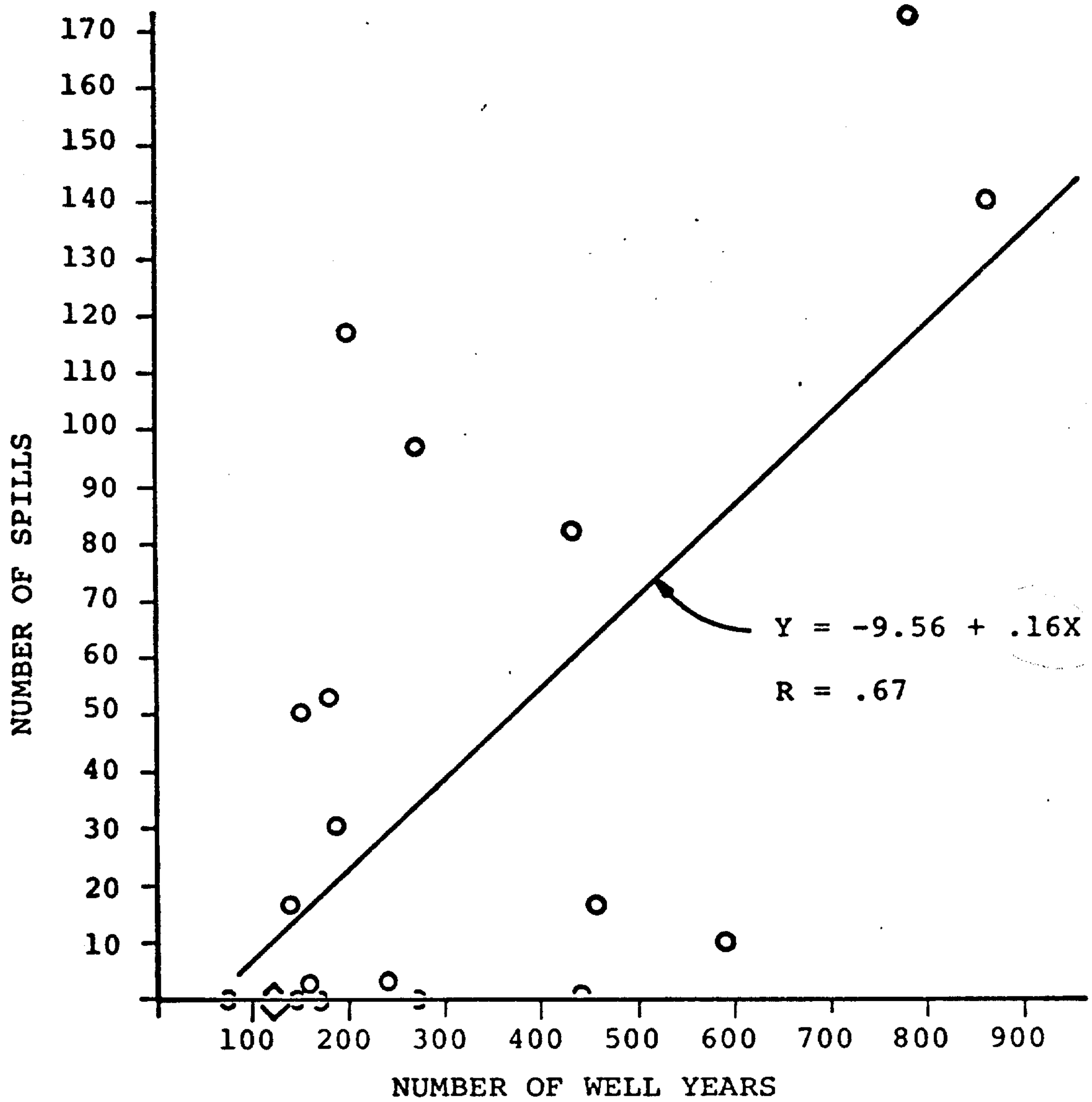
How would these two be tested?

<u>Hypothesis 2</u>: As the installations get older, time and corrosion take their toll, resulting in increased spillage.

Clearly, the selection of either hypothesis over the other cannot be done simply on the data presented. It should be possible, however, to draw some conclusions from a more detailed study of the PIRS data, particularly the relationship of the cause listing with the number of spills. It would also be interesting to see if this relationship holds true for the smaller fields in the Gulf, which, as we mentioned, may not be well represented by our sample.

Another interesting regression is presented in Figure 2.4, the number of spills in 1973 and 1974 (column <u>h</u> plus column <u>j</u>) versus the number of wells (column <u>e</u>) times the number of years (2). Again, standard statistical tests confirmed that the correlation was significant. We can see from the slope of the least squares fit that every six wells could be expected to have one spill per year, although the variance would be large.

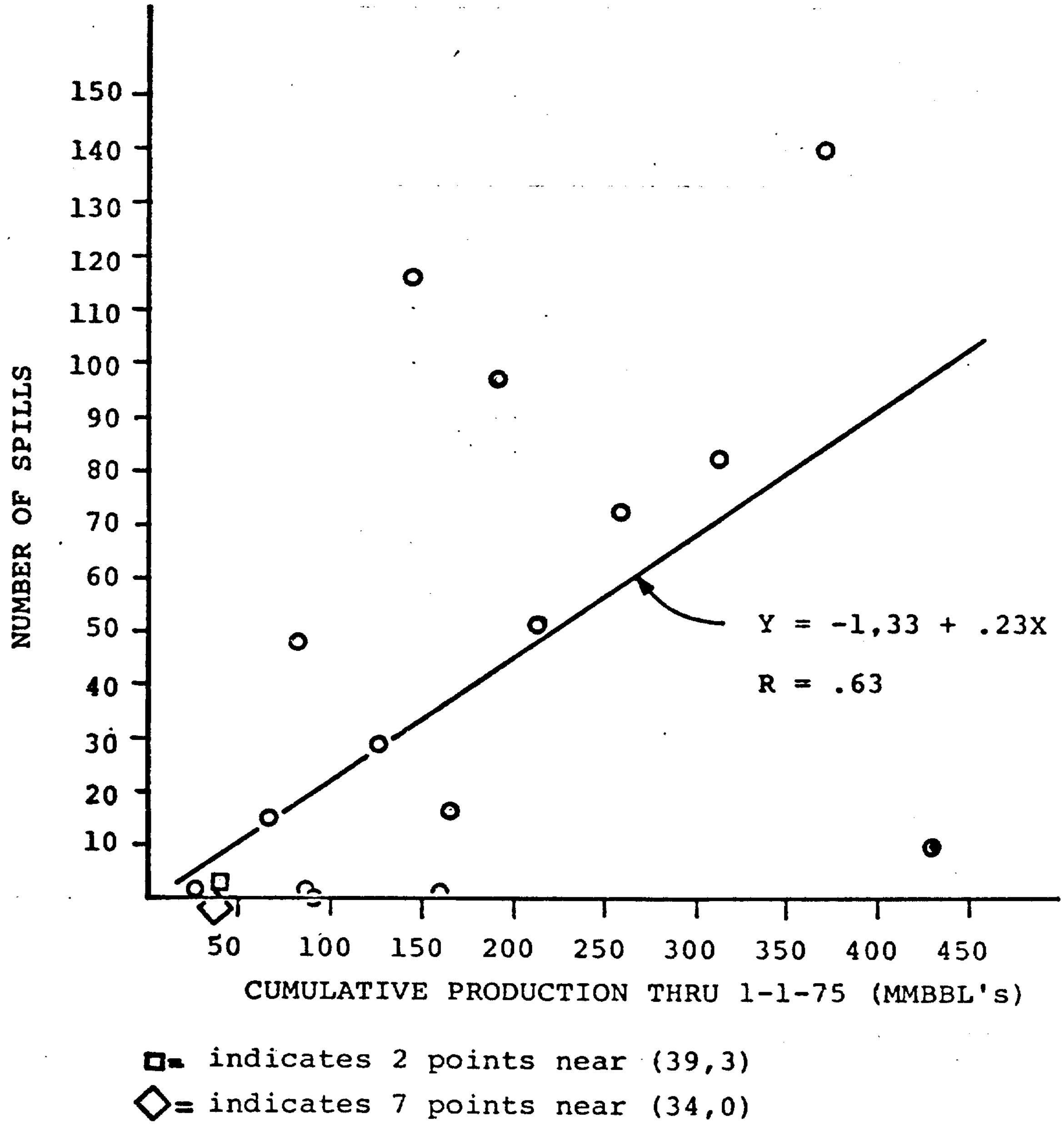
Figure 2.5 presents the results of regressing the number of spills in the period 1973 through 1974 against the OGJ's figure for cumulative production up to 1-1-75. The regression coefficient (R=.63) is slightly lower than that of Figure 2.4. It is nevertheless significant. We can see from the spread of the data points that the one point at (430,10) (Bay Marchand Block Number 2) exerts an enormous influence on the regression.



