will likely become a legal and institutional battleground for advocates of wilderness values and advocates of resource development. Opening the road to Prudhoe Bay to the public will allow more people access to northern Alaska than ever before, and perhaps will result in more environmental damage than the current TAPS construction project or the construction of a second pipeline as required in the reference case.

Alaskan offshore production can be expected to result in oil spills off the coast. Two very large oil spills (over 100,000 barrels

Table 3-21

ENVIRONMENTAL LYPACIES ON ALASKA UNDER THE REFERENCE CASE

	Impact 8	Sculing Facto	Sculing Pactors and Scenario Quantities	les							•
Activity	Impact	Impo	Impact Scaling Pactor		Scenari	nario Quantity whi Determines Impacts	- Ti	uan tative	Indicator	of Environ	Quantative Indicator of Environmental Impact
		Quentity	Units	1975	1985	2000	Units	1975	1985	2000	Unite
Exploration	Urbanization and induced population Francesor								•		
•	Onshore	12 60	People/rig People/rig	125 524 524	150	150 120	Alge Rigs	1,500 [‡] 9,100 [‡]	1,800	1,800	Employees Employees
	Total population [§]	6. 6	Peaple/empioyee	\$,000	B,000	000'8	Employees	#6F	មា	62	103 people
				ří l	1975 - 2000	<u> </u>		***	1975 - 2000		
·	Solid waste production Onshore	93 53	Tons/10 ³ ft of well Tons/10 ³ ft of well		3860		103 ft of well		0.42		10f tons
	-			ĦI	1975 - ZUD	81			1975 - 2000		
	Onsbore lend erea disruption	ED .	Acres/well		960		Number of exploratory wells		3300		Acrest
				Ħ1	1975 - 2000	81		.,	1975 - 2000		
	Offshore	3,000	Acros/well		096		Number of explor- atory wells drilled		1.1		10 ⁶ acres †
Production (normal)	Urbanization and			r		į.	,	'			
	Епріодева	13,600	Englovees por 10 B/D	0.2	9.6	4.4	10 ⁶ B/D production	9,	47	52	10 employees
	Total population	6,5	People	9. 8	47	54	10 ³ emulnyees	13	300	370	103 poople
	Low-level oil releases to the mifshore marine environment	a	u per 10 ⁶ B/D production	6,0	0.5	96.0	10 ⁶ B/T	1.8	e.	æ.	B/D odl
	Wastewator production from onshore production	210	gal/3 oil	•	3.1	3.4	10 ⁶ B/D	Đ	0.65	0.71	10 ⁹ gal/D
	Onshore land area disruption	65	10 ³ acres por 10 ⁶ a/b oll production		3.1	£.	10 ⁶	۰	200	220	10 ³ aares
	Offshore land area disruption	ec	1d ³ acres per pro- dection platform	124	52	25	Production platform	# 6 6	75	43	10 ³ acres

Page 1 of Table 3-21

Table 3-21

ENVIRONMENTAL INDACTS IN ALASKA UNDER THE REFERENCE CASE

	romental Impact	Units		10 ⁶ tons†	106 tons			Mean pumber	or blowouts		Mean number of very large oil spills	Mean number of large spills -	Mean number of moderately large spills over 25 years
	Quentative Indicator of Environmental Imeas:	1975 1985 2060	1975 - 2000	€ ਜ	6.72		1975 - 2000	6.3	0.1	1975 - 2000	ed es	45 4	19
!	itity which Finpacts	Units		10 ⁶ tons [†]	10 ⁶ tons†		1	Number of wells drilled	Number of wells drilled		(Average production)1.0 6 $^6/^1$	(Avorage production) 16 ⁶ B/D [†]	(Averaga produc- tion) 10 ⁶ B/D [†]
E-8	Scenario Quantity which Determines Impacts	1975 1985 2002	1975 - 2000	0.42	0.24		1975 - 200d	089	086	1975 - 2000	9.9	÷.0	
Impact Scaling Factors and Sconario Quantities	Impact Scaling Equipr	Units		Times total solid	atlun			per 10 ³ wells drilled	per 10 ³ wells drillod		Mean number of spills per 10 ⁰ -8/0 production over 25 years	Mean number of spills per 10 ⁶ .B/D production over 25 years	Moan number of settly per 10 ⁶ -B/P production over 25 years
altag Facto	Inga	Quentity		FC	n			0.4	. 0.3		ф	ន	36
Impact Sc.	Impact		Solid weste production	Onshore	Offshore	Blowouts and mesidental relates of oil into the	environment, Bird losses, oiled beaches, fire, loss of life.	Onshore	Offshore	312e of accidental att epills from offshore andretions	Greater than 100,000 B	Between 10,000 B and 100,000 B	Size of oil spills Between Z,000 B and IO,000 B
	Activity		Production	(normal)		Exploration (abnormal	operations)			Production (abhormal			

Pege 2 of Table 3-21

Table 3-21

ENVIRONMENTAL LIPACIS IN ALASKA UNDER THE RELIGIENCE CASE

	Japact S	Scaling Pactor	Impact Scaling Pactors and Sagnatio Quantities	tios							
			1		Scenario	Quanti	Scenario Quantily which		:	-	, , ,
	Impact	Impa	Impact Scaling Factor	1	। हिंह 	Determines Impacts	mpacts	Quantativ	o Indicator	of Environ	Quantative Indicator of Environmental Impact
		Quantity	Unite	1975	1985	2003	Un1+,s	1975	1985	2000	onite
	Air pollution from	1000	Miles/TAPS	Đ	3.1	н Н	10 ⁶ B/D prod-	•	1,000	1,000	
	second TAPS						uction				
				ć	-	-	Number	٠	•	G	Tene (day
	Tall Carrier Co.	4 n	man (and	> =	4 :	. =			1 2	1 E	Trong Annual
	o e	gg.	long/day	=		=	SOUT CEDIES	5 1	i '	7	Tours day
	Kydrocartons	ΔI	Tons/day	;	;	= :	TAPS	٥	ρı	N	Tons/day
	MD _x	36	Tons/day	=	F	=		0	36	36	Tons/day
	· 8	11	Tuns/day	=	5	=		٥	=	11	Tons/day
	Induced urbanization										
_	population and employ-										
-	nont										
	Employees	300	People/TAPS	0	r1	64	Number of TAPS	0	600	909	Employees
	Total population	6.5	People/employee	0	600	900	Епртоусек	E	4,900	4,000	Prople
	Land disruption through construction of new oil atterment facility for	θψ	Acres	0	ч	71	Number of mew TAPS	•	800	800	Acres
	TAPS Number 2,								0002 ~ 0861		
	Potential oil spill from repture of storage tanks at Valdez	όαρ'οτ <u>ς</u> ,	B/tonk	•	끃	7	Number of tanks		<u>α</u>		Maximum potential oll spill-
	Patential oil spill from rupture of TAPS	50,000	B/rupturo						50'0		
	Potential oil spill from tanker grounding	1.5 × 10 ⁶ 0	B/tanker						1.5		:

Approximate conversion fartors: 1 gal = 3.79 x 10⁻³n³, 1 ton = 907 kg, 1 acre = 4.05 x 10³ n², 1 ft = 0.305 m, 10³B = 160,000 m³, 1 pound = 0.454 kg, 1 mile = 1.51 km. Completive for period indicated.

Page 3 of Table 3-21

Completive for period indicated.

*
Applies to 1980 only, not to 1975.

Employees plus associated population.

of oil) can be expected as the mean number over the next 25 years. All Alaskan crude oil will probably be shipped to the West Coast states by tanker; which implies oil spills and sewage production that occur from tanker operations may impact the Pacific coastline from Alaska to California.

Oil spill from earthquake damage to the Valdez storage facility, with its 20-million barrel capacity, is possible, particularly with the frequency and severity of tremors along the Gulf of Alaska* (Valdez was destroyed by the 1964 earthquake).

A second TAPS for transportation of oil from Naval Petroleum Reserve Number 4 (NPR4) to Valdez is required sometime in the 1980s. Considerable impact will be associated with its construction although additional road construction would be needed only across the North Slope tundra from the present pipeline corridor to NPR4.

Many of the impacts in Alaska, although quantitatively less than for onshore production (compare similar categories in Tables 3-20 and 3-21), will be severe in Alaska because relatively few areas will be impacted due to the geographic concentration of resources. Oil production from Alaska will increase many fold under the reference case and the impacts can be expected to rise proportionately.

Between 1899 and 1973, 13 earthquakes with magnitude over 7.0 on the Richter Scale have occurred. 11

c. Offshore Production with Attendant Transport and Refining Operations

The impacts from refinery construction under HG3 are given for two cases: (1) in which all imported oil is unrefined, and (2) in which 50 percent of the imported oil is already refined. If all imported oil is in the form of refined products, then no new refinery capacity is required. Table 3-22 shows the environmental impacts from offshore production, Tables 3-23 and 3-24 show the requirements for additional refinery construction and operation, and Table 3-25 shows the environmental impacts from refinery operation.

