4. Tanker spills over 42,000 gallons

Table 4.1 shows a listing of all non-inland tanker and barge spills over 1000 barrels (42,000 gallons) through 1972 of which we are aware. This list combines data from the ECO Inc. tape, the Georges Bank Petroleum Study (Westinform Ltd.), and the 1970, 1971, and 1972 Coast Guard Reports. In terms of volume, almost all the oil reported spilled by vessels is spilled in spills of this size. 98.4% of the volume reported in the ECO data occurred in 42,000 gallon spills or larger.

The great bulk of all these vessel spills are from the ECO Inc. data. This data was obtained by:

a. identifying some 3,000 tanker casualties that occured in the calendar years 1969 through 1972, principally through insurance company reports (Lloyd's Daily List);

b. internal data on oil company-owned and -chartered tankers involved in the incidents provided through the cooperation of the companies;

c. cross-check with other published data--newspapers and magazines--for details of particular incidents;

d. follow-up interviews with oil company personnel in the case of discrepancies.

The data covers 612 spills. We believe it to be a practically complete list of <u>large</u> tanker spills in the four-year period. In return for the company data, ECO agreed not to identify individual spills. Hence, we have deleted vessel name and exact date

TABLE 4.1

ESTIMATED SPILL IN GALLONS	LOCATION	SOURCE (ECO,CGD,GBS)	TANKER NAME	GROSS REGISTERED TONNAGE	DATE (DAY,MO,YR)
33,804,000	12	ECO		63,989	.12.72
29,000,000	2	GBS	Torrey Canyon		18. 3.67
13,828,000	12	ECO		29,189	. 7.70
13,500,000		GBS	World Glory		13. 6.68
11,240,000	6	ECO		28,339	. 2.71
9,554,000	23	ECO		21,999	. 6.72
8,912,000	1	ECO		16,231	. 1.72
8,800,000	1	GBS	Keo	15,797	5.11.69
8,772,000	1	ECO		19,183	. 2.70
8,434,000	17	ECO		17,328	. 1.69
8,432,000	1	ECO		15,797	. 1.69
8,304,000	1	ECO		20,084	. 3.71
6,250,000		GBS	R. C. Stoner		6. 9.67
5,808,000	2	ECO		17,519	. 3.72
5,732,000	2	ECO		12,607	. 1.70
5,620,000	15	ECO		11,765	. .71
5,300,000	2	GBS	A. M. Browig		20. 2.66
5,232,000	15	ECO		12,113	. 1.70
5,217,000	6	ECO		11,971	. 7.71
5,198,000	2	ECO		12,525	.10.70
5,142,000	11	ECO		11,563	. 4.70
5,000,000		GBS	Andron		5. 5.68
4,864,000	24	ECO		11,079	. 2.70
4,608,000	12	ECO		10,608	. .71
4,594,000	3	ECO		11,177	. 2.70
4,561,000	6	ECO		10,009	. 2.69
3,934,000	23	ECO		15,638	. 1.70
3,850,000	13	ECO		8,864	. 2.70
3,653,000	2	ECO		28,945	. 5.70
3,500,000	2	GBS	Poly Commander	28,945	5. 5.70
3,500,000	7	GBS	Ocean Eagle		3. 3.68
3,372,000	1	ECO		11,379	. 3.70
2,810,000	4	ECO		104,772	. 2.69
2,733,000	15	ECO		10,518	. 9.71
2,529,000	2	ECO		12,821	. 2.69
2,500,000	16	GBS	Tampico		. 3.57
2,457,000	15	ECO		12,200	.11.71
2,108,000	2	ECO		43,371	. 7.69
2,000,000	1	CGD			. 4.69
1,686,000	2	ECO		42,777	.10.70
1,686,000	20	ECO		30,714	. 3.70