◇= indicates 6 points near (120,0)

NUMBER OF SPILLS vs. NUMBER OF WELL YEARS FOR THE 24 LARGEST FIELDS OFF LOUISIANA

Figure 2.4



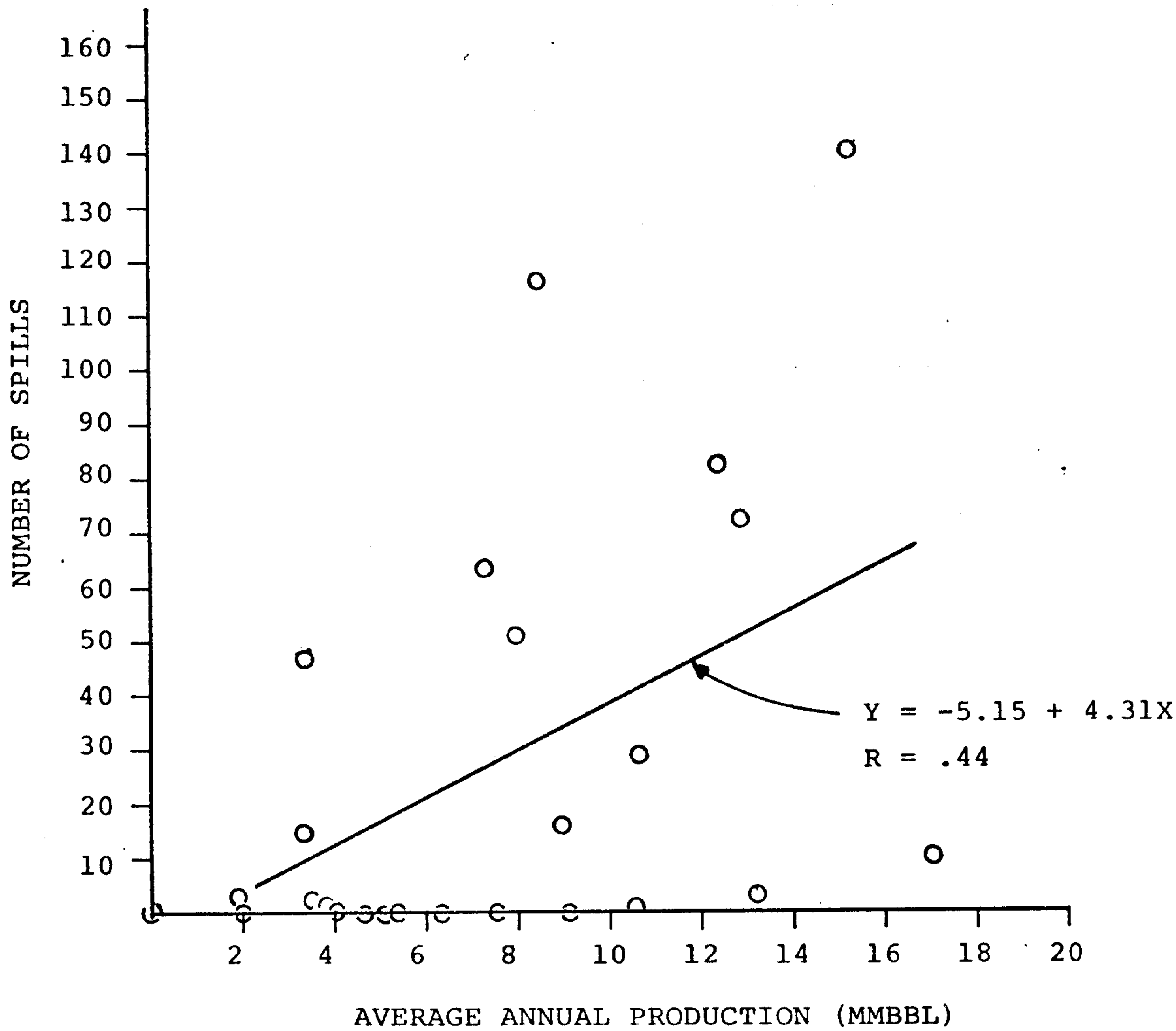
NUMBER OF SPILLS 1973 - 1974 vs.
CUMULATIVE PRODUCTION THRU 1 - 1 - 75
FOR THE 24 LARGEST FIELDS OFF LOUISIANA

Figure 2.5

The least squares fit would ~~almost certainly~~ have had a much greater slope if this point had been thrown out.

Finally, Figure 2.6 presents the most direct test of our hypothesis. It shows the number of spills occurring in 1973 and 1974 versus the average annual field production, assuming the first production began during the year of field discovery. This latter assumption should be viewed as being somewhat conservative in that it must overstate the true producing age of the field by at least one or two years. However, we did not have sufficient data to make a more logical guess and this seemed the simplest choice. Further it has the advantage that the bias is known to lie in the direction of an overstatement.

There are several remarkable things about this technique for estimating the annual average production. First, it is either a reasonably close approximation to the 1974 annual production (in 17 cases), or alternatively, it is about one-half of the 1974 annual production (in the remaining 7 cases). Further, in those cases where the average annual production is below the 1974 production, the fields are either recent discoveries (one case discovered in1971), or very old discoveries (six cases discovered from 1948 to 1956). The explanation for the former discrepancy may be that the field is still being developed. In the latter cases, the production rate might have increased in response to either revisions in



NUMBER OF SPILLS 1973 - 1974 vs.
THE ESTIMATED AVERAGE ANNUAL PRODUCTION
OF CRUDE OIL
FOR THE 24 LARGEST FIELDS OFF LOUISIANA

Figure 2.6

the allowables, or to the development of new producing horizons with the same field.

In any event, we do indeed find a positive correlation that is statistically significant. We must add the cautionary note, however, that if we were dealing with a truely representative sample for the Gulf of Mexico we could be certain of finding a large number of fields exhibiting both small average annual productions, and substantial numbers of oil spills in the 1973 - 1974 period. Whether these would adversely effect the regression results, we cannot say.

