Dick Smith

OIL SPILLAGE ASSOCIATED WITH THE DEVELOPMENT OF OFFSHORE PETROLEUM RESOURCES

by

Robert J. Stewart

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Introduction:

This study has been undertaken at the request of the Organisation for Economic Cooperation and Development (OECD) for the purpose of supporting OECD's mission as an advisor to its member countries on matters relating to energy policy. The particular issue addressed by this report is the spillage of oil associated with the exploration and production of oil in the offshore region.

The purpose of the analyses conducted for this report is to provide additional insight on the characteristics of the oil spillage problem, thereby facilitating the development of reasonable policy recommendations regarding the safeguarding of the environment in those areas subject to offshore petroleum development. The work is an extension of selected portions of a previous study, performed jointly by the author and Dr. John W. Devanney III.[2]

The previous study focussed upon the means whereby we might predict the characteristics of the spillage problem for hypothetical petroleum finds based on our past experience with oil spills. An extensive review of the available data was made, with the result that five principal data sources were identified. This data provided information on oil spills from tankers, tank barges, terminals, offshore production facilities, offshore pipelines, and single buoy moorings. The principal features of this data are described in the earlier report.

Using the Bayesian techniques described in our earlier report, we manipulated this data so that we could make estimates of the number of spills that might be associated with the activities of any one of the sources mentioned above. Further, the sizes of the larger spills were studied to allow us to estimate the probability that a spill from a particular source would exceed any particular volume.

A key feature of the earlier study was the use of the assumption that the frequency of occurrence of an oil spill was related (solely) to the volume of oil handled by the source. For only one source, tankers, was this throughput assumption shown to provide a plausible explanatory variable. The data pertaining to the other sources was either so unreliable as to make such an analysis suspect, or else the observed range of the explanatory variable was so small as to make regression analysis of little utility. As an example of the first problem, the data collected on SBMs was all obtained from SBM operators. Contradictions in their own submittals as well as a tendency to focus mainly on the larger spills suggested that this data was not sufficiently complete to justify a regression analysis.

An example of the latter problem is provided by the U.S. Coast Guard's data. We were quite certain that the U.S. Coast Guard's Pollution Incident Reporting System (PIRS) provided a reliable and substantially complete listing of all the spillage in U.S. waters in 1971 and 1972. Unfortunately, because the reporting system at that time did not retain sufficient information to identify the OCS lease area containing the platform or pipeline where the spill occurred, the range on the explanatory variable (barrels of production, for example) consisted of differences from one year to the next (in U.S. OCS production); this range was very small. This also ruled out a regression analysis.

The purpose of this report is to re-examine some of these problems in light of the data that has become available for 1973 and 1974. We will make use of the U.S. Coast Guard's PIRS data and the U.S. Geological Survey's 1975 compilation of spills over 50 barrels occurring in the period 1964-1974 as a result of OCS oil and gas development operations. Further, we will focus our attention solely upon those spills occurring at production platforms, drilling rigs, and offshore pipelines. Tanker and tank barge spills, as well as terminal spills, will not be considered as they typically do not represent a net effect of OCS production. On the other hand, SBM spills do represent a possible contributor to net spillage from offshore production facilities, but to this author's knowledge, the compilation and analysis of SBM spills in our previous report remains the most complete discussion of this problem. (There are no SBMs representative of the state of the art installed in U.S. waters so the PIRS data cannot help us here.) As we shall see, this data will provide us with a very strong suggestion that our throughput hypothesis for oil spillage may not be the best assumption available, although it is almost certainly as good as any other single parameter we might select.

Survey of Platform and Pipeline Spill Data 1971-1974:

Our previous study demonstrated that the number of oil spills noted in the USCG PIRS data to have occurred at platforms and pipelines in 1971 was reasonably well correlated with the number of spills in 1972, provided we aggregate the two spill sources (pipelines and platforms). On the other hand, when looked at separately there was little agreement between the number of pipeline or platform spills in 1971 and 1972. This was because those spills occurring in the gathering net were counted as pipeline spills in 1971, while in 1972 they were considered to be platform spills. Presumably, the Coast Guard is now consistently considering gathering net spills to be platform spills.