SPILL IN GALLONS	LOCATION	SOURCE (ECO,CGD,GBS)	TANKER NAME	REGISTERED TONNAGE	DATE (DAY,MO,YR)
1,686,000	23	ECO		26,805	.12.72
1,651,000	1	ECO		11,208	. 4.72
1,630,000	13	ECO		32,629	.10.69
1,612,000	3	ECO		29,197	.11.71
1,500,000	1	GBS	Arrow	11,379	. 2.70
1,492,000	11	ECO		48,339	. 8.72
1,400,000	2	GBS	Pacific Glory	42,777	21.10.70
1,300,000	7	GBS	Gen. Colocotronis		7. 3.68
1,300,000		GBS	Esso Essen		29. 4.68
1,262,000	24	ECO		31,275	. 9.70
1,200,000	7	GBS	Argea Prima		17. 7.62
1,124,000	2	ECO		52,510	. 2.71
989,000	1	ECO		46,988	. 8.72
984,000	15	ECO		12,492	. 8.70
943,000	2	ECO		48,267	.11.71
940,000	16	ECO		10,448	. 1.71
939,000	16	ECO		10,533	. 1.71
900,000	20	GBS	Ocean Grandeur	30,714	3. 3.70
857,000	2	ECO		13,604	. 1.71
843,000	11	ECO		48,320	. 8.72
840,000	16	GBS	Oregon Standard	10,448	1.18.71
838,000	23	ECO		33,403	. 8.72
812,000	23	ECO		12,697	. 1.72
794,000	17	ECO		17,543	. 5.72
780,000	1	GBS	Esso Gettysburg		22. 1.71
730,000	2	GBS	Otto N. Miller		27. 3.65
702,000	2	ECO		12,223	. 9.69
674,000	1	ECO		31,289	. 3.69
630,000		GBS	Witwater		12.13.68
590,000	2	GBS	Benedicte	38,700	31. 5.69
562,000	2	ECO		38,700	. 5.69
562,000	12	ECO		97,450	. 9.70
560,000	2	GBS	Floreal		11. 9.65
534,000	13	ECO		17,420	. 2.69
525,000	5	ECO		12,595	. .72
506,000	1	ECO		23,420	. 2.70
501,000	13	ECO		11,237	.10.71
478,000	7	ECO		12,085	.10.69
478,000	1	ECO		30,770	. 7.69
450,000	2	ECO		15,983	. 2.70
436,000	1	ECO		24,008	. 8.70
420,000	7	ECO			. .72

ESTIMATED SPILL IN GALLONS	LOCATION	SOURCE (ECO,CGD,GBS)	TANKER NAME	GROSS REGISTERED TONNAGE	DATE (DAY,MO,YR)
420,000	16	GBS	Evje		2. 5.67
420,000	2	GBS	Gironde		19. 8.69
413,000	12	ECO		12,718	. 5.70
410,000	7	ECO		10,255	. 3.72
398,000	16	CGD	Barge		10.12.71
393,000	23	ECO		20,560	. 1.72
379,000	16	ECO		17,943	. 3.69
372,000	15	ECO		801	.10.70
351,000	23	ECO		13,235	. 4.69
351,000	1	ECO		23,665	. 1.71
351,000	23	ECO		12,029	.11.72
337,200	7	ECO		12,235	. 2.69
337,000	12	ECO		127,158	. 9.70
309,000	23	ECO		19,391	.12.72
306,000	1	CGD			23. 1.71
300,000	1	CGD	Barge		11. 5.71
290,000	1	GBS	Tim		18. 2.68
285,000	2	ECO		499	. 4.72
281,000	1	ECO		20,575	. 1.69
281,000	1	ECO		533	. 2.69
281,000	7	ECO		12,573	. 7.69
281,000	1	ECO		26,968	. 3.70
281,000	19	ECO		17,871	. 3.71
281,000	15	ECO		12,200	.12.71
281,000	13	ECO		105,397	. 6.72
281,000	23	ECO		12,648	. .72
281,000	11	ECO		12,174	. 4.72
264,000	2	ECO		12,377	.11.72
240,000	7	CGD			12. 6.71
239,000	2	ECO		11,842	. 1.70
233,000	1	ECO		16,417	. 2.70
225,000	13	ECO		296	. 8.69
220,000	2	GBS	Esso Wansworth		23. 9.65
220,000	16	CGD	Barge		26. 4.71
220,000	2	GBS	Efthycosta		8. 3.70
211,000	1	ECO		23,665	. 7.70
210,000	2	GBS	Hamilton Trader		30. 4.69
204,000	15	ECO		427	.12.71
200,000	1	GBS	R. L. Polling		10. 5.69
200,000	1	GBS	Barge		27.12.70
200,000	3	ECO		48,801	. 6.71
197,000	13	ECO		771	.11.71