The coastlines receive a large share of the environmental impacts under the reference case, not only because considerable crude oil production will take place offshore, but because the possibility of large-scale oil spills from production and tanker accidents adds ecological disaster potential without analogy in onshore oil production. New refinery capacity is likely to be built along the coastlines at locations at which the increase in crude oil production under HG3 will be delivered. Unless all imports are in the form of refined products, additions to refinery capacity will be required under HG3. Expansion of existing refineries (already concentrated on the coastal regions, particularly the Gulf coast) will cover much of the projected needs.

The mean number of large oil spills (over 100,000 barrels) under HG3 is projected to be 13 over the next 25 years.

Employment-related impacts from offshore oil production will triple under HG3. Offshore-production-related employment will grow from 18,000 to 52,000. Of course, the impacts related to this employment will be dispersed over the Atlantic, Gulf, and Pacific coasts.

The coastal regions experience the most pipeline construction under the reference case. Offshore solid waste from well drilling will

Table 3-22

ENVIRONMENTAL INPACTS FROM OFFNIDRE DEVELOPMENT AND TANEER OPERATIONS UNDER THE REFERENCE CASE.

	Impact 5	Scaling Facto	Impact Scaling Factors and Scenario Quantities	6.8							
* 404	fement	edil	Impact Scaling Pactor		Scenario Quantity which Determines Imports	mario Quantisy who Determines Imports	y which	O to the original or the original origina		Prod Po	Onomiating Toldhator of Engleonments I have at
		Quantity	Units	1975	1.985	2000	Unito	1975	1985	2000	Units
Kxploration	Urbanization and induced population										
	along roastiines Employees	100	Enployees/tik	370	200	900	Birs	37	52	52	10 ³ omployees
	Total population	B 9	Poople per employee	31+	려 	22	103 employdes	240*	340	340	103 poople
	Tons of drill cuttings	23	Tons/10 ³ ft of exploratory well	91	11	01	107 It of wall	-1	1975 - 2000 6,9		10 ⁶ cons
	Offshore land disrupl- ion	3,000	Acres per explora- tory well		11		103 wellst		11		lo acres
Product ton	. Induced urbanization and employment				•	,		1			,
	Enployees	13,000	Employads per 10 ⁶ B/D	1.4	3,0	4.0	10 ⁶ B/b	18	66	22	10 ³ employees
	Total population	6.8	Fuple per employee	18	R .	67 67	10 ³ employees	111	254	338	103 people
	Tons of drill cuttings	m	Times that produced by exploration	튀 !	6.9		106 tons	- , ,	1975 - 2000 21		10 ⁶ tons
	Offshore land disrup- tion	3,000	Acres/production piations	150#	200	002	Production platforms	6.9	9′0	9,0	10 ⁸ offshore Bores
	low concentration bil releases to the narine contronment										
	Atlantic OCS	ET.	R/10 ⁶ B o11	•	0.04	9.0	10 ⁶ B/n n41	Ċ	0.36	0,54	8 oil per day
	Gulf OCS	6	Produced B/10 ⁶ B oil	1,3	87 87	2.0	Promoction 10 ⁶ B/D oil	ė	12	3.6	B of l per day
	Pacific OCS	6.	produced B/10 ⁶ B oll preduced	0,05 8	9.0	1,3	production 10 ⁸ B/D oil production	6.5	5,4	11	B oil por day

Page 1 of Tahle 3-23

Table 3-22

ENFENDAMENTAL THEACTS FROM OFFSHORE LEVILOPHERY.
AND TANKER OPERATIONS INDER THE REPERFROE CASE.

Activity	lmpact	odu:T	Impact Scaling Factor		Scenario Quantity which Peternines Impacts	mario Quantity which	y which	Quantate	ve Indicator	al Envtron	Queniative Indicator of Environmental Impact
		Quantity	Units	1075	1985	2000	unite Unite	1975	1685	2000	Onits
Exploration (Abnormal ectivities)	Blownate and accidental bil releases to the marine environment: hixd deaths, spoiled beaches, danage to flaheries, cleanup cosis, fire and equipment danage.	er 9	per 1800 expluratory Wells drilled	±1	11,000	el	kaploratory weils†	•	3	i i	Mean numbor of blowouts expected
Production (Abnormal activities)	Sizes and Irequency of probable number of ail spills; Greater than 100,000 B	ਾ. ਧ	Mean member of spills per 10 ⁶ N of production per 25 years	_	0"6		Average over 25 years 10 ⁶ -B/D ext		13		Mean number of very large spills over 25 veers
	Between IO,000 B and 109,000 B	13	Mush number of opills per 10 ⁶ -B/D production over 25 years		3.0		٤		ଜେ		Meza number of large spills ovor 25 years
	Botween 2,000 B and 10,000 u	6E	Wean number of spills per 10 ⁶ -8/D production	ı	0°E		τ		130		Mean number of moderately large spitls over 25 years
Crudo Oil Pipo- line System	Offenare pipeline construction - smaled disturbance and potunital navigational hazard .	8,000	Wiles of pipeline per 10 ⁶ B/D increase in crude oil supply	D	1.7	r- ri	10 ⁶ B/D increase over 1974 prod- uction	•	. 14	23	107 miles of offshore pipe-

Puge 2 of Table 3-22

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Table 3-22

BRYTRONBENYAL IMPACTS FROM OFFSHORE DEVELOPMENT AND TANKER OPERATIONS UNDER THE REFERENCE CASE.

Activity	Impact	Ітра	Impact Sculing Factor		Sucarri	uario Quantity whi	Successive Quantity which Dofernines Impacts	Quantatty	re Indicato	r of Baviro	Quantative Indicator of Breisonmental Impact
		Quantity	Units	1975	1985	2000	If mit to	1975	1985	2000	Vert ta
Crudo Oil Pipe- lime System	Air pollutant emissions increase from mew off-										
	shorm crude oil pipe- lines:										
	Particulates	1,25	Tons per 10 ³ miles	۰	17	22	10^3 miles of	¢	18	98	Tons/day
	20%	16					p100117.6	¢		ļ	•
	Hydrocarbons	0,38	1				-	5 5	220	920	
	NO.	5-8.8					Ε	,	20.102	8.4 110.100	
	ູ້ຄວ	0.50					E		2	110-130	;
	Urbanization and assoc- lated population; re- creation domands									1	
	Buployees	20	Employees per 1000 milus of now pipeline	0	11	22	1000 milus new pipelino	0	6.0	1.5	10 ³ amployees
	Total population	£.6	People/omployee	0	6.0	1.5	10^3 amployees	· ၁	5.8	e1	103 people
Tanker Operations	Oil release to the marine environment from ballast cleaning operations Alaskun Pacific Cosst	13-270	B/10 ⁶ B transmorted	51 C	ф г	4		ų c	;	!	,
	oil shipped to wost		from Alaska	;	;	;	From Alaska	t t	6 3	2 2	B/D
	codet ports							š	970	1300	
	coastal waters by									•	
	By Imports	1.5	103 gr1/tanker	4	7.5	12	200,000 dwt	20	11	91	10 ³ gal/D
	By Alaskan oil tankaya	1.0	10^3 gel/tanker – dey	ю	\$	20	tunkers/sey Tankers	e	G.	20	163 gal/D
	Probable oil spills Major										
•	Imports	94	B/10 ⁶ B transported	6,0	21.5	18.4	106 U/U 011	200	380	630	D/D 041
	Alaskan oil	. 34-180	B/10 ⁶ B transported	2.0	9,6	4.4	cransported 10 ⁶ B/D e11	8.0	120	150	10.00 m
							transported	to	ţ	to	
								60	i		

Page 3 of Table 3-22

BRYTRONARNTAL INDACTS FROM OFFSHORE DEVELOPMENT AND TANKER OFFSHALONS UNDER THE HEPERRINGE CASE.

	Posstative Indicator of Environmental Impact	Val ts		B/D oil	B/D 011
	of Environs	2000		9) NI	13
	Indicator	1985		17	#
	Quantativo	1975		6	Đ °0
	Scenario Quantity which Determines Impacts	* Идтья		6.0 11.5 18,4 10 D/n of 1	4.4 10 ⁶ B/N all trunsported
	snardo Quantity whic Determines Imports	2000		18.4	
	Scenario Deter	1985		11.5	3,6
<u></u>		1975		6.0	0.2
Scaling Pactors and Scenario Quantities	tennest Sentions Fuction	Units *		B/10 B transported	D/10 ⁰ B transported
Scaling Pactors	i mis out	Quantity		1.5	रुः
Impact		Taribus T	Probable oil spills	Manor Teperts	Alaskan oil
		Activity	Tanker operations		•

1	1 gul = 3,79 x 10 ⁻³ m ³	L ton = 907 kg	1.acre = 4,05 x 103 m2	ft = 0.303 m	$10^{10} \text{B} = 260,000 \text{ m}^{3}$	1 pound = 0.454 kg	5 mile = 1 fc1 km
	-		H	7	2	П	•
	factors:						
	conversion						
	Approximate conversion factors:	!					
•							

Cumulative for period indicated.