From Table 1.1 we can see that the aggregated number of 1973 and 1974 oil spills (row 1) exhibit a high degree of consistency (ie., 1,749 spills in 1973 and 1,748 spills in 1974). There appears to be considerable variance between the numbers of spills when we look at the disaggregated figures (bottom two rows) particularly the pipeline numbers (234 in 1973 vs. 14 in 1974), but this could represent chance variation and thus are not necessarily inconsistencies in the reporting system.

The aggregated number of spills exhibited a significant decline for the period 1971 to 1973. The drop from 1971 to

Table 1.1

SURVEY OF OIL SPILLAGE 1971 - 1974

	1971		1972		1973		1974	
* **	Number	Volume	Number	Volume	Number	Volume	Number	Volume
All U.S. Offshore Production Platforms and Pipelines	2,452	655,117	2,252	239,515	1,749	581,400	1,748	100,756
Gulf of Mexico Production Platforms and Pipelines	2,420	642,547	2,229	234,216	1,733	576,626	1,725	98,597
Southern California Production Platforms and Pipelines	3	885	9	1,051	0	0	0	0
All Offshore Production Platforms	1,091	117,664	2,211	231,738	1,515	527,516	1,734	83,046
All Offshore Pipelines	1,361	537,453	41	7,777	234	53,884	14	17,710

* Number of Spills
** Total Volume

1972 was 8%, and the drop from 1972 to 1973 was 22%. It seems reasonable to assume that this reduction was brought about at least in part as a result of the increased monitoring of the offshore operations by the Coast Guard, the Geological Survey and the Environmental Protection Agency. The consistency of the number of spills occurring in 1973 and 1974 suggest that if it is indeed the government regulations that are responsible for the decline from 1971 to 1973, then we have gotten about as far as we can with the present regulations and supervision. That is, if we assume that the operations were essentially unsupervised in 1971 (this is a much too pessimistic summary of the situation in 1971) and that no other factors changed between 1971 and 1974, then we might conclude that the expenditure of federal funds associated with supporting the present monitoring system has been responsible for a drop of about 29% in the number of spills.

This, however, is too much of a simplification because the activity in the OCS region evolved rather dramatically from 1971 to 1974. In 1971, there were a total of 10,234 wells, of which 3,724 were producing and active. In 1974 the total number of wells had grown to 12,715 with a corresponding increase in the number of producing and active wells to 5,108. We might postulate that this increase in the number of wells might have caused a growth in the number of spills over the period in question had not the government provided additional supervision.

In contradiction to this trend, the rate of oil production over the period 1971 to 1974 decreased from 615 MMBBL/year in 1971 to 534 MMBBL/year in 1974. This decrease in production rate might have had a beneficial effect upon the number of oil spills, thereby diminishing the apparent effectiveness of the government's supervisory activities. In the following section we shall show that both these hypotheses regarding the number of spills and their dependence upon either the number of active wells or upon cumulative production are plausible explanations,so this problem is not simply resolved.

Another interesting feature of the 1971 to 1974 spill data is the lack of correlation between the volume spilled per year. As we ventured to suggest in our previous study, this is to be expected for any random process like the oil spill problem because of the enormous range observed in the spill volume. Simple statistical theory shows that for a process like ours where the standard deviation is typically 10 times the mean, we would need an enormously large number of samples to achieve any degree of consistency in the sample sum. In fact, in the Georges Bank Petroleum Study,[5] this author made the estimate that about 10,000 samples would be required for a similar process to bring the standard deviation down to a range similar to that of the mean. Thus, we shouldn't be too surprised at the variability observed in the volume spilled from one year to the next. However, if we break out the volume spilled into groupings consisting of orders of magnitude, we can begin to see some consistency in the data. This has been done in Table 1.2 for pipelines, platforms and combined pipelines and platforms for the period 1971 through 1974. Notice the preponderance of incidents in the 1 gallon to 100 gallon range, and the gradual tapering in number as the volume gets larger. Notice also that there appears to be some trend towards smaller spills with increasing years. This is most evident in the bottom grouping, Platforms and Pipelines. Clearly, the data is still too sparse to suggest any strong statement to this effect, but it certainly presents some hopeful possibilities.