It should be clear by now that the 1973 and 1974 oil spill data do exhibit some rather interesting statistical properties. A cursory glance at any of the figures can convince us that the number of wells, the age of the field, and the average annual production can all tell us something about the incidence of oil spills. The same glance can also tell us that these simple measures do not tell the whole story. The large number of fields having no reported oil spills in 1973 and 1974 raises the very intriguing possibility that there may be some combination of modern technology and managerial techniques that might allow us to substantially eliminate oil spillage. Certainly, a further study of this observation seems warranted.

Incidence of Oil Spillage in Hypothetical Developments:

The previous section demonstrated that for the largest 24 fields in the OCS region off Louisiana, oil spillage exposure parameters based on the number of wells, the cumulative production, or the average annual production all had some modest explanatory powers. It was also pointed out that this particular sample of fields did not appear to be very representative of the total population of oil fields with respect to the spillage problem because

1. the number of spills normalized either per well or per barrel of production was a factor of four or more lower for our sample than for the population treated as a whole, and

2. the number of oil spills per year in our sample decreased from 1973 to 1974, whereas the aggregated data showed no change from 1973 to 1974.

These observations have been repeated to emphasize that the following predictions of the probabilities of observing N_o oil spills in the life of a field are highly speculative.

Following the techniques used in the CEQ report,[2] the exposure parameter was specified to be the cumulative production over the life of the hypothesized field. The Bayesian statistical technique was then used to determine the probabilities of observing N_o spills greater than 42,000 gallons, and N_o spills of any size, over the life of the field.

The large spills prediction was updated for this report by

1. incorporating the U.S. Geological Survey's most recent listing of spills over 42,000 gallons, and
2. carefully examining the 1973 and 1974 USCG PIRS data for large spills.

We found that the PIRS data contained one pipeline spill of 42,000 gallons that was not contained in the USGS listing. We investigated this discrepancy and verified that the incident had indeed occurred and included it in our data base on large spills. Tables 3.1 and 3.2 summarize the data for platforms and pipelines respectively.

In the previous study, a cumulative production equal to the total OCS production from 1964 to 1972 was used as the historical exposure for platform spills. This was updated to include 1973 and 1974 production. The number of spills was increased from 9 to 12 for the period in question. One of the additional spills occurred in January of 1973, and the two other spills (Ship Shoal Block 29 in July 1965 and Eugene Island Block 208 in October 1964) were incorporated after being mistakenly omitted from the earlier report.

Figure 3.1 shows our revised probabilities for the occurrence of N spills from the three hypothesized field

Table 3.1

SPILLS OVER 1000 BBL
FROM U.S. O.C.S. PLATFORMS*

Date (d-m-yr)	Location Area	Block	Amount (gals)	Cause
8- 4-64	E.I.	208	107,478	Collision
3-10-64	S.S.	198	66,738	Hurricane
3-10-64	E.I.	208	217,560	Hurricane
3-10-64	S.S.	149	214,200	Hurricane
19- 7-65	S.S.	29	70,896	Blow Out
28- 1-69	Santa Barbara Channel		991,620	Blow Out
16- 3-69	S.S.	72	105,000	Blow Out
17- 8-69	M.P.	41	512,000	Storm
10- 2-70	M.P.	41	1,281,000	Fire
1-12-70	S.T.	26	2,226,000	Explosion/Fire
9- 1-73	W.D.	79	417,270	Structural Failure
20- 7-72	Platform 15 miles Offshore		168,000	

* U.S. Geological Survey [3]

Table 3.2

SPILLS OVER 1000 BBL
FROM PIPELINES IN OCS*
AND COASTAL REGION
1964 - 1974

Date (d-m-yr)	Location: Area	Location: Block	Amount (gals)	Cause
15-10-67	W.D.	73	6,746,838	Anchor Dragging
12- 3-68	S.T.	131	252,000	Anchor Dragging
11- 2-69	M.P.	299	316,344	Leak
12- 5-73	W.D.	73	210,000	Leak Corrosion
2- 8-73	Avco "C" S.P	60**	43,000	Leak
17- 4-74	E.I.	317	832,986	Anchor Dragging
9- 9-74	M.P.	73	92, 946	Hurricane
18-10-70	L.A. Coastal Channel		1,050,000	Tug Propeller
17- 3-71	L.A. Coastal Channel		154,980	Leak
28- 9-71	L.A. Coastal Channel		43,000	Pipe Parted
30-11-71	Texas Coastal Channel		43,000	Leak
12-12-72	L.A. Coastal Channel		160,000	Equipment Failure

* U.S. Geological Survey [3]

** Not in U.S.G.S. Data but incident confirmed by Mr. Dillard of the U.S. Coast Guard 8th District Environmental Protection Board, New Orleans, Louisiana.