.TIMATED SPILL IN GALLONS	LOCATION	SOURCE (ECO,CGD,GBS)	TANKER NAME	GROSS REGISTERED TONNAGE	DATE (DAY,MO,YR)
197,000	23			13,393	. 2.70
180,000	16	GBS	Marita		20. 9.62
177,000	1	ECO		82,793	. 6.71
172,000	1	GBS	Florida		10. 9.69
169,000	2	ECO		12,575	. 4.69
169,000	15	ECO		382	. 8.70
169,000	5	ECO		1,944	. 3.72
168,000	7	CGD	Barge		1. 1.71
168,000	24	CGD	Barge		20. 7.72
168,000	1	GBS	Algol		9. 2.69
165,000	2	GBS	Hullgate		8. 4.71
160,000	4	ECO		13,580	. 7.69
147,000	7	CGD	Barge		15. 3.72
140,000	1	ECO		12,618	. 2.69
140,000	1	ECO		1,286	. 2.69
140,000	15	ECO		361	. 1.69
140,000	15	ECO		338	.10.70
140,000	16	ECO		14,671	. 1.71
140,000	2	ECO		1,594	. 4.71
140,000	23	ECO		1,594	. 6.72
140,000	17	ECO		14,456	. 3.72
140,000	2	GBS	Monti Ulia		27. 7.70
135,000	1	CGD			12. 6.72
135,000	15	ECO		282	. 2.71
134,000	5	ECO		3,738	. 6.70
131,000	1	GBS	Barge		22. 5.70
126,000	1	ECO		20,889	.12.72
126,000	2	ECO		12,146	.12.72
112,000	23	ECO		1,588	. 4.69
112,000	15	ECO		199	. 2.69
112,000	2	ECO		54,908	. 9.69
112,000	23	ECO		23,664	.10.72
112,000	13	ECO		854	. 2.72
110,000	23	ECO		3,553	. 8.71
100,000	1	CGD			22. 7.72
85,000	16	CGD			18. 1.71
84,000	1	ECO		382	. 3.69
84,000	2	ECO		12,493	. 4.69
84,000	2	ECO		12,423	. 4.70
84,000	1	GBS	Barge		26. 5.70
84,000	2	GBS	Texacao		11. 1.71
84,000	1	CGD	Barge		6. 9.72

ESTIMATED SPILL IN GALLONS	LOCATION	SOURCE (ECO,CGD,GBS)	TANKER NAME	GROSS REGISTERED TONNAGE	DATE (DAY,MO,YR)
82,000	13	ECO		395	. 2.72
76,000	7	GBS	Barge		23. 5.69
75,000	16	CGD	Barge		28. 2.71
72,000	2	ECO		13,718	. 5.71
72,000	2	GBS	Heruluv		15. 5.71
70,000	15	ECO		170	. 7.70
70,000	1	ECO		11,010	. 4.71
70,000	13	ECO			. .71
70,000	23	ECO		45,162	. 2.71
70,000	13	ECO		15,564	.11.72
70,000	17	ECO		16,563	.12.72
68,000	15	ECO		142	. 8.72
67,000	7	GBS	Barge		26. 5.70
67,000	1	GBS	Barge		12. 7.70
66,000	15	ECO		317	. 3.71
62,000	1	ECO		1,103	. 3.72
60,000	1	CGD	Barge		12. 5.71
56,000	2	ECO		15,880	: 8.69
56,000	24	ECO		11,136	. 5.69
56,000	2	ECO		107,426	.12.71
56,000	2	ECO		20,414	.12.71
56,000	15	ECO		357	. 9.72
47,000	13	ECO		899	. 2.72
46,000	20	ECO		254	.10.70
42,000	19	ECO		45,752	. 8.71
42,000	1	GBS	Kenai Peninsula		5.11.68
42,000	1	CGD			20. 1.72

from those spills for which our only source was thé ECO tape. A cursory examination of the list will reveal that with respect to large spills, the non-ECO sources are woefully incomplete. For example, in 1969 ECO reports 40 large (over 42,000 gallons) spills. The other data sources combined report 8, 6 of which spills are in the ECO data. Since the data prior to 1969 is patently incomplete and since the Coast Guard data refers only to U.S. waters and contains only a small sample of non-harbor spills (see Table 1.1), we have decided to rely solely on the ECO Inc. data in deriving densities of tanker spills over 42,000 gallons.

With respect to the incidence of vessel spills, our earlier assumptions imply that the probability of n spills occurring given a specified amount of exposure, t, is given by

$$p(n|\lambda) = e^{-\lambda t} (\lambda t)^n / n!$$

where λ is a parameter which specifies the <u>intensity</u> of the Poisson process governing spill frequency. We will use the ECO spill data to make some judgments about λ. But first we have to ask ourselves what exposure variable, $\bar{t}$, we should use. Several possibilities come immediately to mind - amount of oil being transported, number of landfalls, number of

---

*Coast Guard personnel feel that their system is picking up 90% or more of the actual spills from fixed sources. However, the legal requirement for reporting extends only to the three-mile limit and these same personnel have some doubts that vessels operating near the three-mile limit are completely faithful reporters.

ton-miles, etc. In short, our task is to identify an explanatory variable, t, to which spillage appears related in the above manner. We also need an explanatory variable whose ability to explain we can test with the available data.