Applies to 1980 anly, not to 1975.

Page 4 of Table 3-22

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Table 3-23

NEW REFINERY REQUIREMENTS FOR REFERENCE CASE OVER AND ABOVE 1975 REFINERY CAPACITY IMPORTS ARE CRUDE OIL ONLY

	Date			100	1441
	Data and Assumptions		1975	1985	2000
Production Sc	Production Schedule: Refinery Capacity increase over 1975 in 10 ⁶ Barrels per Day	ncrease over 1975	a	12.0	19.0
Input	Inputs and Outputs	Scaling Factors	}		
Items	w Units	of new capacity (in units specified)	•		
Construction .					
Capital	10 1973 \$ (cumulative)	2,000	Ф	2.4 x 10 ⁴	3.8 x 10 ⁴
Labor	Man-years (cumulative)	38,000	0	4.5 x 10 ⁵	7.1×10^{5}
Steel	10^3 tons (cumulative)	850	c	1.0 x 10 ⁴	1,6 x 10 ⁴
Land	103 acres	22	0	260	420
Operation					
Operating costs	10 ⁶ 1973 \$/year	200	ü	6×10^3	9,5 x 10 ³
Labor force	Number of people	9,500	0	1.1×10^5	
Water	$10^3~ m acre-ft/year$	дэ	0	720	1,100
Electric power	MIN	.250	0	3,000	4,800

1 ft = 0.305 m, $10^{9}B = 160.000 \text{ m}^3$, 1 pound = 0.454 kg, 1 mile = 1.61 km

80

Table 3-24

NEW REFINERY REQUIREMENTS FOR REFERENCE CASE OVER AND ABOVE 1975 REFIRERY CAPACITY (50 PERCENT OF LEPORTS ARE REFINED PHODUCTS)

				Impact for Year	lear
	Data and Assumptions		1975	2861	2000
Production Sche	Schedule: Additional Capacity in Units of $10^6~\mathrm{B}/\mathrm{D}$	in Units of 10 ⁶ B/D	0	5,9	6.3
Input	Inputs and Outputs	Scaling Factors for a 10 B/D Plant			
Items	Units	(in units specified)		**	-
Construction				•	′ <
Capital	10 ⁶ 1973 \$ (cumulative)	2,000	o	1,2 x 10 ⁷	1.9 x 10 ¹
Labor	Man-years (cumulative)	38,000	0	2.2×10^5	3.5 x 10 ³
Stee1	103 tons (cumulative)	850	0	5.0×10^{3}	7.9×10^{3}
Lend	10 ³ acres	22	Φ	130	200
Operation				•	:
Operating costs	10 ⁶ 1973 \$/year	500	0	3×10^3	4.7 x 10 ³
Labor force	Number of people	9,500	0	5.6×10^4	8.8 x 10 ⁴
Water	103 acre-ft/year	09 ·	•	350	260
Electric power	MAW	250	0	1,500	2,300

* Approximate conversion factors: 1 gal = 3.79 x 10^{-3} 3 , 1 ton = 907 kg, 1 acre = 4.05 x 10^3 m,

l ft = 0.305 m, $10^{6}B$ = 160,000 m³, l pound = 0.454 kg, l mile = 1.61 km

Table 3-25

ENVIRORIZENTAL IMPACTS FROM TILE OFFILMTION OF MEN REFINERIES UNDER THE RUFFILENCE CASE,

Refineries

Activity	impact impact Scaling Factor	Inpact Sca	Inpact Scaling Factor	; ;	Scenario Quantity which Determines Impacts	nario Quantity which	y which pacts	Quanta Imports	tive Indica	Quantative Indicator of Environmental Impact	ronnental	Impact
		Quantity	Units	1,975	1985	2000	Units	refined in U.3.	1975	1988	2000	Vaits
fineries	Wistewater production Coastal regions	420	10 ⁶ gal/3 per 10 ⁵ B/b refined	0 0	6, 6 T	9,3	10 ⁶ B/D	, 56 26, 76	00	5.5	6. 8 0. 8	10 ⁹ gal/D
	Water pallution BOD	15	Tons/D per 10 ⁶ B/D	00	5.9 12	. 6. 6.8	10 ⁶ B/D	50% 0%	0 0	85 1.80	140 290	To sect
	con	10 40	Tons/D per 10 ⁶ B/D	٥٥	5.9	9.3	10 ₆ a/o	90k	٥ ٥	320	510	Tons A
,	913	4	Tons/D per 10 ⁶ B/O	00	5.9	9,3 19	10 ⁶ B/D	80 8 0	٥٥	24	37	Tons/Ti
c	Phonolis .	1	Tons/D per 10 ⁶ b/D	00	5,9 12	9.3	10 ⁶ µ/v	80 80	٥٥	5.9 12	. 9 . 3	Tons/D
	Suspended solids	10	Tons/D per 10 ⁶ B/D	\$ \$	5.9	e.	40° 8,70	50% 0%	0 0	120	93 150	Tons/D
	Dissolved solids	250	Tons/D per 10 ⁶ B/D	00	5.9 12	9,3 19	10 ⁶ B/0	50%	٥٥	1,500	2,300	Tons/D
	Sulfidos	1.5	Tons/D per 10 ⁶ B/D	00	0.9	6,0 19	10 ⁶ B/0	50% 0%		. 8 6.8	, 14	Tons/D
	Phosphorus	9,5	Tons/D per 10 ⁶ B/D	90	5, 9 12	9.3 19	10 ⁶ a/p	50%, 0%	co	9.0	4.4 6.6	Tons/D
	Nitrogen	0.5	Fons/D per 10 ⁶ B/D	• •	8,8 12	9,3 19	10 ⁶ B/D	30% 80	0 0	12	38	, Tans/D
	Air pollution Particulates	io S	Tons/D per 10 ⁶ B/D	• •	5,9 12	E. 6 19	10 ⁶ B/D	80 85 60	e e	32 88	51	Tons/D
	€08 .	J 6	Tous/D per to H.D	o o	بر و چار	9.3 19	10 ⁶ µ/D	20%	6 6	456 916	710 1,409	Tons,/D
	Mydrocarbons	Ğ	Tons/D per 10 ⁶ B/D		5,9 12	9,3 19	10 ⁶ B/D	50% · 0%	• •	410 830	640 1,300	Tons/D
	(MC).	34	Tons/D per 10 ⁶ B/D	00	5.4	9.3	10 ⁶ 8.70	50% 0%	5 C	200 410	320	Tons/B
	ប	41	Tons/D per 10 ⁶ B/D	၁၁	5.6 12	9,3	10 ⁶ B.TJ	20 20	00	240 490	380	Tons/D

Page 1 of Table 3-25

Table 3-25

ENVIRONMENTAL INDACTS PROM THE OPERATION OF NEW REFINMALITS UNDER THE REFERENCE CASE.

	Impact Scaling Pactors and Scenario Quantities	Pactors and	Scenario Quan			1	de de	Quants	tive ledic	Quantative Indicator of Envisonmental Impact	honmental	Inpact
	Tenact	Impact Sec	Impact Scaling Factor		Percentage Impacts	Retermines Impacts	pacts	Imports	ı			*
,	-	Quantity	Volts	1975	1985	2000	Units	1п П.В.	1975	1985	2000	Ontto
	Employment, urbanization, and recreation Employment	00 9 16	Employees per 10 th /D capacity	0 \$	6, 5 81	6. e	a.3 10 ⁶ n/o 19	50%, 0%,	o c	. 54 111	n8 180	10 ³ employees
	Total population	6.5	Psopie per employae	0 0	114	88 180	Epploymes	20 20 20 20 20 20 20 20 20 20 20 20 20 2	60	350	1,200	10 ³ prople

Approximate conversion factors: 1 gal = 3.79 x 10^{-3} m ³	, 1 ton = 907 kg	1 pare = 4.05 \times $10^3 \cdot m^2$	1.1t = 0.305 a	10 8 = 160,000 m ³	1 pound = 0,454 kg	I pile = 1,81 km
* Approximate conversion factors						

Page 2 of Table 3-25

create unconsolidated sediment and poor habitat around the sites of offshore drilling; the volume will be about 200 ft by 200 ft and 1 ft thick around the base of each drill site. However, this amount of solid waste is dwarfed by the amount of sludge produced by coastal cities (e.g., New York).

Employment-related impacts from refinery construction and operation could be more substantial than for crude oil production. Refinery employment under HG3 could double from 150,000 in 1975 to over 300,000 in 2000 if all imports are in the form of crude oil.