Table 1.2

OIL SPILL VOLUME DISTRIBUTION

	0-1	1-10	10-100	100-1K	1K-10K	10K-100K	100K-1M	1M
Offshore Pipelines:								
1971*	222	403	496	257	42	13	2	0
1972*	15	24	61	61	32	7	3	0
1973	94	78	42	18	1	1	0	0
1974	3	6	2	1	1	1	0	0
Production Platforms:								
1971	230	305	395	146	13	2	0	0
1972	431	784	728	244	20	4	0	0
1973	418	595	392	95	12	2	1	0
1974	629	604	405	84	12	0	0	0
Platforms and Pipelines:								
1971*	452	708	891	403	55	15	2	
1972*	446	808	1123	305	52	11	3	
1973	512	673	434	113	13	3	1	
1974	632	610	407	85	13	1	0	

* The tabulation of 1971 and 1972 pipeline spills by volume category was performed so as to include river and coastal channel pipelines as well as those lying offshore. This problem has been rectified in the 1973 and 1974 tabulations.

Regression Analysis:

The purpose and scope of this study do not warrant an intensive, definitive investigation of the possible relationships between the occurrence of oil spills and the many parameters describing offshore exploration and production of oil. This is not to say that such a study would not be valuable. For example, the previous study's results and conclusions were very much weakened by the absence of regression results that would prove or disprove the suitability of the proposed exposure parameter, cumulative production, as an explanatory variable for oil spill incidence.

Regression results were not included in the previous report because suitably disaggregated oil spill data were not available at that time. However, in 1973 the USCG PIRS records were modified to include either detailed area and block information on oil spills, or (alternatively) the latitude and longitude of the spill. Thus it is now feasible to perform the requisite correlation studies. The question is "how much is enough?".

Certainly, any analysis performed should be directed so as to provide some insight on our exposure parameter. Equally true, however, is the observation that limitations on both time and money would force us to quit long before we had exhaustively examined the problem. Consequently, the studies we performed were selected to satisfy the following two objectives:

1. They should demonstrate that our exposure parameter (cumulative production) is, or is not, a suitable selection.
2. They should provide sufficient insight so that this preliminary reconnaissance could be used to guide subsequent investigations.

Since the bulk of oil produced from any collection of fields tends to come from the largest fields due to the great range in reservoir size, it was felt that a representative sample might be made up of only the largest fields in the OCS region.* Using the Oil and Gas Journal's[7] tabulation of the 24 fields lying off Louisiana that are expected to produce over 100 MMBBL in their lifetime we acquired the data contained in Tables 2.1 and 2.2. Table 2.1 lists the name of the lease area in which the field is located, and Table 2.2 lists the various parameters which might be correlated in some fashion to the number of spills or, less probably, to volume of oil spilled. The explanation for our selection of these parameters is as follows: (by column)

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* For example, of the several tens of thousands of producing fields in the U.S., 75% of 1974 production was from the 500 largest fields.

Table 2.1

OIL AND GAS JOURNAL* LISTING
OF THE 24 LARGEST FIELDS OFF LOUISIANA

GROUP NUMBER	AREA	BLOCK
1	Bay Marchand	2
2	Eugene Island	126
3	Eugene Island	175
4	Eugene Island	275
5	Grand Isle	16
6	Grand Isle	43
7	Grand Isle	47
8	Main Pass	35
9	Main Pass	41
10	Main Pass	69
11	Main Pass	306
12	South Marsh Island	73
13	Ship Shoal	204
14	Ship Shoal	207
15	Ship Shoal	208
16	South Pass	24
17	South Pass	27
18	South Pass	62
19	South Pass	65
20	Eugene Island	330
21	Timbalier Bay	21
22	West Delta	30
23	West Delta	58
24	West Delta	73

* 5 May 1975, pg. 232 [7]