In attempting to find such a variable, we have made a number of false starts. Figure 4.1 shows one such failure. The ECO data breaks the world down into twenty regions and identifies in which of these regions each spill occurred. We hypothesized that spill frequency was proportional to the amount of oil flowing through each region. Department of Interior reports [7] on world oil flows were used to estimate the amount of oil flowing through each such region over the four-year period. We then plotted the number of spills which took place in each region against the amount of oil flowing through that region. Figure 4.1 shows the resulting scatter diagram. Obviously, there appears to be little or no dependence between spill incidence and regional throughputs. The total volume spilled in each region, Figure 4.2, also shows no relation to regional throughput but this was not unexpected because volume spilled can be drastically affected by a single spill. However, with a sample of 612 spills, if there were a relationship between incidence and regional throughput, with high probability Figure 4.1 would have revealed it.

The ECO Inc. data also breaks the spills down by locale:

1. pier (touching a dock)
2. harbor

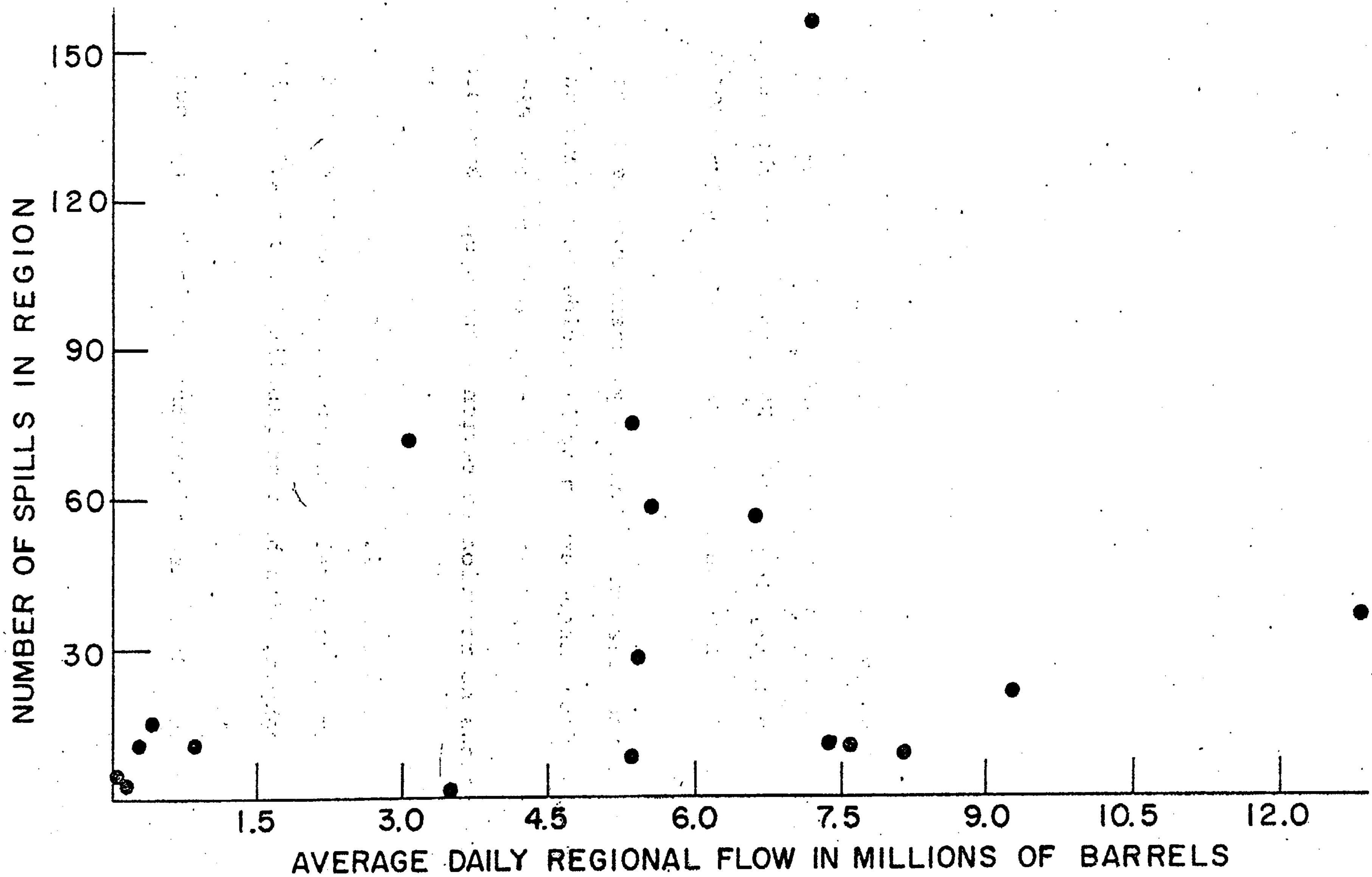

FIGURE 4.1 SCATTER DIAGRAM OF NUMBER OF SPILLS IN REGION VERSUS VOLUME OF CRUDE FLOWING THRU REGION. Based on all ECO spills (612).