The coastal regions will experience impacts that are quantitatively similar to the impacts from onshore production (compare similar categories in Tables 3-21 and 3-22); however, the impacts will be concentrated in a smaller region. In addition, pipeline construction, refinery construction and operation, and increased tanker activity will bring impacts to the coastal regions unlike those in onshore production. Tables 3-22 and 3-25 support the conclusion that under the reference case the coastal regions will experience the most significant air pollution increases of the three reference case regions and the greatest potential for large oil spills, in addition to major employment-related impacts.

APPENDIX A

QUANTITIES OF OIL RESOURCES AND RESERVES

The distinction between resources and reserves is often misunder-stood. In general, resources refer to physical quantities, while reserves implies recoverability of a fraction of the resource as determined by prevailing economics and technology. Figure A-1 illustrates the relationship of the various classes of oil resources and reserves. The quantities of the important classes of resources and reserves are: 2

- 440 x 10 barrels of crude oil resources identified in the United States as of January 1975.
- 106 x 10 barrels of crude oil resources produced as of January 1975.
- 40 x 10 barrels of discovered crude oil resources classified as economically producible (demonstrated reserves) as of January 1975.
- 82 x 10 barrels of undiscovered oil resources estimated by the USGS as producible with 50 percent certainty at 1973 crude oil prices (assumes 32 percent recovery of the undiscovered resources).
- Up to an additional 130 x 10 barrels of oil of the resources (discovered and undiscovered), which may be recoverable with advanced recovery techniques (up to 50 percent recovery of the original resources both discovered and undiscovered) at much higher crude oil prices.

Much of the oil resource cannot be recovered because of the difficulties of extracting oil from the porous oil-bearing rock strata, which can lie up to 20,000 ft (6000 m) underground. Estimates of the percentage of the resource eventually producible generally vary between 30 and 50 percent. Primary recovery (producing oil from self-pressured fields

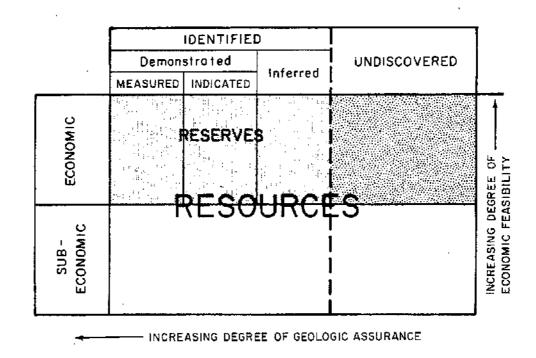
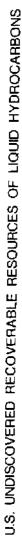


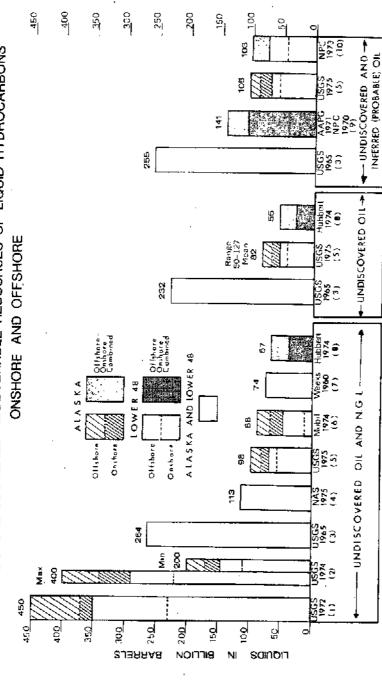
FIGURE A-1. DIAGRAMATIC REPRESENTATION OF PETROLEUM
RESOURCE CLASSIFICATION BY THE U.S. GEOLOGICAL
SURVEY AND THE U.S. BUREAU OF MINES

or from artificially pumped fields) and secondary recovery (producing oil by pressurizing the field through water injection or through natural gas injection) together generally achieve about 30 percent recovery of the original resource. Advanced recovery or tertiary recovery (producing oil by injecting solvents, steam, CO_2 , or other chemicals or producing oil by any technique not classed as primary or secondary recovery) may achieve an additional 20 percent recovery of the initial resource. This additional recovery percentage varies considerably among actual fields—in some cases 90 percent recovery can be achieved. Unfortunately, however, no general agreement exists over the percentage of the resource that can be recovered by advanced recovery techniques.

Today's technology and economics make 70 percent of the resources either too expensive to produce or impossible to produce. For future oil production, increased oil prices can make some of the last 70 percent of the resources available. However, it takes considerable time to bring advanced recovery into widespread use and significant production by advanced recovery cannot begin for at least a decade.

Considerable controversy surrounds the quantity of undiscovered oil resources, although recent estimates agree remarkably. Figure A-2 shows several of the important estimates. In mid-1975, USGS estimated that undiscovered ultimately recoverable oil resources (at 1973 crude oil prices) consist of between 50 and 127 billion barrels with the mean estimate of 82 billion barrels (assuming 32 percent recovery of the undiscovered resources). A recent study by the National Academy of Sciences reports that about 113 billion barrels remain to be found and produced. These estimates implicitly assume recovery at 1973 prices.





Source: U.S. Geological Survey, Circular 725

- Theobald and others, USGS Circ. 650 (1972). Includes water depth to 2,500 m (8,200 ft).
 - USGS News Release (March 26, 1974). Includes water depth ta 200 m (660 lt). 5
- Hendricks, USGS Circ. 522 (1965). Adjusted through 1974. Includes water depth to 200 m (660 ft). 3
- National Academy of Sciences," Mineral Resources and the Environment," (1975). Water depth not indicated. 5 (2
- USGS "Mean," Oif and Gas Branch Resource Appraisal Group (1975). Includes water depth to 200 m (660 ft).
 - Mobil Oil Carp., "Expected Value," Science (12 July 1974). Includes water depth to 1,830 m (6,000 ft). 9
 - Weeks, L.G., Geotimes (July-August 1960). Adjusted through 1974. Water depth not indicated. (2
 - Hubbert, M. K., Senate Committee (1974). Includes water depth to 200 m (660 ft). 8
- American Association Petroleum Geologists Memoir 15, (1971); National Petroleum Council, "Future Petroleum Provinces of
- National Petroleum Council, "U.S Energy Outlook--Oil and Gas Availability," (1973). Includes water depth to 2,500 m (8,200 ft). the United States," (1970). Some areas are excluded from this estimate, Includes water depth to 2,500 m (8,200 ft) 2

COMPARATIVE ESTIMATES OF OIL RESOURCES IN THE UNITED STATES FIGURE A-2.

Thus, taking into account reserves, the USGS estimates that, at 1973 prices, recoverable resources yet to be produced amount to about 120 billion barrels. If advanced recovery could be applied to the remaining discovered and estimated undiscovered resources so that 50 percent of the resource could be produced, the recoverable resource, which could actually be produced, would be about 250 billion barrels. More detailed estimates of the oil recoverable by advanced techniques are not available and the 250 billion barrels must, at this time, be viewed as the most credible upper limit to the amount of resources left to be produced. Furthermore, tertiary recovery is a slow process which takes many years to complete in a given field but it contributes to overall oil production by maintaining production rates higher and longer than possible under long-term primary and secondary recovery. If today's oil prices are maintained, then the limits of the reserves (120 billion barrels) virtually assure that U.S. crude oil production will begin a long-term decline in the early 1980s (completion of TAPS will stave off the decline in U.S. production rate for 5 to 8 years). Higher crude oil prices can extend the reserves to a maximum of 250 billion barrels, but because of the long time required to bring tertiary recovery projects up to full production and the generally slow rate of recovery by tertiary methods, production rates during the late 1980s and thereafter for the nation as a whole are unlikely to increase beyond those achievable in the early 1980s. Increasing crude oil prices will have the long-term effect of preventing declines in production, but because of the limits of the resource base now projected, substantial increases in future crude oil production rates would seem impossible.

APPENDIX B

METHOD FOR HG3 REGIONAL SUPPLY PROJECTION

The limitations of the oil resource base discussed in Appendix A help determine a credible upper limit to the future production rate from U.S. resources. Of the 120 billion barrels available at 1973 oil prices and producible by primary and secondary recovery, about half of this amount is physically producible by the year 2000 if prices remain constant in 1973 dollars. Thus, cumulative production of more than about 60 billion barrels by the year 2000 requires much higher crude oil prices and the application of advanced recovery to many fields. Indeed, physical considerations together with the new USGS estimates imply that crude oil production rates past the year 2000 cannot exhibit long-term increases, not even a constant production rate.

With these limitations imposed on the quantity and the rate at which oil can be recovered, we selected from among the EPP scenarios of domestic oil production in the absence of synthetic crude oils scenario HG3, which has the lowest cumulative production between 1975 and 2000 and a non-increasing rate of domestic production between 1985 and 2000. The remainder of the scenarios in Table 3-1 imply that the rate of domestic production increases to the year 2000 and beyond.