Table 2.2

REGRESSION DATA

a	b	c	d	e	f	g	h	i	j	k
1	49	430	650	293	33	33	5	107	5	123
2	50	89	125	53	5	4	0	0	1	8
3	56	37	120	76	10	8	0	0	0	0
4	64	47	165	60	6	5	0	0	0	0
5	48	211	350	92	19	20	30	269	21	272
6	56	164	270	230	21	21	9	226	7	44
7	55	65	100	71	5	4	2	13	13	200
8	51	80	100	77	2	2	39	262	9	66
9	57	145	280	100	15	10	47	132	69	79
10	48	191	260	134	11	8	27	1097	70	1818
11	69	32	150	134	7	6	0	0	0	0
12	63	41	105	37	5	5	0	0	0	0
13	68	27	105	58	5	6	1	84	0	0
14	67	44	175	53	7	6	0	0	0	0
15	62	92	224	86	11	11	0	0	0	0
16	50	371	489	436	17	15	95	1666	45	804
17	54	259	385	342	13	12	43	600	29	324
18	65	48	190	64	9	6	0	0	0	0
19	69	46	190	62	12	10	0	0	0	0
20	71	40	231	120	*	20	1	84	2	1890
21	59	160	260	221	*	9	0	0	1	4
22	49	312	450	216	*	23	43	3866	39	624
23	55	38	150	81	*	10	3	136	0	0
24	62	128	275	96	*	8	15	405	14	209

[a] Group number

[b] Year discovered

[c] Cumulative production through 1974, millions of barrels

[d] Cumulative production through 1/1/75 plus estimated reserves, 1/1/75, millions of barrels

[e] Number of wells, 1974

[f] 1973 production, millions of barrels

[g] 1974 production, millions of barrels

[h] 1973 number of spills

[i] 1973 volume spilled, gallons

[j] 1974 number of spills

[k] 1974 volume spilled, gallons

*Unknown

a) Group: See Table 2.1.

b) Year of Discovery: It was felt that this parameter would serve as a useful if approximate surrogate for two parameters we expected to be important. These parameters were the age of the installed equipment (which should be a measure of the equipment's physical condition), and secondly, the amount of practical experience gained through the design,installation and operation of previously installed equipment. That is, platforms installed in the 1960's should represent a wealth of design experience gained in the late 1940's and 1950's.

c) Cumulative Production to 1-1-75: This parameter divided by the age of the field on 1 January 1975 should yield a representative annual production figure for the various fields. This average figure should then be reasonably well correlated with the amount of activity required to produce the oil, which in turn should give us the best test for the validity of our exposure parameter.

d) Estimated Ultimate Recovery: If this value was determined with accuracy, then it would provide an even better test of our hypothesis that the exposure parameter is cumulative (field-life) production than would parameter c), the cumulative production through 1-1-75. This is particularly true for those fields in which all installations were essentially completed by 1973. Unfortunately, it is our experience that the estimated reserves figure is almost always greatly understated and so we do not have confidence in the accuracy of this value.

e) Number of Wells 1974: This parameter is also a measure of the state of development and activity on a field. It has the problem that newer technology, primarily directional drilling, and relaxed allowables have caused the number of wells to decrease for a profit maximizing development, all other things being equal. Of course, all other things are not equal, as reservoir characteristics, design wave height and the depth of water in the region all conspire to effect the profit maximizing number of wells.

f-g) Annual Production 1973, 1974: These parameters might at first appear to be the most direct comparison to our proposed exposure parameter. Unfortunately, the older fields will be in their declining phase and so their annual production will not be an accurate measure of the amount of activity associated with that field. Similarly, newly discovered fields might only now be achieving their peak production, although significant activity had to occur in previous years to install the platforms and wells required to achieve this production.

j-k) <u>USCG PIRS 1973 and 1974 Oil Spill Data</u>: These four columns specify the total number of oil spills and/or the volume of oil spilled within each of the given blocks for the years 1973 and 1974. These numbers were obtained by selecting from the PIRS data all platform and pipeline spills noted to have occurred either in the block, or within the latitude and longitude bounding the block. There is some inconsistency in counting the pipeline spills in this group as the pipeline may be carrying oil produced from another lease block. However, for our purposes, it was judged that the problems raised by the inclusion of the pipelines would be of little overall significance.