Figure 3.1

PROBABILITY OF OBSERVING N SPILLS OVER 42,000 GALLONS FROM PLATFORMS* OVER THE LIFE OF THE FIELD

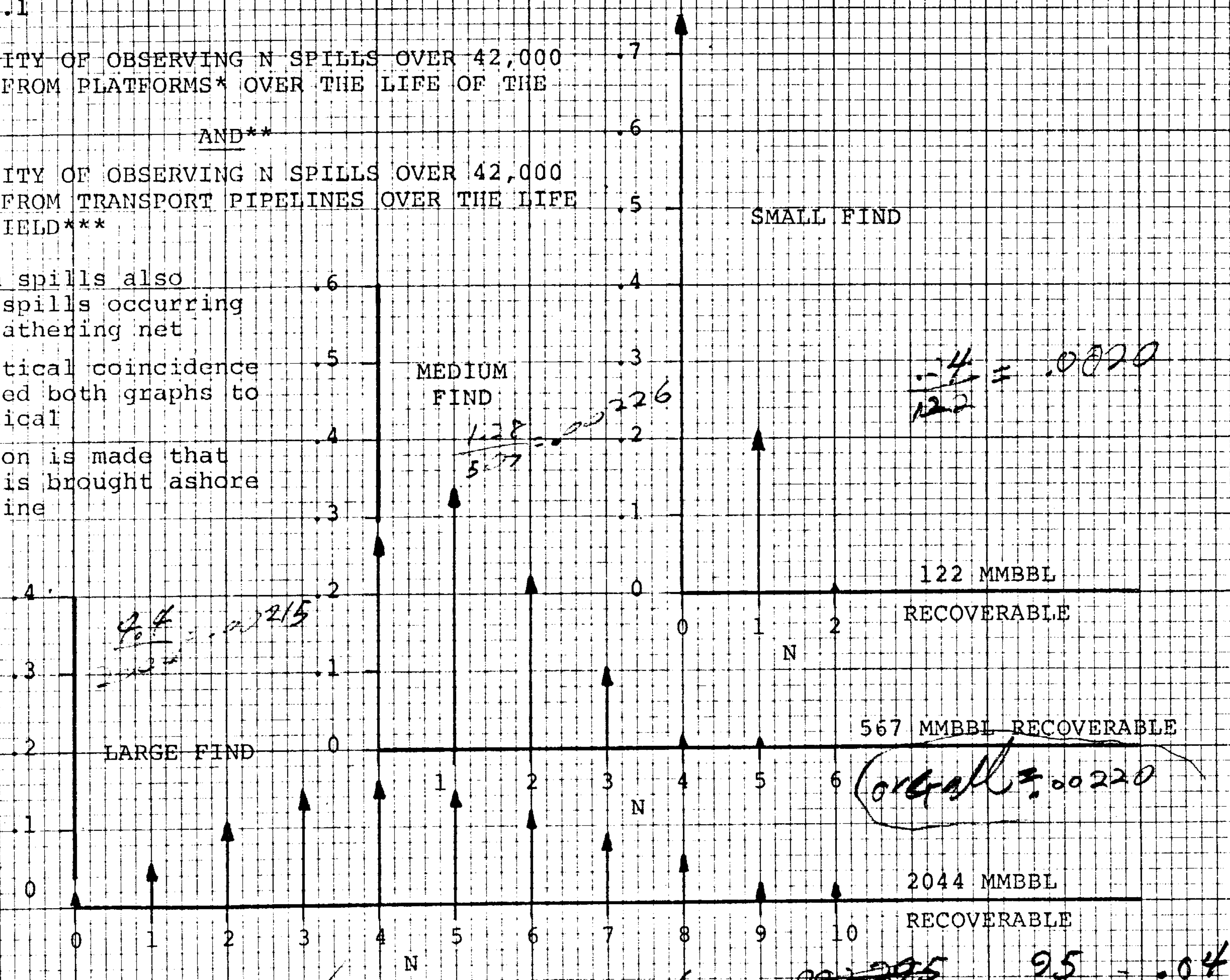
AND**

PROBABILITY OF OBSERVING N SPILLS OVER 42,000 GALLONS FROM TRANSPORT PIPELINES OVER THE LIFE OF THE FIELD***

* platform spills also include spills occurring in the gathering net

** a statistical coincidence has caused both graphs to be identical

*** assumption is made that all oil is brought ashore by pipeline



sizes. Notice that for "small" finds the probability of observing N_o large oil spills over the life of the field is .75. For the larger fields this probability decreases rapidly.

For the largest field, 2,044 MMBBL recoverable, we find that for numbers in the range of 2 to 7 we have probabilities in the range of .10 to .16, the most likely outcome being four spills. This appears to be consistent with the U.S. spill experience, i.e., twelve large spills observed while producing 5,045 MMBBL.

The large pipeline spill problem was addressed from the standpoint that there was perhaps a significant difference between those spills occurring in OCS waters and those occurring in coastal channels. Certainly for some hypothetical developments there would be no pipelines laid in regions like those found along the Gulf coast, where there are numerous dredged channels. Therefore two spill probability predictions were made. One for just pipelines lying in federal OCS waters, and the other for pipelines lying in regions where both OCS and coastal channel experience might be applicable.

The exposure parameter for pipeline spills was updated to include all OCS production for the period 1964 to 1974. The number of OCS pipeline spills was updated to seven, including four in the 1973 to 1974 period, while the number of coastal channel pipeline spills remained at five. Figure 3.2 shows the resultant probabilities for OCS pipelines, while Figure 3.1 may be used to determine the probabilities for the combined coastal and OCS pipeline spillage. Notice that in Figure 3.2 the most likely number of spills from OCS pipelines for both the small and medium finds is zero, while for the large find,two spills in the life of the field is the most probable outcome.

The probabilities for the total number of spills over 42,000 gallons from both platforms and pipelines is shown in Figure 3.3. The assumption made here is that the pipeline spills will be like those for the combined OCS and coastal pipelines in the U.S. Notice that a small find still has a high probability of observing no spills over the life of the field, but now the large find is almost certain to have at least one spill.

The prediction for the total number of oil spills irrespective of size for the hypothetical finds was updated from our previous report by incorporating all PIRS platform and pipeline spills for the period 1971 through 1974, coupled with the U.S. OCS crude and condensate production for the same period. Figures 3.4 through 3.6 show the probability that the observed number of spills will be less than or equal to N_o. For this small find, the model now predicts a .5 chance that there will be less than or equal to 428 spills in the life of the field

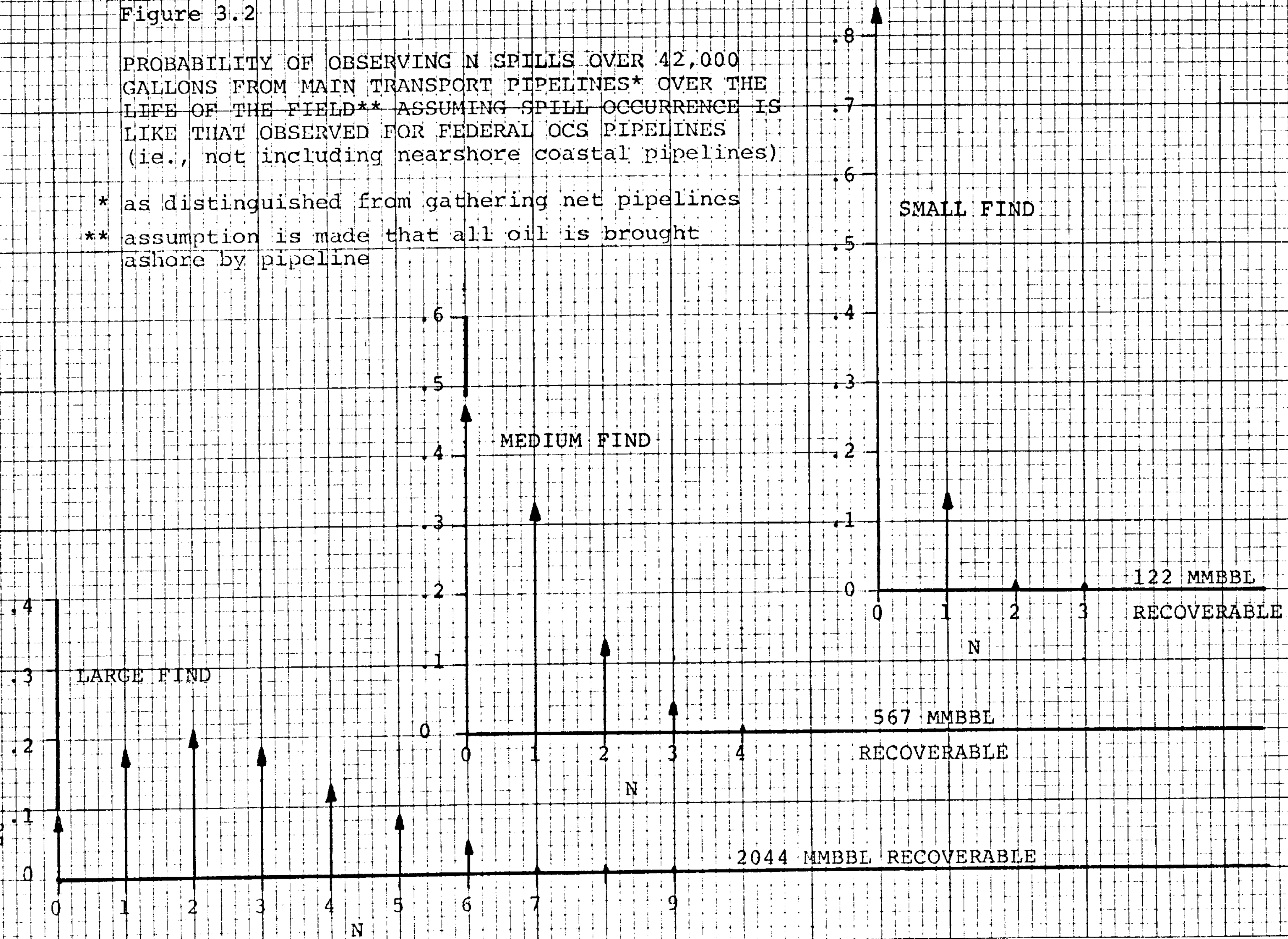
y = 7 69-74
τ = 5000

Figure 3.2

PROBABILITY OF OBSERVING N SPILLS OVER 42,000 GALLONS FROM MAIN TRANSPORT PIPELINES* OVER THE ~~LIFE OF THE FIELD**~~ ASSUMING SPILL OCCURRENCE IS LIKE THAT OBSERVED FOR FEDERAL OCS PIPELINES (ie., not including nearshore coastal pipelines)