Scenario HG3 itself requires that about 70 billion barrels of oil be produced by advanced recovery techniques by the year 2000. Since cumulative production over the last 100 years has only been 106 billion barrels using conventional oil recovery techniques, the 70 billion barrels recovered in 25 years by applying advanced techniques probably represent the upper limit to domestic oil production, and indeed lower

cumulative production and smaller production rates in the year 2000 than HG3 are more likely, particularly if the new USGS estimates of the domestic resources base are approximately correct. Thus, HG3 represents a scenario of maximum credible domestic oil production, even assuming much higher crude oil prices. (It is not possible to estimate at this time what price of crude oil would be necessary to bring about production of the 70 billion barrels of oil by advanced recovery techniques for HG3, since not enough is actually known about the economics of applying advanced recovery techniques on a wide scale.)

For analysis of the impacts of HG3, we have used the Project Independence scenarios in the Oil Task Force Report 4 for determining the percentage breakdown of regional oil supplies from national production under HG3 as shown in Table 3-1. Table B-1 shows the regional oil supply projected by HG3 and serves to illustrate environmental impacts. The supplies shown in Table B-1 may never be realized; they are intended to serve a similar function in this study to that served by the maximum credible implementation scenario, Chapter 6. One major difference in credibility between the two scenarios rests in the area of the resource estimated. No one really knows how much oil is left for discovery, where it is, or how rapidly it can be produced. However, the location and the quantities of the oil shale and coal resources for syncrude are known.

Table B-1

HISTORICAL GROWTH SUBSCENARIO 3--REGIONAL SUPPLY

OF OIL AND NATURAL GAS LIQUIDS

(Millions of barrels per day)

Region or Source	1974	Percentage of Total Supply*	HG3 1985	Percentage of Total Supply	HG3 2000
Prudhoe	0	13.4	1,80	8.6	1,20
North Slope	0	9.4	1.30	5.1	0.68
NPR4	0	0	0	11.7	1,60
NPR1	0	0	0	0.6	0.08
Military Reserves	0	0	0	1.2	0,16
1	0.201	4.0	0.54	7.2	0.96
2	0.792	4.4	0.59	2.8	0.38
2A	0,058	4.5	0.60	9.0	1,20
3	0.215	1.2	0.16	0.9	0.12
4	0.614	2.5	0.34	1.7	0.23
5 -	2,553	12,1	1,60	8.0	1.10
6	3.526	24,0	3.20	18,1	2.40
6A	1.311	17.4	2.30	15.2	2.00
7	0,994	6.4	0,86	4.2	0.56
8-10	0.213	2.1	0.28	1.4	0,19
11	0.007	0	0	0.1	0.013
11A	_0	0.3	0.040	4,5	0,60
* Totals	10.50	100	13,400	100	13.400

^{*} Items may not sum to totals due to rounding.

[†] Percentages based on data on Exhibit IV-2, Business-As-Usual, \$7/B, 1985.

Percentages based on data in Exhibit IV-2, Accelerated Development, \$7/B, 1988.

APPENDIX C

TRENDS IN PAST U.S. PRODUCTION AND THEIR IMPLICATIONS FOR FUTURE PRODUCTION

Hundreds of oil fields produce oil in the United States. Production into the rest of this century is certain to include oil from most of the existing fields, some of which have been producing for over 60 years, and presumably from fields yet to be discovered. Section 1 below presents a brief history of U.S. consumption of crude oil and crude oil prices. Declining annual discovery rates for new oil fields and declining crude oil prices (in constant dollars) characterize the 20 years prior to 1973. Dramatic crude oil price increases characterize the last two years.

1. A Brief History of U.S. Oil Production and Oil Exploration

Table C-1 summarizes the history of U.S. crude oil production and discovery. Column 2 of the table shows the annual U.S. crude oil production for the selected years. Each year, oil is produced from the economically proven reserves (Column 3 of Table C-1) remaining at the end of the previous year. Production increased nearly 3 percent per year on the average from 1890 until production peaked in 1970. After 1970, production began a decline, which continues (late 1975). This trend is expected to continue until TAPS is completed. In 1974, reserves were estimated to be about 34 x 10⁹ barrels, and production was 3.0 x 10⁹ barrels. Thus, if all else were constant, economically producible known reserves would be exhausted in only 11 years. However, each year brings new discoveries and new economic conditions, which change estimates of reserves. Increasing the real price of crude oil can result in new

Table C-1

HISTORICAL RECORD OF PRODUCTION AND PROVEN RESERVES: ALSO
THE ULTIMATE RECOVERY AND ORIGINAL OIL IN PLACE BY YEAR
OF DISCOVERY--TOTAL UNITED STATES FOR SELECTED YEARS
(Billions of barrels of 42 U.S. gallons)

	For All Fig	elds Discovered	For Fields I During	
	to	Date	1974 Estimate	1974 Estimate
Selected	Production	Proved Reserves	of Ultimate	of Original
Years	During Year	at End of Year	Recovery	Oil in Place
(1)	(2)	(3)	(4)	(5)
Pre-1920	5.1		25.8	98.0
1925	0.8		1.0	4.0
1930	0.9		7.7	13.6
1935	1.0		2.5	7.1
1940	1.3		3.8	9,6
1945	1.7	19.9	2,2	7.0
1950	2.0	25.3	2.6	7.3
1955	2.4	30.0	1.5	5.6
1 96 0	2.5	31.6	0.9	3.1
1965	2.7	31.3	1.3	4.5
1966	2.9	31,4	0.5	2,0
1967	3.0	31.4	0.7	2.9
1968	3.2	30,7	10.6	25.4
196 9	3.2	29.6	0.6	2.3
1970	3.3	39.0	0.7	2,2
1971	3.3	38.1	0.4	1.3
1972	3,3	36.3	0.2	1.0
1973	3.2	35.3	0.2	1.0
1974	3.0	34.3	0,06	0.3
Total cumulative for all				
years	106		140	440

Source: Summarized from Tables III and IV of Reserves of Crude Oil, Natural Gas Liquids in the United States and Canada; and United States, Productive Capacity as of December 31, 1974.

reserves. The following equation shows the relationship.

(Proven reserves in previous year) - (Production that year) +. (Discoveries in new fields) + (Extensions to old fields) = (Proven reserves at the end of the year).

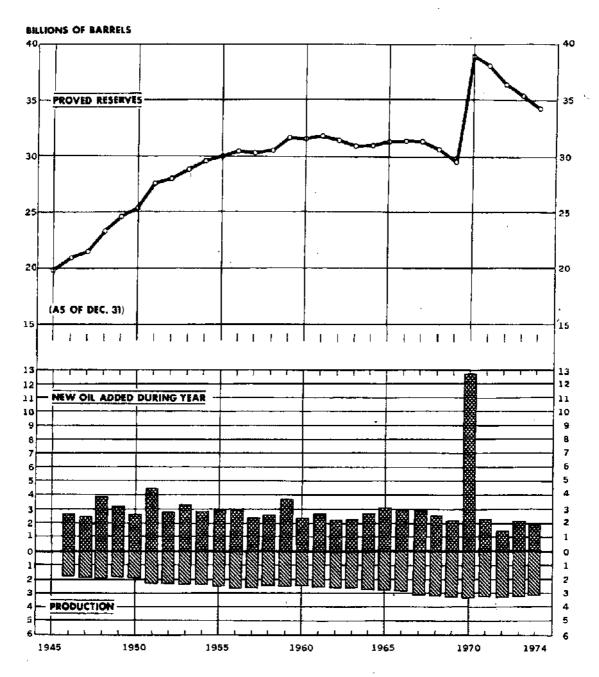
Indeed, since 1945, reserves have fluctuated around 10 times the annual production.

For the past 20 years, discoveries in existing oil fields exceeded discoveries of new fields—except for 1969 with 10 x 10^9 barrel discovery under the Alaskan North Slope. The year 1974 exemplifies this dominance trend. Discoveries in new oil fields (column 4 of Table C-1) added only 0.1×10^9 barrels to ultimately recoverable oil while extensions to old oil fields added approximately 1.9×10^9 barrels.

Column 4 of Table C-1 reflects the 1974 estimate of the ultimate recovery from all known oil fields at January 1974 crude oil prices-approximately 140 x 10 barrels, of which 106 x 10 barrels have been produced. Figure C-1 shows the history of U.S. reserves since 1945. A comparison of new field discoveries (column 4 of Table C-1) with the new oil added (cross-hatched histogram in Figure C-1) demonstrates the trend discussed in the previous paragraph.

Not only does much of the exploration activity take place in known fields, but all production takes place in them as well. Figure C-2 shows the oil produced in 1973 from 228 major U.S. oil fields (fields which produced at least 1×10^6 barrels during the year). The data are tabulated by year of discovery of the field. Several apparent facts are:

- Approximately 80 percent of the oil from the 228 major fields was produced from 190 fields, all at least 20 years old.
- The 228 major fields accounted for almost 60 percent of all domestic production.