The question must also be raised regarding the suitability of our proposed sample. Is it representative of all OCS developments in the Gulf of Mexico, or do these 24 large fields each tend to have fairly unique characteristics? The following comparisons provide us with some insight:

1. The fields selected account for about 262 MMBBL of production in 1974 out of a total production of 532 MMBBL for the entire OCS. Thus, for describing the production of oil in the Gulf they are a very representative sample. explain

2. Of the 1725 oil spills noted to have occurred in the Gulf of Mexico in 1974, only 325 spills occurred in our sample.
3. Of the 5108 active wells in the federal OCS region in 1974, 3140 wells are contained in the 24 samples.

Thus it appears that our sample is almost exhaustive if we wish to speak of production or of the properties of active wells, but if we wish to discuss the oil spillage problem the sample is probably not very representative. This is unfortunate because we have no alternative but to use this sample. Selecting a more representative sample or treating the problem exhaustively is of course feasible in principle, but not within the contraints of this study. Furthermore, as we shall see, the results of the analysis are illuminating and they do serve to satisfy the two objectives we set for ourselves.

The first regression we attempted was between the number of spills in 1973 and the number of spills in 1974. The data points and the least squares linear fit to the data are shown on Figure 2.1. The regression coefficient (R) for the data is .74. Based on this result we can be better than 95% confident that (with 24 samples) the actual regression coefficient lies in the range (.45,.87). Alternatively, it is extremely unlikely that the processes are not correlated. Notice that the least squares fit indicates a decline in the number of spills from 1973 to 1974 of about 33% for those fields having enough spills in 1973 so that the constant 3.45 can be neglected. Treated as a group, the number of spills decreased by about 10% from 1973 to 1974. This points out yet another discrepancy between our sample's spill behavior and that of the total population, because the total number of spills for all fields was about constant from 1973 to 1974 (see Table 1.1).

The utility of this graph is that it supports our earlier statement that the number of spills should be a reasonably consistent statistic from one year to the next. Notice also the grouping of 11 points near the origin (0,0). This feature suggests that some fields are operated in such a fashion as to be consistently successful at avoiding mention in the PIRS data.* This in turn suggests that a more detailed study of the various fields using the methods of factor analysis might be expected to unearth the underlying parameters responsible for one group's success from one year to the next in avoiding oil spillage.

It is also possible to regress column *i* against column *k* thereby demonstrating the lack of correlation between volume