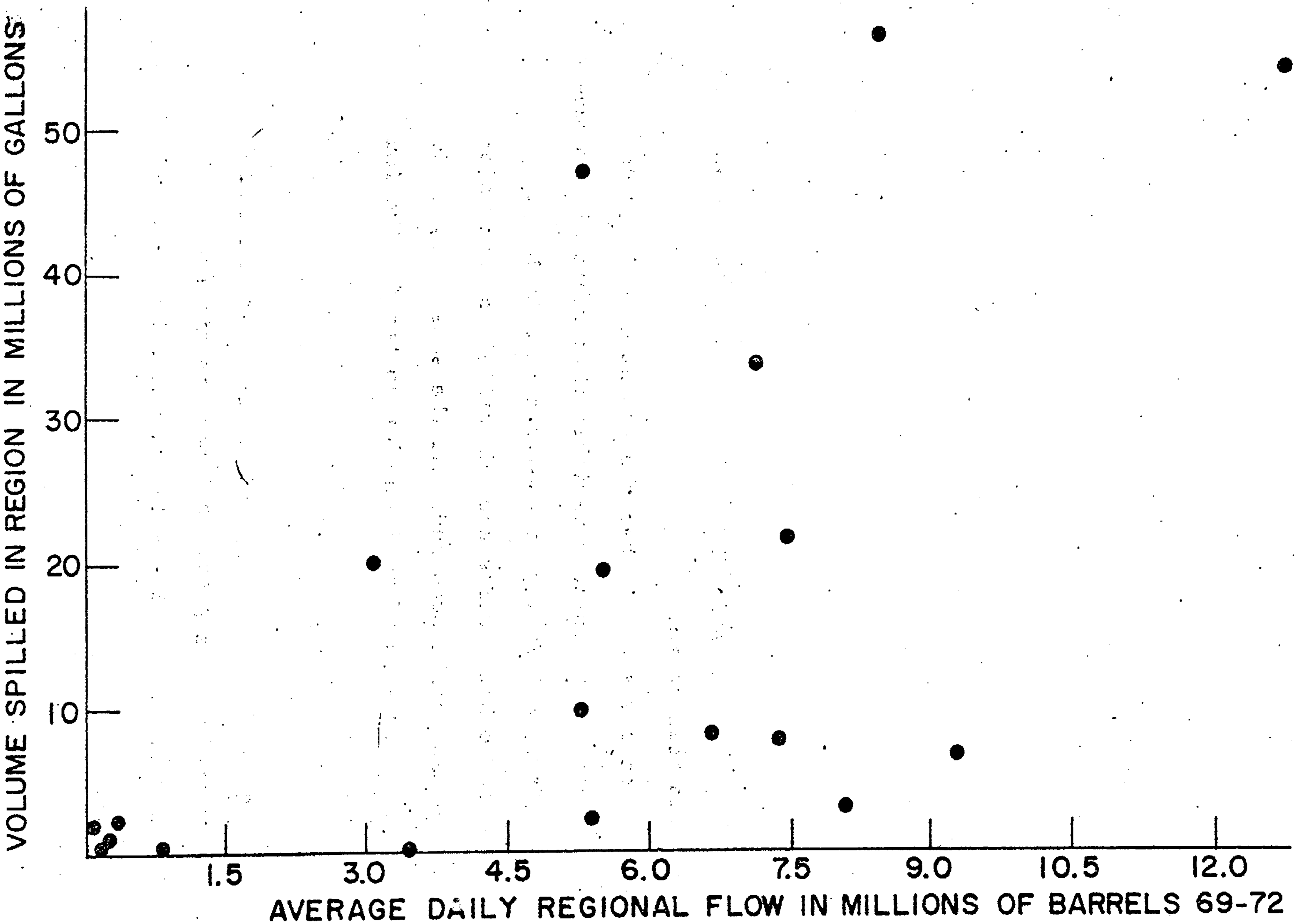

FIGURE 4.2 SCATTER DIAGRAM OF VOLUME SPILLED IN REGION VERSUS REGIONAL THROUGHPUT. Based on all 612 ECO spills.

3. bay

4. outside bay but within fifty miles of shore

5. outside fifty-mile limit.

Of the 359 spills for which locale is listed, 291 or 83% occurred within fifty miles of land. Figure 4.3 shows the breakdown. This figure, together with the earlier negative results, suggests that most spills occur at either end of the voyage. This suggestion is buttressed by Figure 4.4 which indicates that sizable portion of the spills are caused by grounding or ramming (vessel hits fixed structure) or collision. Groundings and rammings can only occur near shore, while collision frequency depends on traffic density, which is at a maximum near shore.