Source: American Gas Association

FIGURE C-I. PROVED RESERVES OF CRUDE OIL IN THE UNITED STATES, 1945-1974

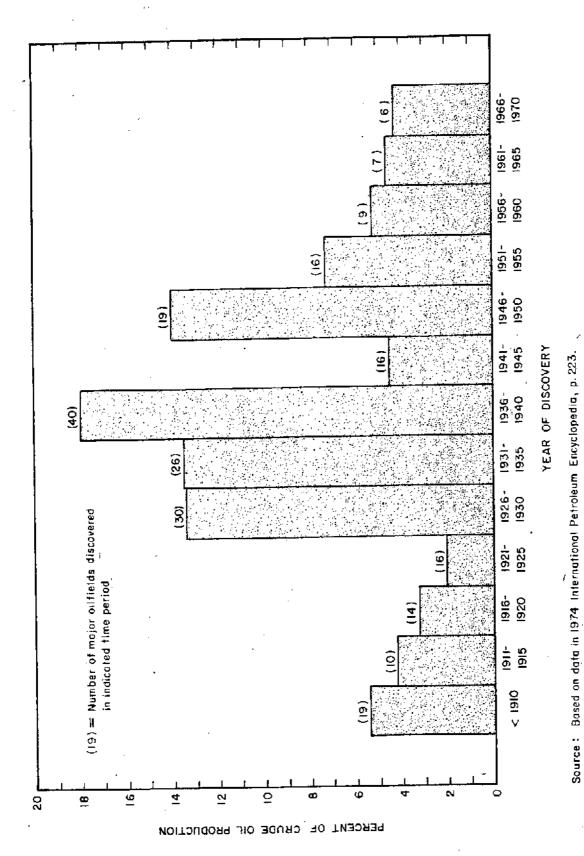


FIGURE C-2. 1973 CRUDE OIL PRODUCTION FROM 228 MAJOR DOMESTIC OILFIELDS BY YEAR OF DISCOVERY

- Production from most of these major fields is likely to continue into the rest of the century.
- Any impacts already associated with these oil fields will continue.

A comparison of the statistics for 1968 on major U.S. oil fields (those producing over 10⁶B per year) 44 with statistics for 1973 8 shows that production in many of these major fields increased substantially-most often due to more wells coming into production by 1973 (i.e., new wells were drilled).

Predicting future production from currently producing oil fields is difficult. Future production depends on the price of crude oil, on the existence of economic or other incentives for developing oil reserves which are uneconomic to produce at today's prices and, crucially, on the amount of oil left to produce.

2. A Brief History of U.S. Crude Oil Supply and Demand

Table C-2 shows the history of U.S. crude oil supply and demand between 1944 and 1973. While domestic supply was 11.3 million barrels per day in 1970, it declined to 10.5 million barrels per day in 1974; imports nearly doubled, from 3.2 x 10⁶ barrels per day to 6.2 x 10⁶ barrels per day. Total U.S. demand between 1944 and 1973 rose at about 4 percent per year, while imports grew from supplying 23 percent of domestic demand in 1970 to 36 percent of domestic demand in 1974. Table C-2 makes three important points:

- Domestic demand grew between 1944 and 1973 at 4 percent per year to 17.3 x 10⁶ barrels per day in 1973.
- Imports grew between 1970 and 1974 to supply 36 percent of domestic demand.
- Domestic supply fell between 1970 and 1974 to only 10.5 x 10⁶ barrels per day in 1974.