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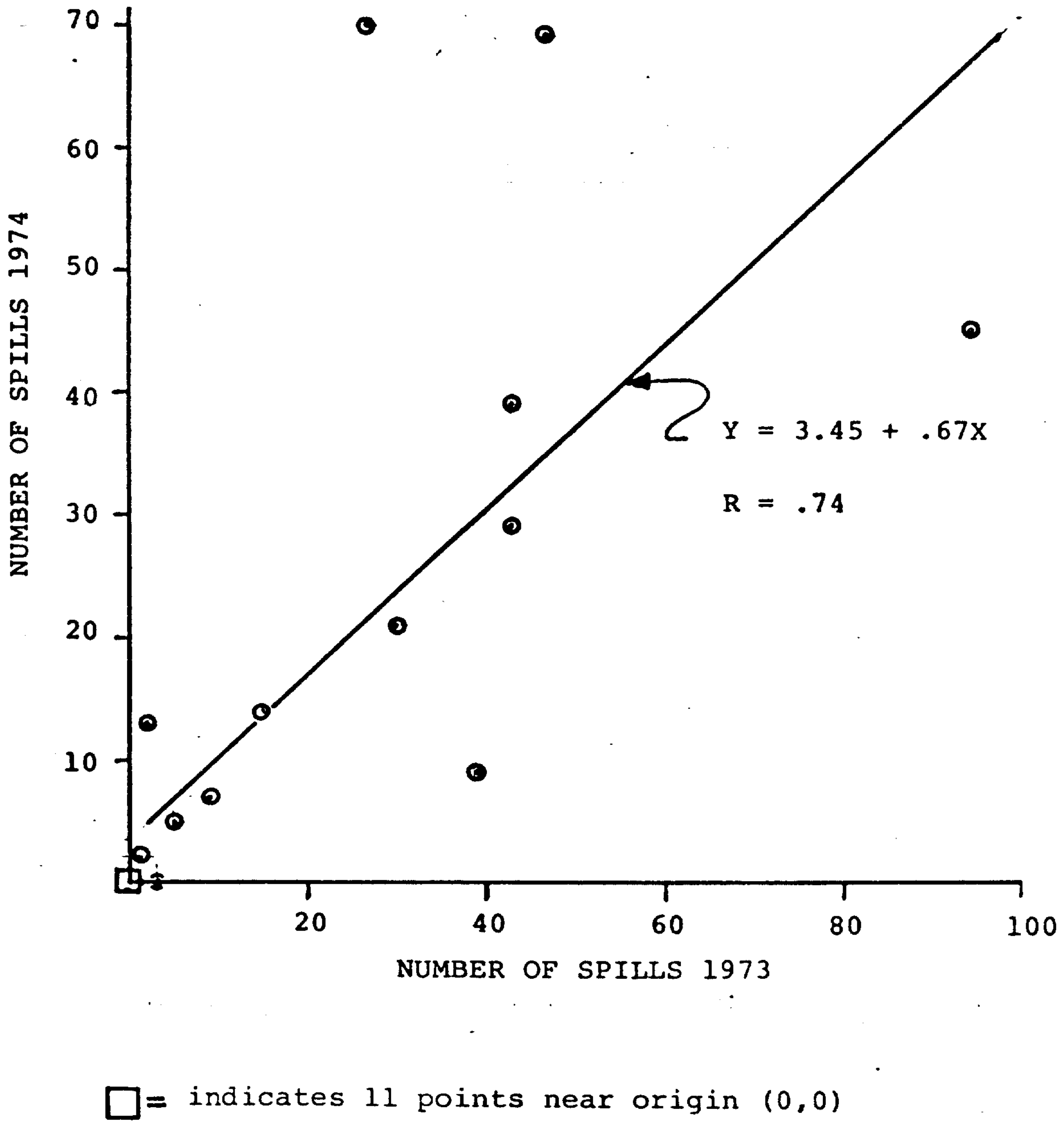
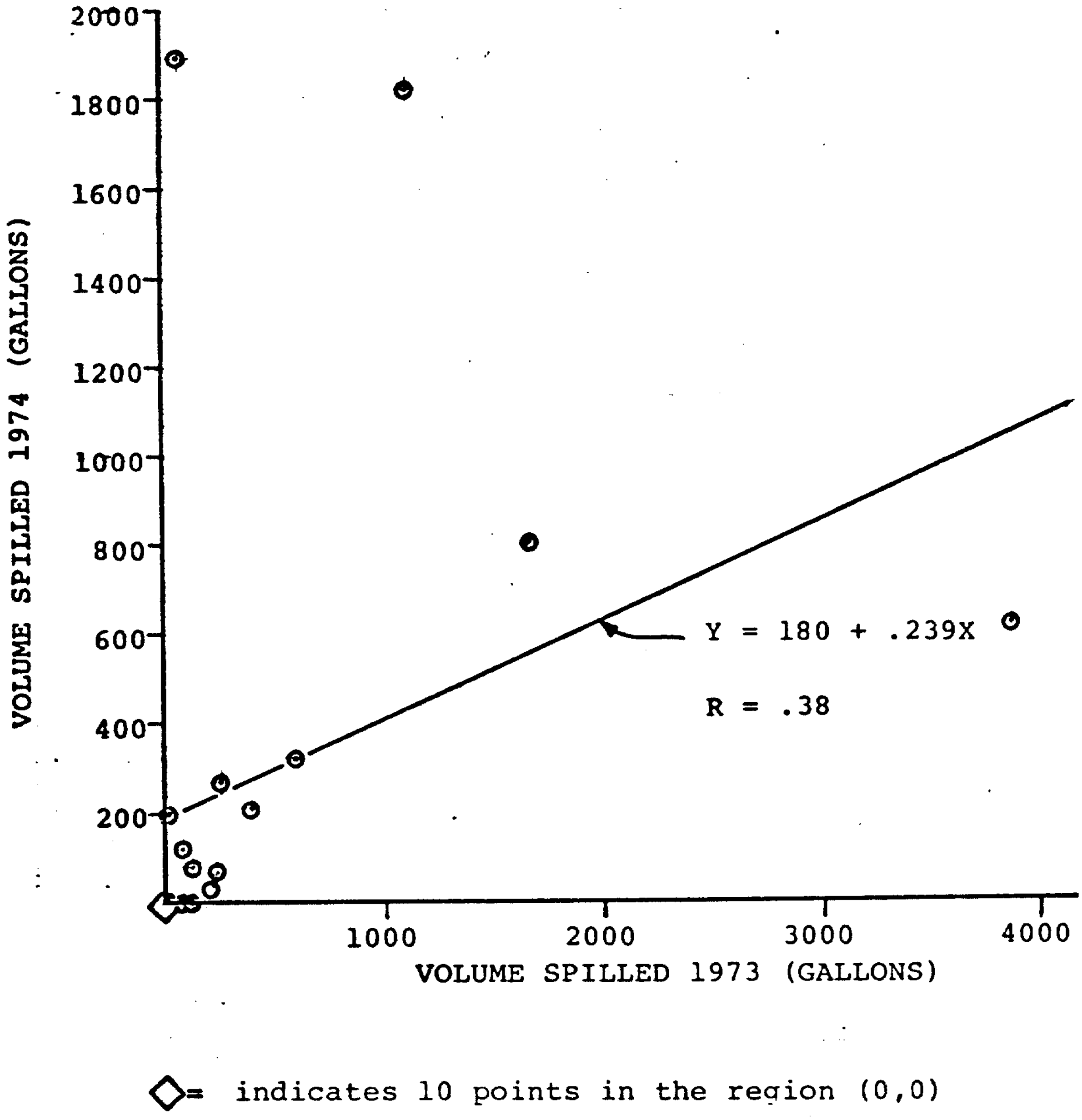
* Hopefully this indicates a true absence of oil spills. Certainly the Coast Guard personnel working with PIRS and with the associated monitoring programs believe this is the case.