These results suggest that the amount of oil landed might be a better explanatory variable than regional throughput. Therefore, ECO Inc. personnel returned to Lloyd's Daily List and other records and identified on what major trade route each spill occurred. At the same time, trade route volumes for each of twelve major routes for the four years were compiled from Department of Interior sources. Figure 4.5 shows the resulting scatter diagram: number of spills on each route against volume handled on that route. This figure indicates a possible linear relationship. The least squares fit is $n = 3.9 + 10.1 \cdot v$ which has a correlation coefficient of .88 and a standard error of 8.3. Interestingly enough, the three points to the high side of this fit all involve routes which terminate in the U.S. This raises two possibilities:

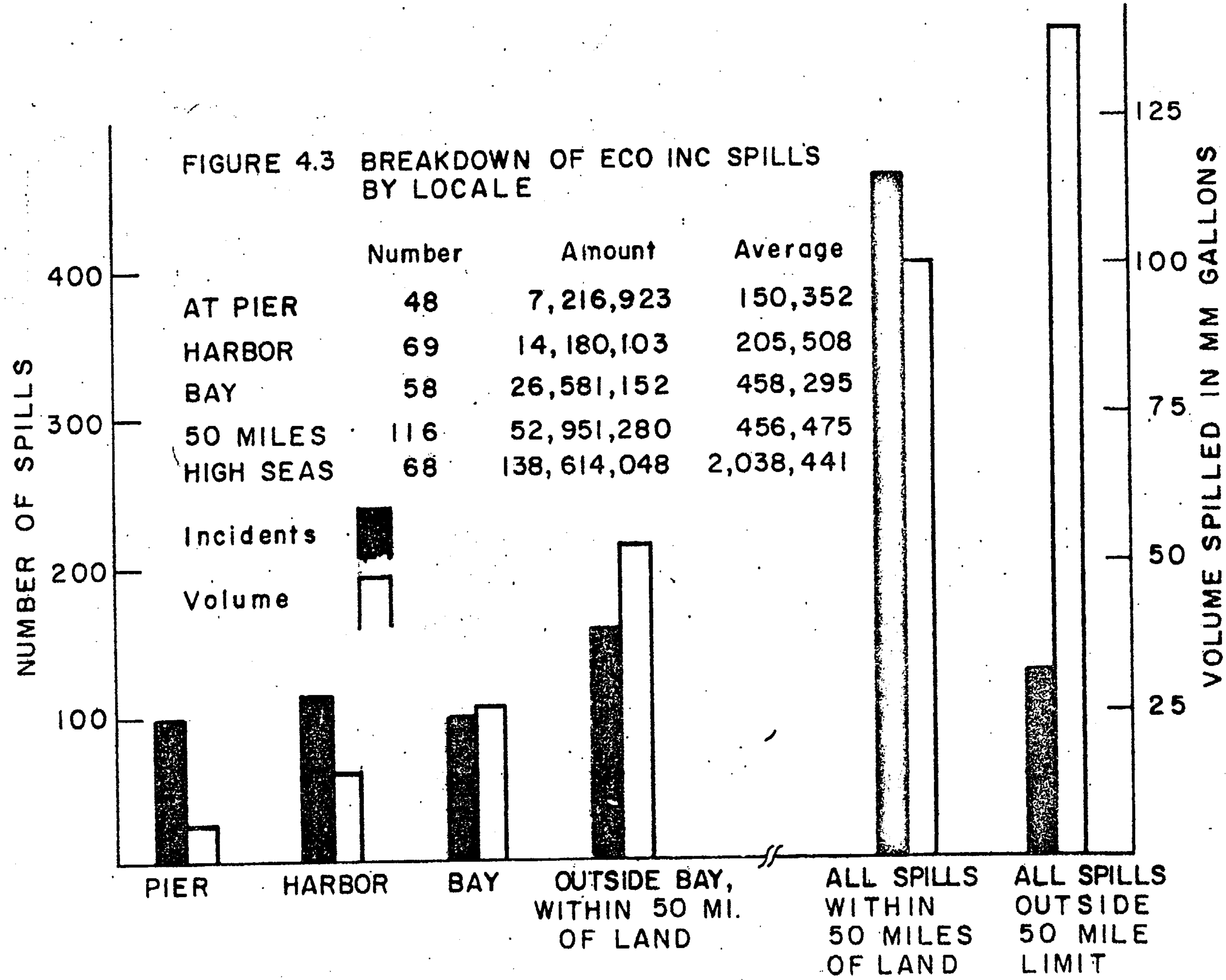

FIGURE 4.3 BREAKDOWN OF ECO INC SPILLS BY LOCALE

	Number	Amount	Average
AT PIER	48	7,216,923	150,352
HARBOR	69	14,180,103	205,508
BAY	58	26,581,152	458,295
50 MILES	116	52,951,280	456,475
HIGH SEAS	68	138,614,048	2,038,441