* as distinguished from gathering net pipelines

** assumption is made that all oil is brought ashore by pipeline



$\nu = 5$

$\xi \cong$ ~~[illegible]~~ ~~1000~~ 900

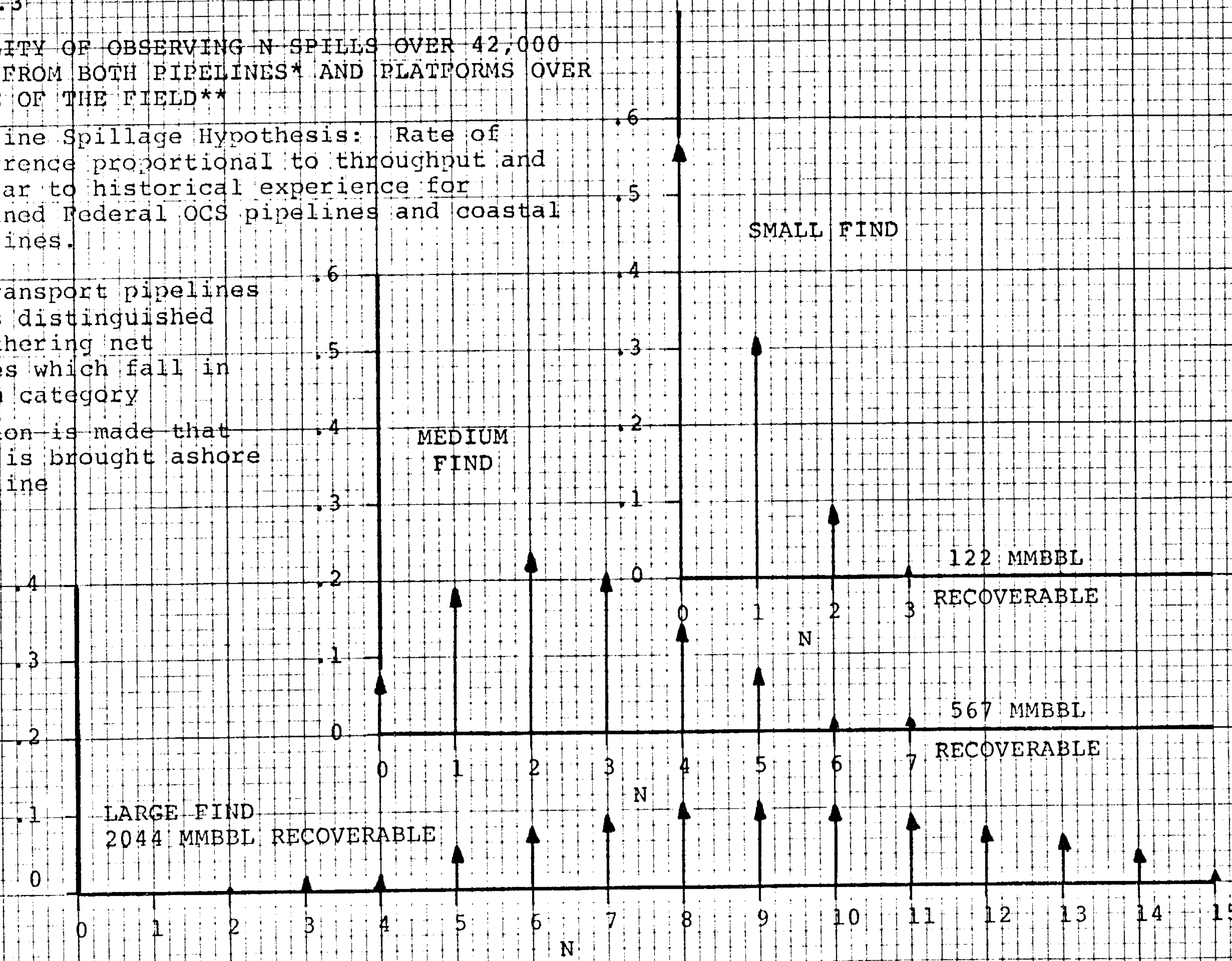
Figure 3.3

PROBABILITY OF OBSERVING N SPILLS OVER 42,000 GALLONS FROM BOTH PIPELINES* AND PLATFORMS OVER THE LIFE OF THE FIELD**

Pipeline Spillage Hypothesis: Rate of occurrence proportional to throughput and similar to historical experience for combined Federal OCS pipelines and coastal pipelines.

* large transport pipelines only, as distinguished from gathering net pipelines which fall in platform category