Table C-2 STATISTICS OF THE PETROLEUM INDUSTRY

YEAR Clude FADRAGE COURD RAPIRED COURD FADRAGE COURD COURD TAGN TAGN <th></th> <th></th> <th>PRODUCTION</th> <th></th> <th></th> <th>MPORTS</th> <th></th> <th></th> <th>TOTAL</th> <th>PETR</th> <th>PETROLEUM DEMAND</th> <th>AND</th>			PRODUCTION			MPORTS			TOTAL	PETR	PETROLEUM DEMAND	AND
Coling C		Crude	Nat. Gas		Crude	Refined		OTHER				
1,000 1,00	YEAR	ā	Picards	Testal	ā	Products	Tola	SUPPLY	SUPPLY	Domestic .	Export	Table
H/O3 R/O3 B/O3 B/O3 <th< td=""><td></td><td>(1,000</td><td>00011</td><td>(1,00%</td><td>000,1)</td><td>300(1)</td><td>000'0</td><td>1</td><td>000,1</td><td>000:1</td><td>00011</td><td>000 [1]</td></th<>		(1,000	00011	(1,00%	000,1)	300(1)	000'0	1	000,1	000:1	00011	000 [1]
4.695 316 5.010 202 1441 377 — 5.521 4.857 501 6.086 3.64 5.672 2.86 141 377 — 5.850 4.912 4.9		(Q/B)	(0/e	B/O)	(O/G	B/D)	(Q/G		(C/8	- (0/9	8/0)	6/D)
4,751 322 5,073 236 141 377 — 5,480 4,912 4,91 4,91 4,91 4,91 4,91 4,91 4,91 4,91 4,91 4,91 5,478 4,21 224 4,45 — 5,489 5,492 4,90 4,90 5,492 4,90 4,90 5,478 4,21 224 6,48 — 6,189 5,700 427 4,90 5,803 307 4,90 6,189 5,700 422 6,189 305 6,189 305 305 6,189 305 305 305 305 305 305 305 305 306 3	1945	4.695	315	5.010	200	108	311		5.321	4,857	26	5,358
5,086 254 5,452 256 170 436 — 5,889 5,482 440 5,087 407 4592 355 161 574 — 5,889 5,475 369 5,047 431 557 247 27 7,757 7,060 422 6,047 431 353 840 7 7,577 7,060 422 6,256 6,122 6,846 570 379 942 7 7,577 7,060 422 6,436 6,526 6,136 6,137 369 1,082 2 6,789 450 422 460 422 460 460 422 460 460 422 460	1946	4.751	322	5.073	236	141	377	ŀ	5,450	4,912	419	5,331
5.820 407 5.922 3.55 161 514 — 6,436 5,775 369 377 369 377 378 367 368 377 378 378 378 377 378 378 377 378	1947	5,088	364	5,452	586	170	436	ı	5,869	5,452	450	5,902
5,047. 431 5,478 421 224 645 — 6,173 5,603 377 6,126 6,126 6,126 6,126 6,127 7,133 646 7,133 646 7,134 7,137 7,050 422 6,245 6,126 6,126 6,126 6,127 6,134 373 373 364 7 7,571 7,060 422 6,245 6,12 6,136 6,136 6,137 6,137 7,050 422 401 6,345 6,12 6,136 7,131 646 3,96 1,248 3,64 7 7,784 401 6,345 6,12 7,131 666 1,248 3,431 8,433 401 7,131 801 7,134 953 747 1,700 64 9,232 9,146 276 7,103 802 1,045 7,333 966 8,149 7,750 9,232 9,146 276 1,746 1,746 <t< td=""><td>1949</td><td>6 520</td><td>402</td><td>5,922</td><td>353</td><td>161</td><td>57.4</td><td>1</td><td>6,436</td><td>5,775</td><td>368</td><td>6.143</td></t<>	1949	6 520	402	5,922	353	161	57.4	1	6,436	5,775	368	6.143
6,156 6,52 6,506 487 363 850 2 6,769 6,508 305 6,156 6,126 6,720 491 395 844 7 7,571 7,609 422 6,246 655 7,143 646 386 1,034 20 8,167 7,624 401 6,343 692 7,143 646 386 1,032 23 8,10 7,784 365 6,343 692 7,133 656 396 1,248 34 8,891 401 6,343 692 7,624 46 1,248 34 8,892 484 7,151 801 7,519 953 747 1,700 64 9,892 8,89 8,89 8,89 8,89 8,89 8,89 8,89 8,89 8,89 8,99 9,49 2,78 1,78 1,78 1,78 1,78 1,78 1,78 1,78 1,78 1,78 1,78 1,78 <td>1945 2</td> <td>5.047</td> <td>431</td> <td>5 478</td> <td>424</td> <td>224</td> <td>645</td> <td>1</td> <td>6,123</td> <td>5.803</td> <td>377</td> <td>6,130</td>	1945 2	5.047	431	5 478	424	224	645	1	6,123	5.803	377	6,130
6.156 562 6.720 491 353 944 7 7.571 7.050 422 6.256 6.156 6.373 379 945 7 7.571 7.050 422 6.456 655 7.056 1.052 23 7 7.724 4.36 436 6.343 692 7.133 656 396 1.052 23 8.110 7.734 365 6.340 672 7.62 4.36 1.248 34 8.643 366 6.710 801 7.518 953 7.47 1.720 4.36 8.643 367 8.64 3.431 8.643 368 6.710 806 7.518 953 7.47 1.700 64 9.239 9.494 2.55 7.053 806 7.524 4.26 4.36 4.36 9.431 8.62 4.36 9.431 8.62 4.30 8.64 9.431 4.36 8.64 9.431	1950	5.407	498	5,906	487	363	950	Çų.	6.758	6,508	305	6,814
6.256 612 6.884 573 379 952 7 7,827 7,283 436 6.458 685 7,113 646 386 1,034 20 81,67 7,283 401 6,343 682 7,113 664 1,246 34 34,10 7,784 401 7,151 801 7,512 804 502 1,246 34 34,31 8,682 401 7,151 801 7,513 965 1,246 42 9,694 56 6,436 43 3,431 8,682 430 7,053 800 7,514 965 1,674 42 9,694 2,79 1,770 1,700 8,69 9,494 2,79 1,780 8,69 9,494 2,79 1,780 8,69 9,494 2,79 1,780 8,69 9,494 2,79 1,780 8,69 9,431 1,780 1,780 8,69 9,431 2,79 1,780 1,780 8,69 </td <td>1921</td> <td>6.158</td> <td>299</td> <td>6,720</td> <td>491</td> <td>353</td> <td>844</td> <td>^</td> <td>1,571</td> <td>7,060</td> <td>422</td> <td>7,482</td>	1921	6.158	299	6,720	491	353	844	^	1,571	7,060	422	7,482
6.458 6.55 7,113 6.46 3.66 1,034 20 8.167 7,524 401 6.343 6.92 7,135 6.66 3.96 1,052 2.3 8,110 7,724 365 7,151 801 7,579 7,823 666 3.96 1,248 34 8,431 8,433 36,81 7,151 801 7,872 1,023 552 1,574 42 9,592 6,431 8,822 430 7,170 806 7,519 95.3 747 1,700 64 9,292 9,434 36,81 56 7,035 800 7,534 95.3 747 1,700 64 9,292 9,434 255 7,035 800 7,534 95.6 1,700 1,86 9,434 1,89 1,46 1,700 1,700 1,700 1,700 1,700 1,700 1,700 1,700 1,700 1,700 1,700 1,700 1,700 1,700	1952	6,256	612	6,868	573	379	952	7	7,827	7.283	436	7.719
6.343 692 7.035 656 396 1,052 23 8,110 7.784 355 7.170 480 7.62 456 1,248 34 8,891 8,493 368 7.170 800 7.518 953 747 1,704 42 9,595 8,891 568 7.170 806 7.518 963 747 1,704 42 9,595 8,802 450 7.053 880 7.518 965 815 1,780 66 9,739 9,444 276 7.053 981 7.761 1,780 66 9,739 9,444 276 7.054 981 1,126 956 2,082 1,75 10,49 2,75 7.163 981 1,126 956 2,082 1,75 10,49 2,75 7.163 981 1,126 956 2,082 1,75 10,49 17,4 7.332 1,021 1,139 <td< td=""><td>1963</td><td>6 458</td><td>655</td><td>7,113</td><td>648</td><td>386</td><td>1,034</td><td>8</td><td>8.167</td><td>7,624</td><td><u>•</u></td><td>6.025</td></td<>	1963	6 458	655	7,113	648	386	1,034	8	8.167	7,624	<u>•</u>	6.025
6,807 772 7,579 782 4,66 1,248 34 8,881 8,493 368 7,151 801 7,892 1,82 502 1,436 43 9,431 8,62 430 7,170 808 7,518 1,623 562 1,744 42 9,585 8,680 430 6,710 808 7,518 963 847 1,700 64 9,282 9,146 276 7,053 880 7,518 966 815 1,780 86 9,789 9,694 276 7,163 981 1,045 871 1,780 1,696 1,789 1,784 1,744<	1954	6.343	692	7,035	929	396	1,052	ន្ត	9,110	7.784	355	8,139
7,151 801 7,892 804 502 1,436 42 9,431 8,822 450 7,170 808 7,879 1,023 552 1,704 42 9,685 869 430 6,710 808 7,593 965 815 1,704 64 9,585 9,494 255 7,053 890 7,593 1,045 81 1,780 86 9,792 9,494 255 7,053 891 1,045 87 1,780 1,61 10,496 9,792 9,494 255 7,332 1,024 9,626 1,780 1,61 10,496 1,78 1,74 1,74 1,74 7,342 1,024 9,626 2,123 202 10,610 10,416 168 7,544 1,135 9,626 2,123 202 10,733 10,416 11,744 8,295 1,286 1,289 1,280 2,573 246 10,362 10,416	1965	40,907	772	7,579	782	456	1,248	34	9,851	8.493	36B	9.861
7,170 800 7,979 1,023 552 1,574 42 9,586 8,640 569 7,053 800 7,519 953 747 1,700 64 9,582 9,146 276 7,053 800 7,519 965 1,015 710 1,815 146 9,582 9,146 276 7,035 800 7,965 1,015 710 1,815 146 9,592 2,782 9,494 296 7,332 1,021 8,783 1,126 992 2,123 202 10,496 10,496 178 7,514 1,155 8,789 1,131 992 2,123 202 10,730 10,496 168 7,614 1,155 8,789 1,131 992 2,123 202 10,732 10,732 10,732 10,732 20,86 10,732 10,732 10,732 10,732 10,732 10,732 10,732 10,732 10,732 10,732 10,732	1956	7,151	301	7,952	8	205	1,436	4	9,431	8,822	430	2 52 5
6,710 R06 7,519 95.3 747 1,700 64 9,282 9,146 276 7,053 980 7,533 966 1,015 799 1,780 66 9,739 9,494 256 7,053 980 7,965 1,015 871 1917 178 10,270 1,986 174 7,332 1,021 8,532 1,126 956 2,082 175 10,510 10,410 164 7,332 1,024 8,640 1,131 992 2,123 202 10,466 176 10,610 10,410 164 7,542 1,026 8,640 1,334 992 2,123 202 10,436 10,406 17,244 11,032 208 7,644 1,155 8,749 1,230 2,468 2,273 226 11,702 10,41 10,406 2,573 226 11,704 11,624 10,606 2,573 226 11,704 11,633 10,404	1957	7,170	6 06	6/6'/	.83	225	1,574	₹	9,595	8.860	568	9,428
7,053 880 7,933 966 815 1,780 86 9,739 9,494 255 7,053 980 7,965 1,015 719 1,815 146 9,739 9,494 255 7,183 981 3,174 1,045 976 2,082 175 10,270 9,986 1,74 7,332 1,021 8,334 1,131 992 2,123 202 10,496 10,496 10,406 10,496 10,406	858	6.710	808	7,518	58	747	1,700	64	9.282	9,146	276	8,422
7,035 980 7,995 1,045 799 1,845 148 9,986 9,807 202 7,183 991 1,124 1,045 871 1,917 179 10,270 9,996 174 7,342 1,024 8,352 1,126 995 2,123 202 10,965 10,966 10,702 10,410 168 7,542 1,036 8,769 1,198 1,060 2,213 202 10,366 10,702 10,466 202 7,604 1,155 8,769 1,230 2,668 220 11,704 11,002 208 8,295 1,284 1,230 2,688 220 11,704 11,002 202 8,295 1,284 1,289 1,580 1,409 1,587 3,46 11,002 10,006 2,45 12,397 12,695 19,69 9,036 1,604 1,128 1,409 1,550 2,46 3,419 3,66 14,702 11,702 1	956	7,053	980	7,933	966	815	1,780	8	9.799	9.49 A	255	9,749
7.163 981 9.174 1.045 871 1.917 178 10.270 9.96 1.76 1.76 10.610 10.46 178 10.270 9.96 1.77 10.610 10.410 10.46 10.410 10.46 1.76 10.65 2.02 10.76 10.66 1.76 10.66 2.02 10.76 10.76 10.66 2.02 10.76	1960	7,035	930	7.965	1.015	799	1,815	148	3,926	9,807	202	10,009
7,332 1,021 8,332 1,126 956 2,082 175 10,610 10,416 168 7,332 1,026 8,640 1,331 992 2,123 202 10,935 10,732 208 7,614 1,155 8,789 1,399 1,090 2,483 277 10,935 10,732 208 7,614 1,155 9,678 1,290 2,468 277 11,244 11,032 208 8,295 1,284 1,239 1,286 2,573 245 12,397 12,095 196 9,036 1,503 1,289 1,787 3,468 2,577 246 12,394 231 9,036 1,503 1,0827 1,094 1,787 3,468 236 3,419 3,45 3,414 9,637 1,660 11,297 1,324 2,094 3,419 3,65 15,707 14,404 231 9,463 1,680 11,185 1,681 2,246 3,4	1961	7,163	196	9,174	1,045	87.1	1 917	178	10.270	9866	174	10,159
7,542 1,086 8,640 1,131 992 2,123 202 10,965 1,123 202 10,753 208 7,644 1,155 8,789 1,198 1,060 2,256 11,744 11,032 2,08 8,295 1,284 1,286 1,348 2,573 245 11,244 11,032 14,7 8,295 1,284 1,287 1,286 1,287 12,039 12,039 18,7 8,810 1,410 10,280 1,128 1,409 1,580 1,546 2,34 12,049 12,34 12,049 1,346 2,31 9,636 1,609 1,280 1,580 1,580 1,44 1,344 13,44 2,31 9,463 1,689 1,189 1,287 1,44 1,479 2,31 9,463 1,686 2,246 3,926 4,74 16,370 14,709 2,29 9,441 1,74 1,74 1,74 1,74 1,72 1,72 <td< td=""><td>1962</td><td>7,332</td><td>1,021</td><td>B.353</td><td>1,126</td><td>926</td><td>2,082</td><td>175</td><td>10,610</td><td>10,410</td><td>158</td><td>10,579</td></td<>	1962	7,332	1,021	B.353	1,126	926	2,082	175	10,610	10,410	158	10,579
7,614 1,155 8,7799 1,198 1,060 2.258 217 11,244 11,032 2.02 7,804 1,210 9,014 1,239 1,230 2,468 220 11,702 11,523 187 8,295 1,286 1,286 1,286 1,287 1,287 12,337 12,095 198 8,096 1,600 1,280 1,580 1,680 10,589 1,577 346 13,787 13,49 23 9,637 1,660 11,287 1,324 2,094 3,419 36 15,071 14,709 25 9,463 1,882 1,1155 1,681 2,246 3,419 36 15,071 14,709 25 9,463 1,784 11,185 1,681 2,246 3,419 36 15,071 14,709 22 9,463 1,784 11,185 1,681 2,246 3,419 36 16,370 16,370 16,380 22 9,483 1	1963	7,542	1,088	8,640	1,131	695	2.123	205	10,965	10 753	208	10,961
7,804 1,210 9,014 1,230 2,468 220 11,702 11,523 187 8,295 1,284 1,286 1,286 1,286 1,287 12,397 12,095 196 8,096 1,603 1,1280 1,550 1,687 1,687 1,677 3,46 346 13,787 13,464 235 9,636 1,609 1,1287 1,409 1,757 3,465 340 14,732 14,46 236 9,637 1,660 11,287 1,324 2,094 3,419 365 15,071 14,709 259 9,463 1,892 1,1155 1,681 2,246 3,419 365 15,071 14,709 259 9,463 1,784 11,185 1,681 2,246 3,419 365 4,371 14,709 222 9,463 1,784 1,784 3,419 3,612 4,44 16,370 16,380 221 9,208 1,736 3,474	1964	7,614	1,155	8,765	1,198	1.060	2.259	217	11,244	11,002	202	- - - - -
8.295 1.284 9.579 1.245 1.225 1.348 2.573 245 12.397 12.095 196 9.096 1.410 10.220 1.128 1.409 1.757 3.46 3.47 3.43 12.095 196 9.036 1.600 1.0287 1.757 3.465 3.40 14.533 14.48 233 9.637 1.660 11.287 1.324 2.094 3.419 365 15.071 14.709 259 9.463 1.680 11.155 1.691 2.246 3.419 365 15.071 14.709 259 9.463 1.784 11.185 1.691 2.246 3.419 365 4.531 15.205 15.205 224 9.208 1.734 11.186 2.244 3.012 4.44 16.370 16.330 222 9.208 1.758 10.462 3.477 2.511 6.088 500 17.050 16.042 220	1965	7,804	1,210	9,014	1,23B	1,230	2 468	220	11,702	11,523	187	11,710
8.810 1.410 1.128 1.409 2.537 229 13.049 12.569 307 9.096 1.503 10.589 1.290 1.550 2.946 34.6 13.747 13.404 231 9.637 1.669 11.297 1.304 2.094 3.419 3.66 15.071 14.709 236 9.463 1.682 11.155 1.691 2.245 3.826 439 15.226 15.25 224 9.463 1.734 1.1165 2.246 3.626 4.741 444 16.370 15.226 224 9.471 1.758 10.462 3.477 2.511 6.086 500 17.687 17.321 231	1966	3295	1,284	9/2/6	1,225	1.348	2 573	245	12,397	12.095	196	12,293
9,096 1,503 10,509 1,290 1,550 2,840 346 13,747 13,404 231 9,238 1,509 1,097 1,757 3,165 340 14,532 14,146 235 9,637 1,689 1,297 1,324 2,094 3,419 365 15,071 14,709 259 9,463 1,689 1,286 2,216 2,246 3,419 365 16,520 16,226 224 9,463 1,744 1,1,195 2,216 2,246 4,44 16,370 16,330 22 9,208 1,738 10,946 3,244 3,012 6,088 500 17,060 16,042 220	1967	8.810	1,410	10,220	1,128	1.409	2,537	262	13,049	12,569	307	12876
9,238 1,689 10,827 1,409 1,757 3,165 340 14,533 14,48 235 9,637 1,660 11,297 1,324 2,094 3,419 366 15,071 14,709 259 9,463 1,682 1,287 1,681 2,246 3,419 36 15,071 14,709 259 9,463 1,682 2,216 2,246 2,246 4,44 16,370 16,380 222 9,208 1,738 10,946 3,244 3,012 4,541 444 16,370 16,380 222 9,774 1,688 10,462 3,477 2,511 6,088 500 17,050 16,042 220	1368	960.6	1.503	10.599	1,290	1.550	2,840	348	13,787	13.404	231	13,635
9,637 1,660 11,287 1,324 2,094 3,419 3,65 15,071 14,709 259 9,463 1,892 1,1155 1,691 2,245 3,826 4,39 15,526 15,225 22,4 9,441 1,734 1,1185 2,274 2,214 444 16,370 16,326 22 9,208 1,738 10,946 3,244 3,012 495 17,687 17,381 22 8,774 1,688 10,462 3,477 2,511 6,088 500 17,050 16,042 22	1969	9,238	1,689	10,827	- 60 -	1,757	3 166	4	14,533	14,148	233	14,381
9,463 1,892 1,155 1,691 2,246 3,826 439 15,220 15,226 22,7 9,441 1,124 11,186 2,276 2,274 4,741 444 16,370 16,326 22 9,208 1,736 10,946 3,244 3,012 495 17,687 17,321 231 8,774 1,688 10,462 3,477 2,511 6,088 500 17,050 16,042 220	1970	9.637	1,660	11,297	1,324	2.094	3,419	366	15,071	14,709	259	14,963
9,441 1,744 11,185 2,216 2,525 4,741 444 16,370 16,380 222 5,208 1,738 10,946 3,244 3,012 6,256 485 17,687 17,321 231 8,774 1,688 10,462 3,477 2,511 6,088 500 17,050 16,042 220	1871	9,463	1,692	11,155	1.681	2.245	3,926	439 439	15,520	15.225	55	15,449
9,208 1,738 10,946 3,244 3,012 6,256 465 17,687 17,321 231 8,774 1,688 10,462 3,477 2,511 6,088 500 17,050 16,042 220	1972	9.44	1,744	11,185	2,216	2.525	4,741	444	16,370	16,380	222	16,602
8,774 1,688 10,462 3,477 2,511 6,088 500 17,050 16,042 220	1973	9,208	1,738	10,946	3,244	3,012	6,256	485	17,687	17,321	231	17,552
	1974	8,774	1,688	10,462	3,477	2,511	6,08B	200	17,050	16.042	220	16,862