NUMBER OF SPILLS IN 1974 vs. NUMBER OF SPILLS IN 1973 FOR THE 24 LARGEST FIELDS OFF LOUISIANA

Figure 2.1



VOLUME SPILLED IN 1974 vs. VOLUME SPILLED IN 1973 FOR THE 24 LARGEST FIELDS OFF LOUISIANA

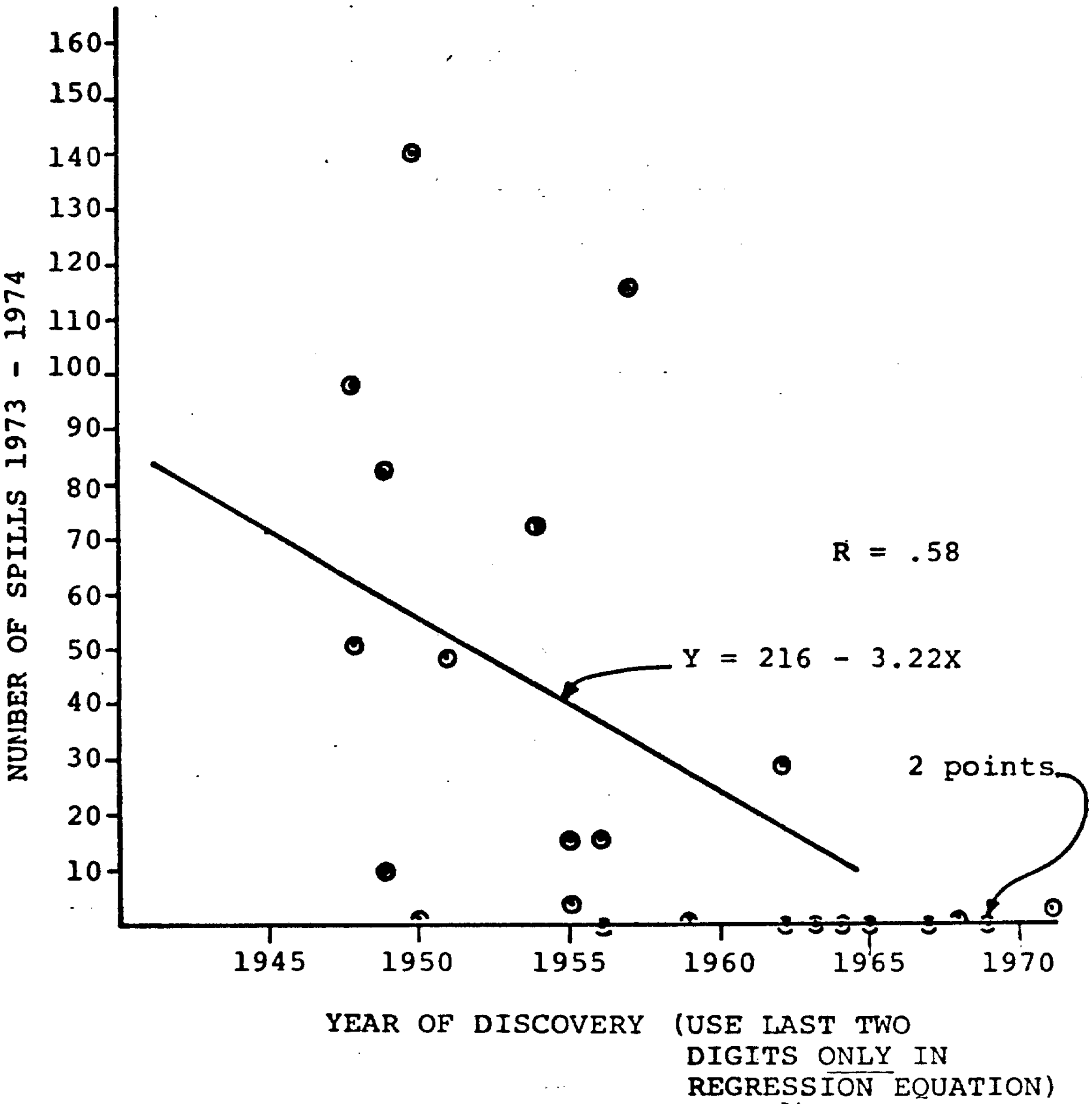
Figure 2.2

spilled from one year to the next, as shown in Figure 2.2. The regression coefficient value of .38 is below the 5% significance level of .40 and the t value for this fit was 1.926, indicating a fair possibility that the data are not even correlated. This behavior, of course, springs from the enormous variance observed in individual spill sizes, and the subsequent requirement that samples be very large to ensure repeatability.

One of the most striking regression results is shown on Figure 2.3. This figure shows the results of regressing the number of spills in 1973 and 1974 versus the OGJ's field discovery date. The relatively low regression coefficient (R=.58) is more indicative of the observation that the proper fit may not be a straight line but rather some higher order polynomial. Notice that for the fields discovered after 1957, only three of the eleven had one or more spills, while of the thirteen fields found prior to 1957, only two had no spills in 1973 and 1974, the remainder averaging about thirty spills per year.

This observation suggests two divergent hypotheses.

> <u>Hypothesis 1</u>: The technology may have improved greatly since 1957 and we can therefore expect far fewer spills from modern developments than from their predecessors.



NUMBER OF SPILLS IN 1973 - 1974 vs. YEAR OF FIELD DISCOVERY FOR THE 24 LARGEST FIELDS OFF LOUISIANA

Figure 2.3