** assumption is made that all oil is brought ashore by pipeline



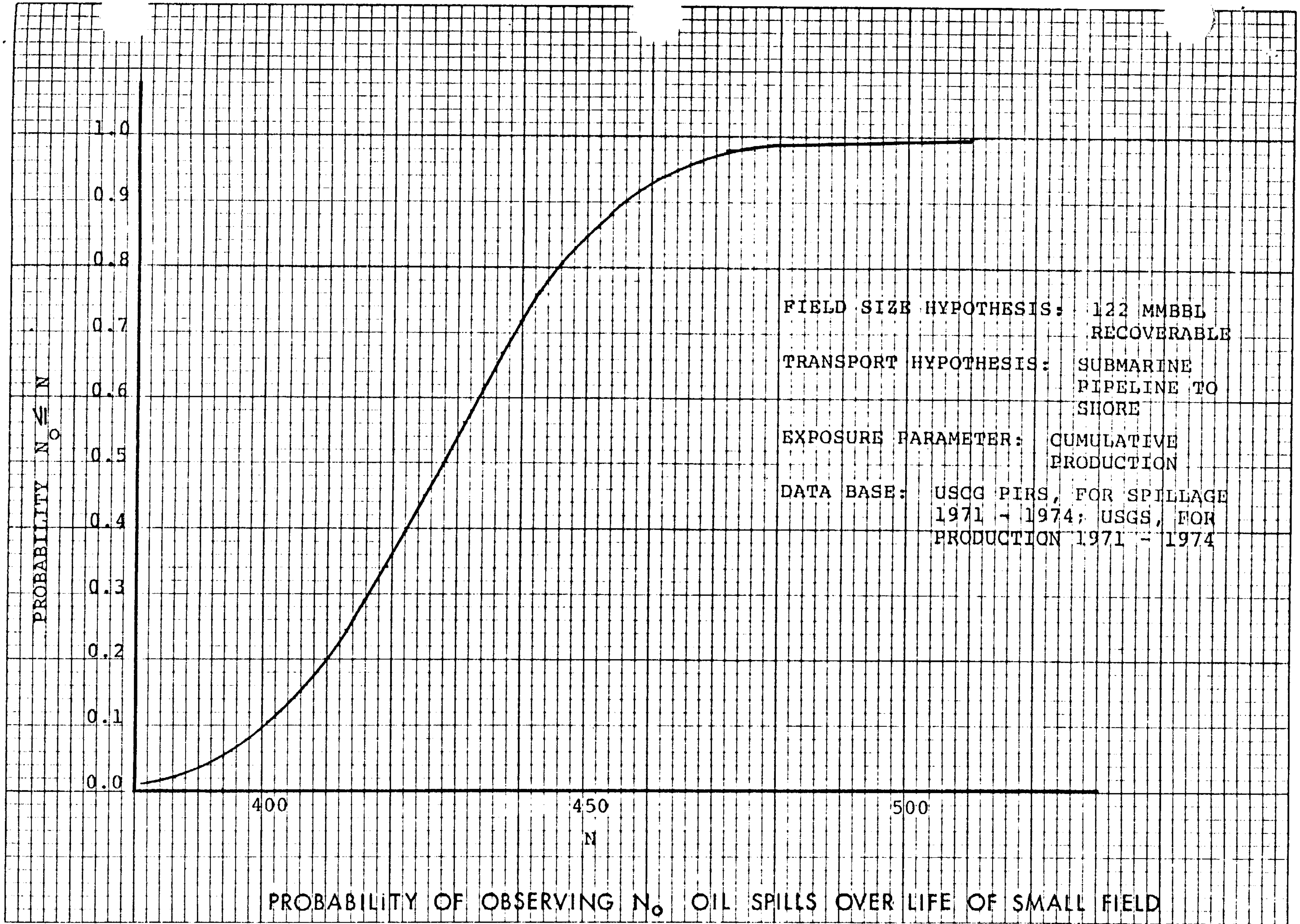
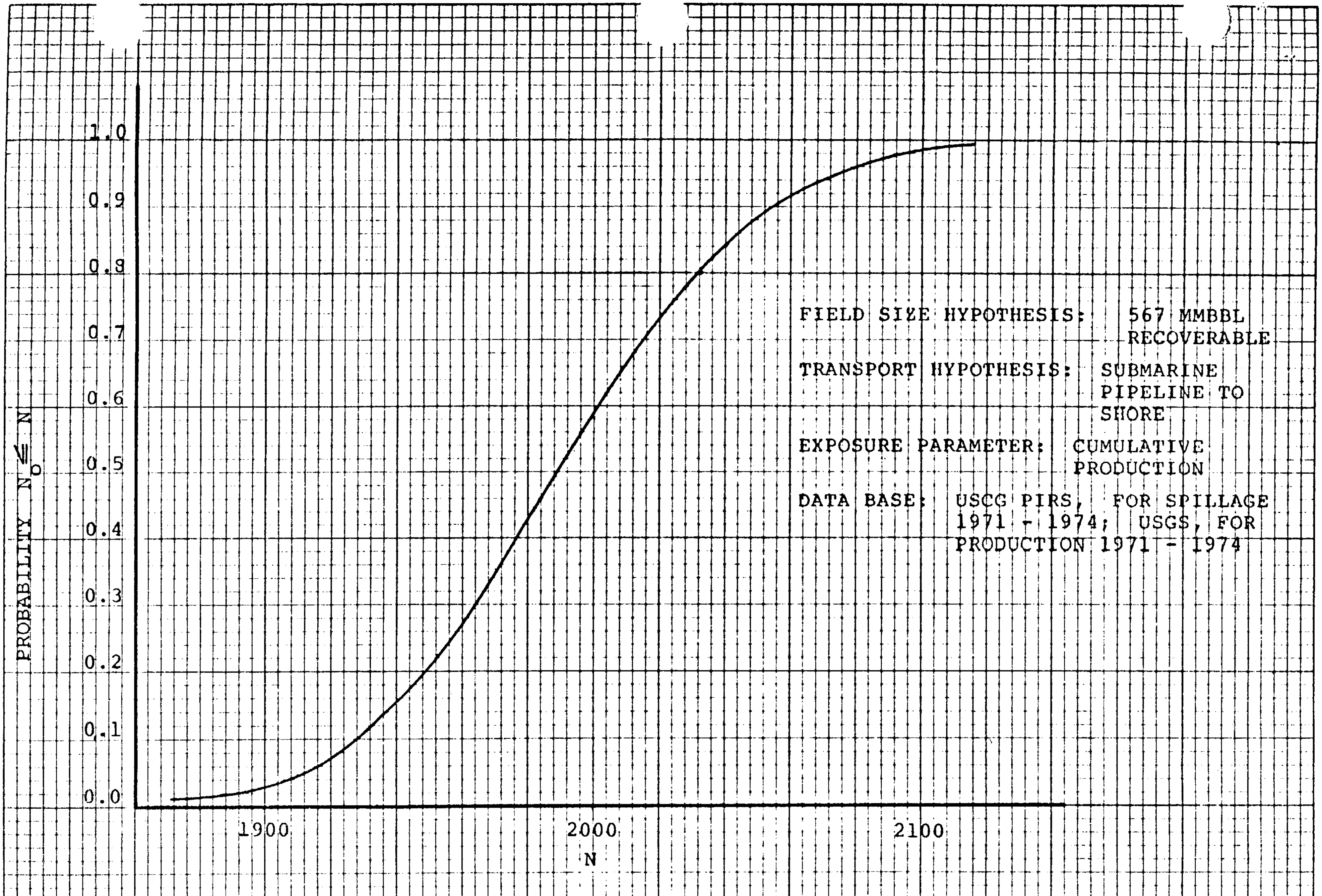
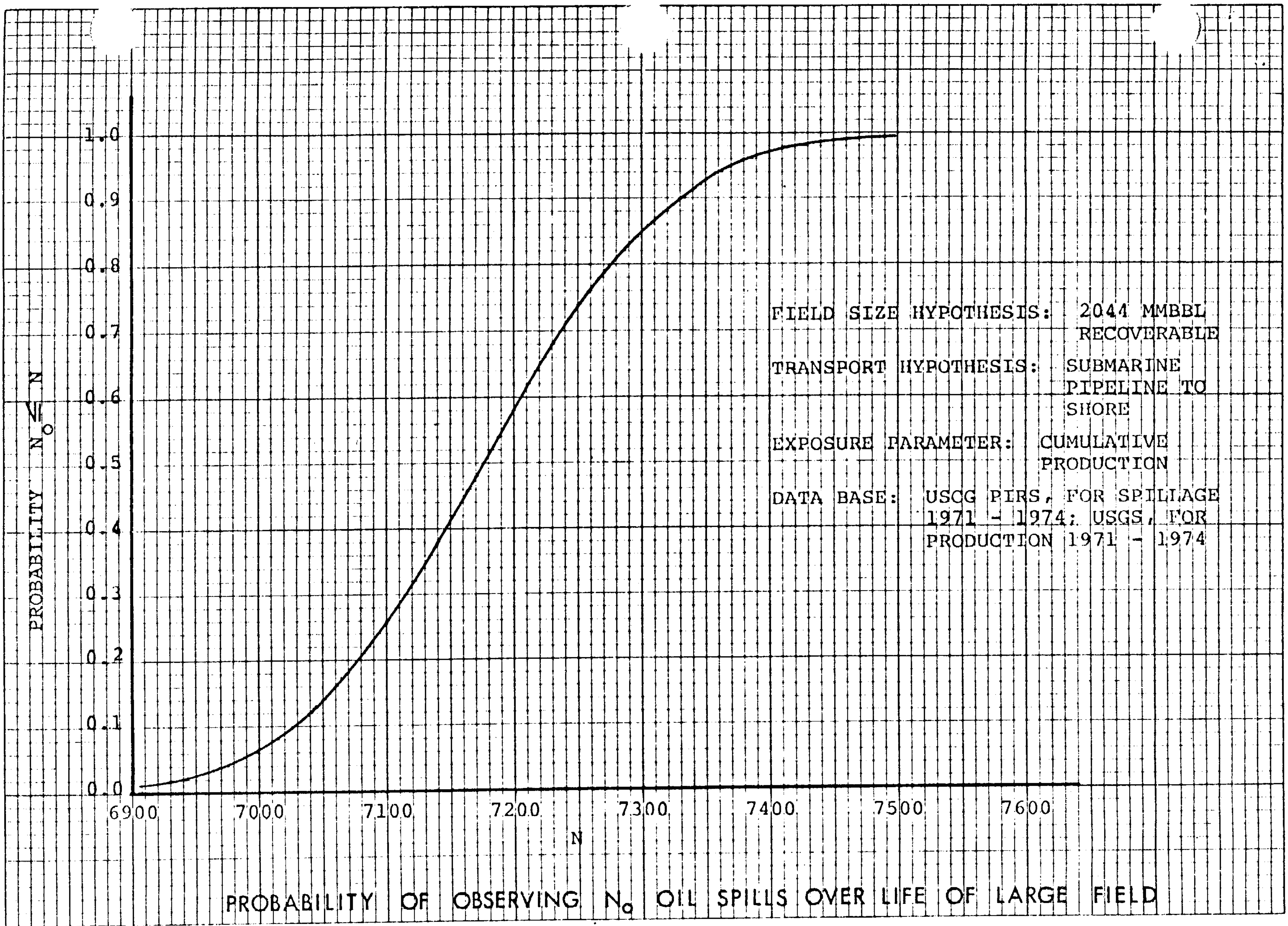