Source: Reference 25

Table C-3 shows a history of crude oil prices. Although prices in current dollars rose between 1954 and 1973, prices in constant 1973 dollars fell until 1974. The effective decline in crude oil prices made drilling and exploring for oil increasingly unprofitable. For example, the number of new oil wells drilled fell from 30,000 in 1954 to 9900 in 1973. The total footage of wells drilled also declined from 220 x 10 ft in 1954 to 140 x 10 ft in 1973. Recent increases in crude oil prices stimulated drilling activity and it remains to be seen if many new resources are added and if a net U.S. production increase takes place.

Table C-3
OIL PRICES

		Crude Oil	
	Year ²⁵	Current	Constant 1973 \$
	1954	2.78	4.77
	1955	2.77	4.69
	1956	2.79	4.57
	1957	3.09	4.88
•	1958	3.01	4.63
	1959	2.90	4.39
	1960	2.88	4.29
	1961	2,89	4.25
	1962	2.90	4,22
	1963	2.89	4.15
	1964	2,88	4.07
	1965	2.86	3.97
	1966	2.88	3.89
	1967	2.91	3,81
	1968	2,94	3,70
	1969	3,09	3,71
	1970	3.18	3.62
	1971	3,39	3,38
	1972	3.39	3.57
	1973	3.89	3.89
	1974	6.74	6.32
November	1975 ⁴⁵	8.75	7.18

Source: References 25, 45

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