PROBABILITY N0 ≤ N
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
400
450
500
N
FIELD SIZE HYPOTHESIS: 122 MMBBL RECOVERABLE
TRANSPORT HYPOTHESIS: SUBMARINE PIPELINE TO SHORE
EXPOSURE PARAMETER: CUMULATIVE PRODUCTION
DATA BASE: USCG PIRS, FOR SPILLAGE 1971 - 1974; USGS, FOR PRODUCTION 1971 - 1974
PROBABILITY OF OBSERVING No OIL SPILLS OVER LIFE OF SMALL FIELD

Figure 3.4



PROBABILITY OF OBSERVING N_o OIL SPILLS OVER LIFE OF MEDIUM FIELD

Figure 3.5



FIELD SIZE HYPOTHESIS: 2044 MMBBL RECOVERABLE
TRANSPORT HYPOTHESIS: SUBMARINE PIPELINE TO SHORE
EXPOSURE PARAMETER: CUMULATIVE PRODUCTION
DATA BASE: USCG PIRS, FOR SPILLAGE 1971 - 1974; USGS, FOR PRODUCTION 1971 - 1974
PROBABILITY $N_o \leq N$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
6900
7000
7100
7200
7300
7400
7500
7600
N
PROBABILITY OF OBSERVING N_o OIL SPILLS OVER LIFE OF LARGE FIELD

Figure 3.6

and a .99 chance that there will be less than or equal to 490 spills. These results are quite similar to our earlier estimates (see Figures 7.1, 7.2 and 7.3 of the CEQ report[2]).

Spill Volume Distribution:

The spill volume distribution was also recalculated for this study, based on the revised spill data of Tables 3.1 and 3.2. In addition to the new entries and corrections to these tables noted in the previous section, the decision was made to use the Geological Survey's estimate of the volume of oil spilled in the Santa Barbara Channel blow-out versus our old estimate of 3,250,000 gallons.

One unexpected and very much unwelcome result of the decision to recalculate these probability densities was the discovery that our old program was yielding erroneous estimates of the density. The problem was apparently associated with the numerical integration procedure, the resultant calculations being off-the-mark by 20%-40%. After a great deal of exasperating, but finally satisfying, reprogramming, we convinced ourselves that the routine was working properly.

The fruits of our labor are shown in Figures 4.1a and 4.1b. Both graphs depict the cumulative distribution function, the difference between a and b being the scale of the horizontal axis. Graph a depicts the behavior in the range 0 to 8 million gallons, while graph b gives us a good picture of the behavior of the function in the range 0 to 800,000 gallons. Also shown on graph b are the proper locations for

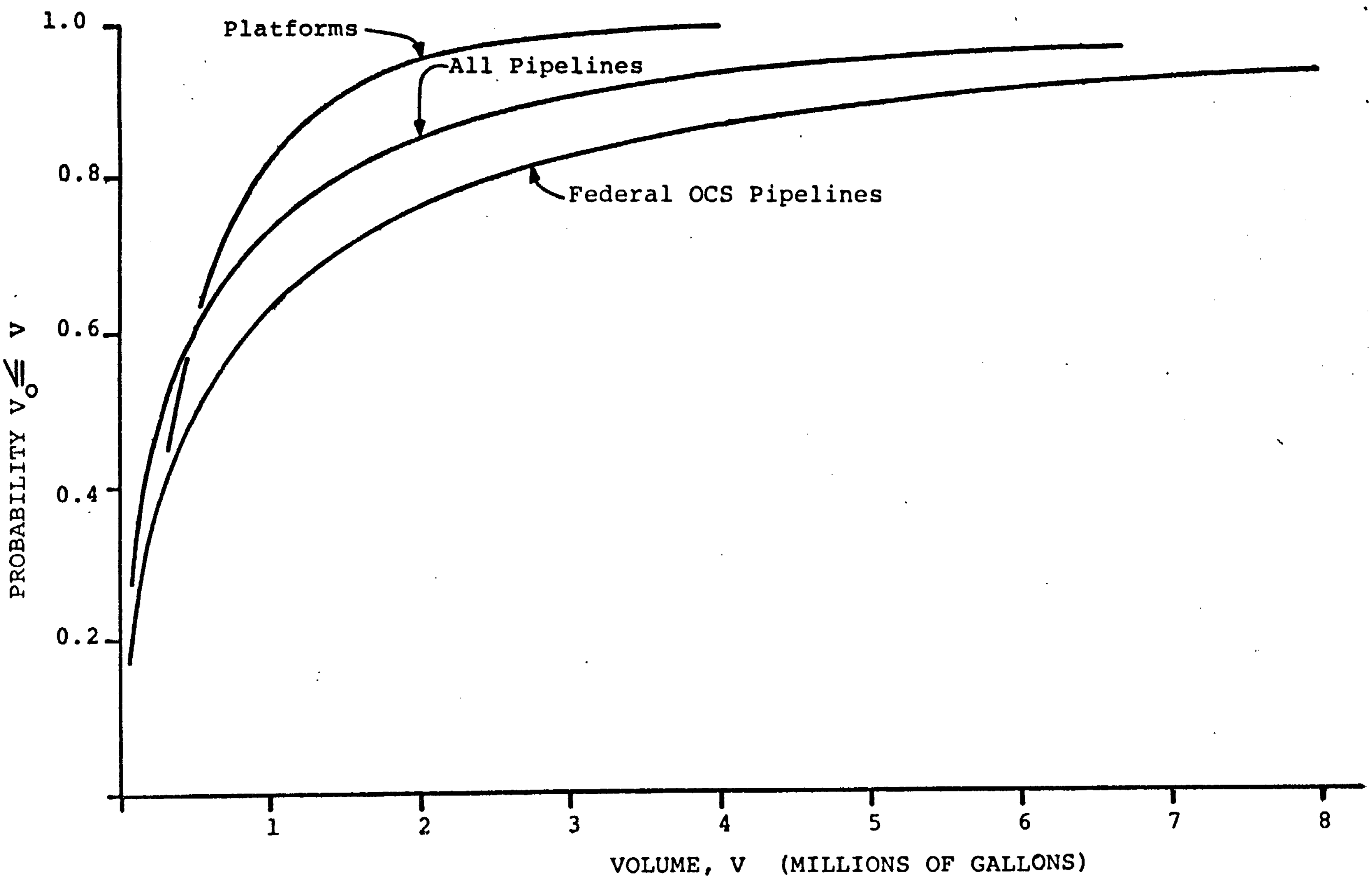


Figure 4.1a

PROBABILITY THAT A SPILL IS LESS THAN OR EQUAL TO V_o GALLONS GIVEN THAT IT IS LARGER THAN 42,000 GALLONS

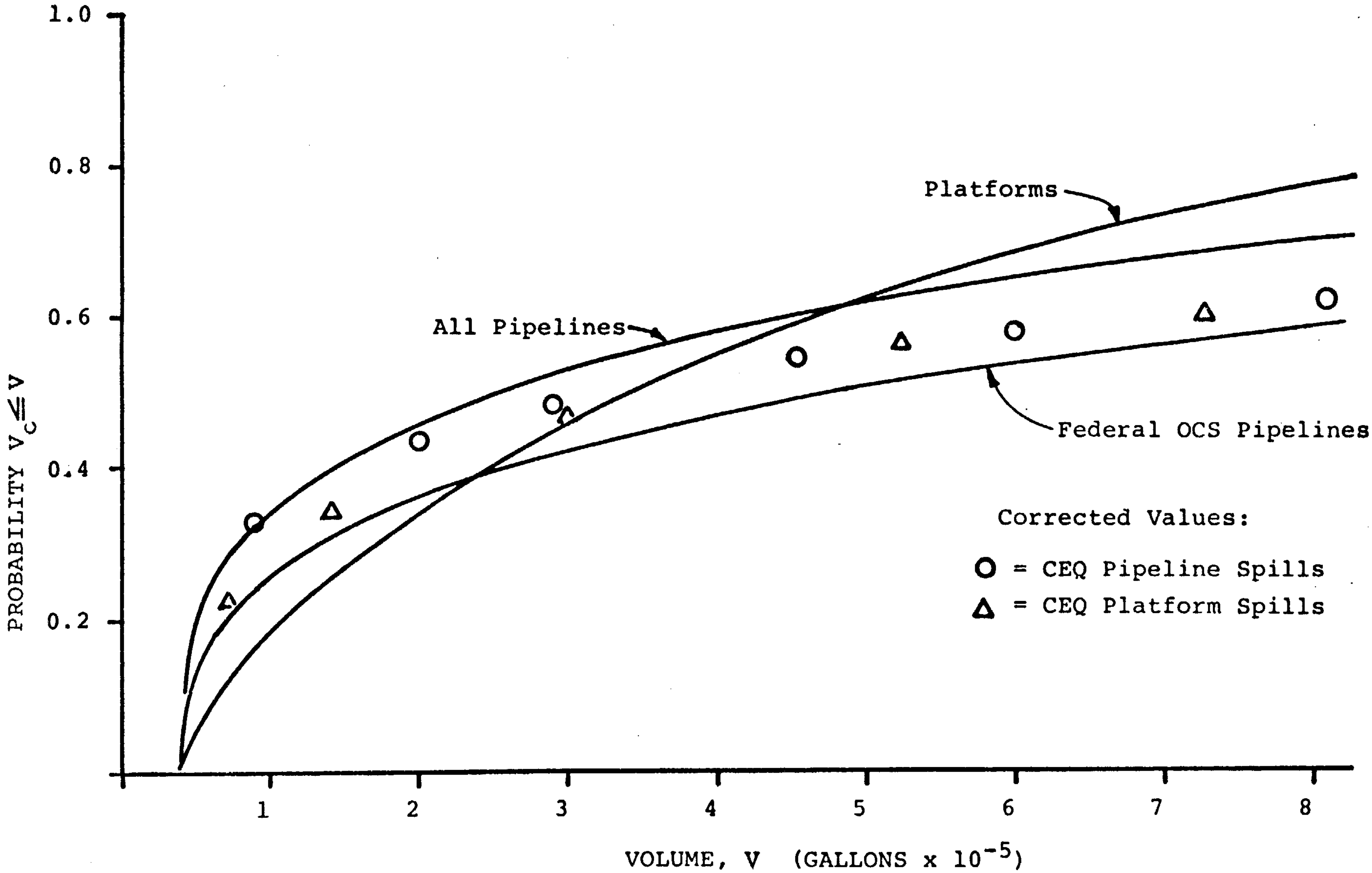


Figure 4.1b

PROBABILITY THAT A SPILL IS LESS THAN OR EQUAL TO V_o GALLONS GIVEN THAT IT IS LARGER THAN 42,000 GALLONS (EXPANDED HORIZONTAL SCALE) a few selected points of the cumulative density function as it should have looked in the CEQ report.

Notice that the platform spill cumulative density function rises quite rapidly to its limit of 1.0, indicating that spills in excess of 3 or 4 million gallons should be extremely unlikely. The pipeline spills do not exhibit this property primarily because of the one 6 million gallon spill noted to have occurred in 1967. Again, the two pipeline curves shown correspond to

1. only those pipeline spills that occurred in the federal OCS region ("Federal OCS Pipelines"), and
2. all pipeline spills, including the federal OCS pipeline spills as well as the coastal channel spills.

The behavior of the pipeline curves in the range 42,000 - 200,000 gallons strongly suggests that if the one 6 million gallon spill could be disregarded, then the pipeline curves might approach 1.0 faster than the platform curve.

Conclusion:

The platform and pipeline spillage figures of our earlier report have been re-examined in light of the data now available on the spillage of oil in the U.S. in 1973 and 1974. This data was of sufficient detail to allow us to make a preliminary analysis of possible relationships between the incidence of oil spills and several of the parameters describing an offshore petroleum development. The principal results of the regression portion of this study are as follows:

1. A reasonably strong argument can be made that cumulative production, average annual production, number of wells, and age of field are all correlated in some fashion to the incidence of oil spills in the large fields investigated.

2. The problem is not simply one of linear relationships. The large number of fields in the sample that avoided even one recorded spill incident over a two year period suggest very strongly some fundamental grouping of fields, perhaps based on age or technological factors.

3. The sample chosen for the regression analysis was unfortunately not very representative of the total population. Future investigations must be prepared to look at the data exhaustively.

Utilizing the number of spills in the period 1971 through 1974 and updating the exposure parameter with the cumulative production in those four years, the probability of observing a particular spill outcome in the life of small, medium and large developments has been recalculated. We might remark in passing that the probabilities of observing large spills have come out almost identical to those of the CEQ study. This suggests that our earlier results would have made good predictors for the observed U.S. spillage in 1973 and 1974.

The cumulative density for the spill volume has been recalculated for platform and pipeline spills over 42,000 gallons. An error in our program was discovered and rectified. The correct distributions are now shown on Figures 4.1a and 4.1b.

The important policy issue raised by this report is the observation that there is apparently some way of grouping Louisiana leases into those that do have oil spills and those that do not. This could be simply an artifact of the USCG PIRS data, but we judge this to be unlikely. Much more probably, this phenomena is related either to the type (or age) of equipment installed, the nature of the management system, or some combination of the two. Certainly, if the particular mix of elements could be identified, it would provide some insight into the types of regulations and supervision that ought to be provided by the leasor in order to safeguard the environment.

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* References are numbered in text of the report.