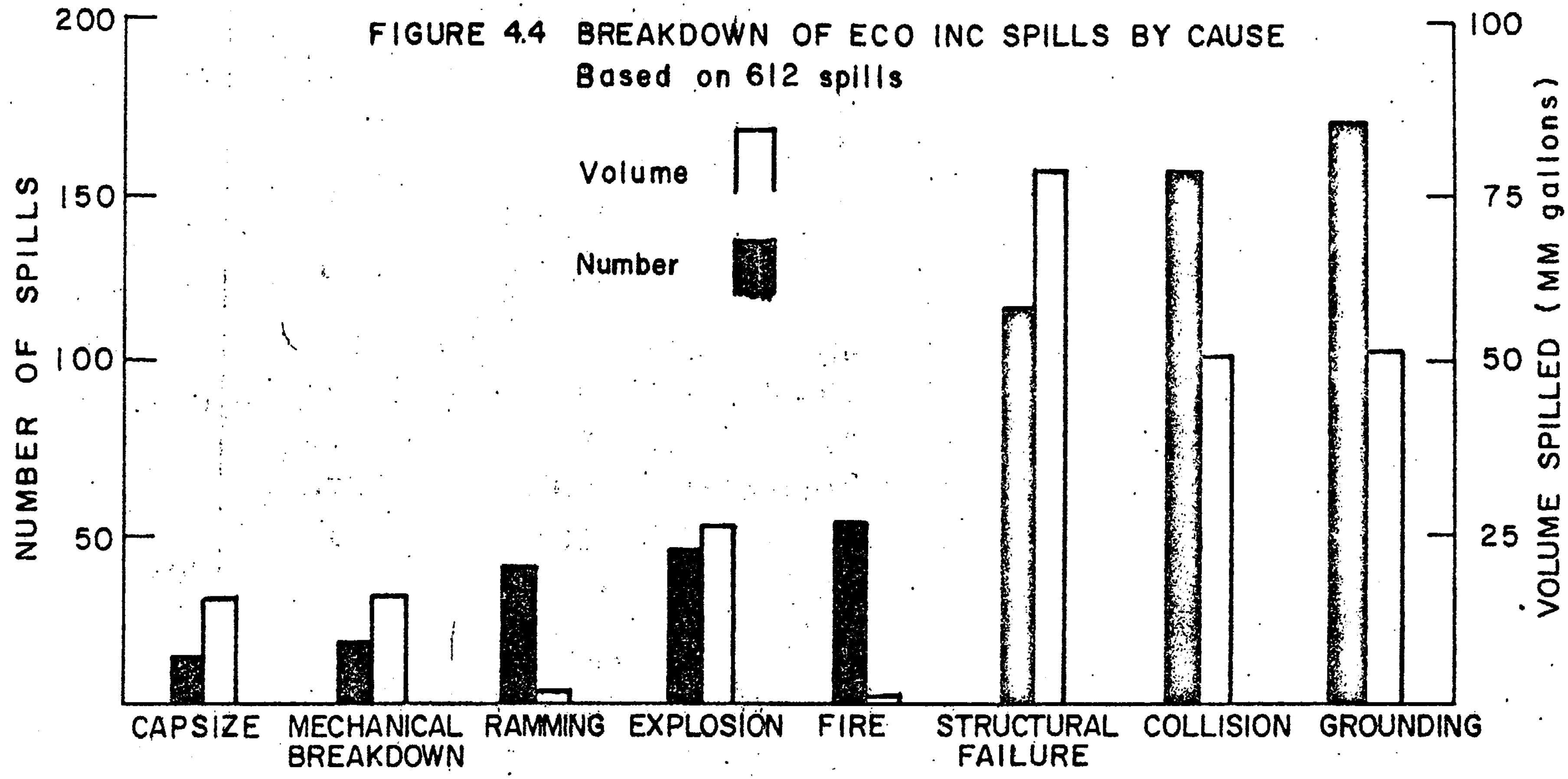

FIGURE 4.4 BREAKDOWN OF ECO INC SPILLS BY CAUSE
Based on 612 spills

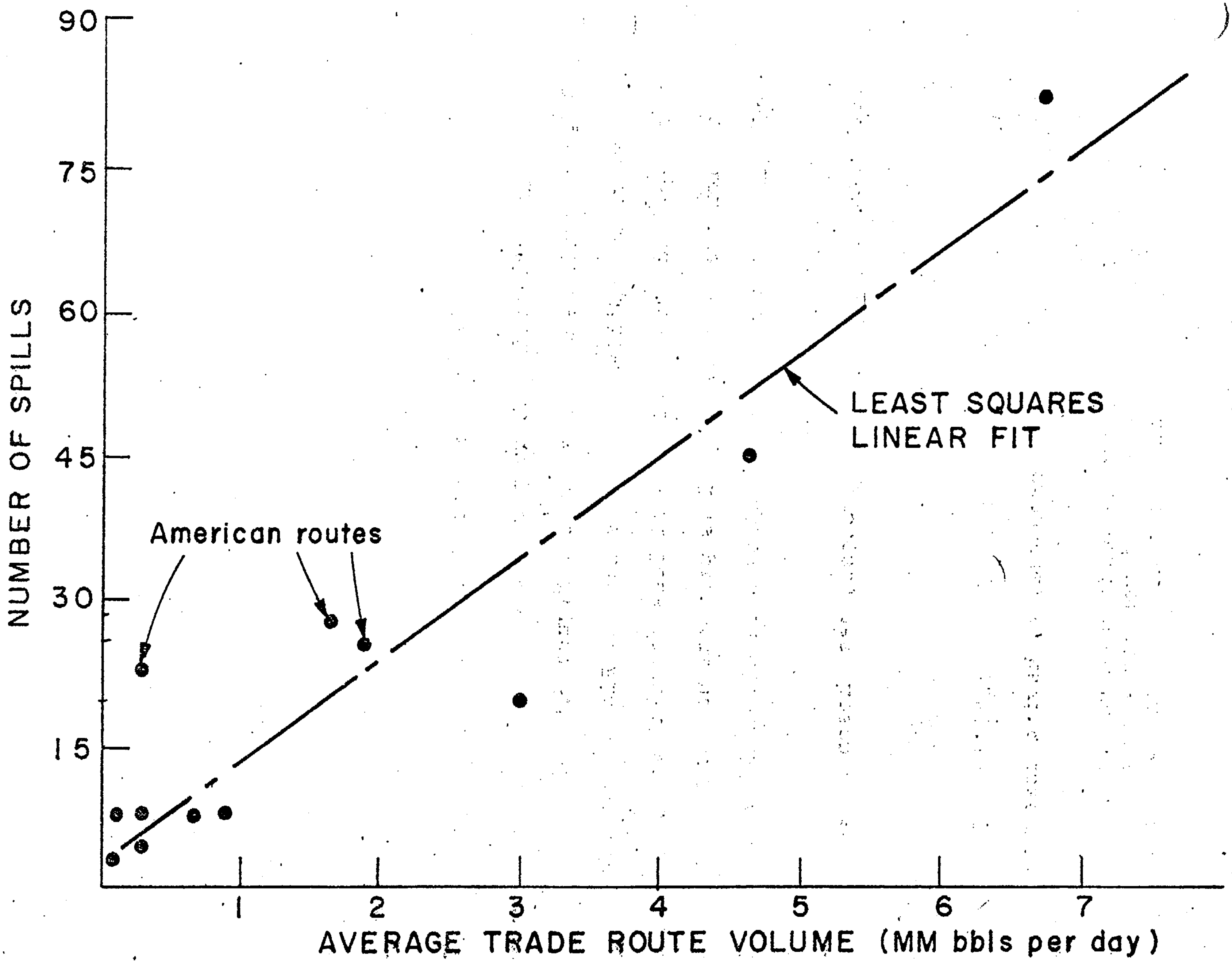

FIGURE 4.5 SCATTER DIAGRAM OF NUMBER OF SPILLS OBSERVED VERSUS AVERAGE TRADE ROUTE VOLUME, 69 THRU 72

1. Spills in U.S. waters are more carefully reported than elsewhere.

2. Since U.S. routes involve generally smaller ships than other major routes due to draft limitations at terminals, the same volume landed involves more landfalls. This suggests that the number of landfalls may be a still better explanatory variable than the volume landed. However, we did not check this possibility due to time comstraints, but, on the basis of Figure 4.5, chose to operate with volume landed as the exposure variable.

It is interesting to compare the correlation between number of spills and volume landed, Figure 4.5, with that between volume spilled and volume landed, Figure 4.6. As expected volume spilled shows a great deal less correlation, yet the assumption that volume spilled is proportional to volume landed is almost universally employed in oil-spill analysis.

As Section 3 argues, once one has decided to model spill frequency by a Poisson process, has chosen an exposure variable, and has assumed that the intensity of this process, λ, is an unknown variable whose density should depend solely on the available spill data,* then the probability of obtaining n spills in a given amount of exposure, t, having observed ν

*To put this third assumption in precise but impenetrable jargon, we have assumed that the intensity λ is a random variable which is governed by the non-informative conjugate prior.

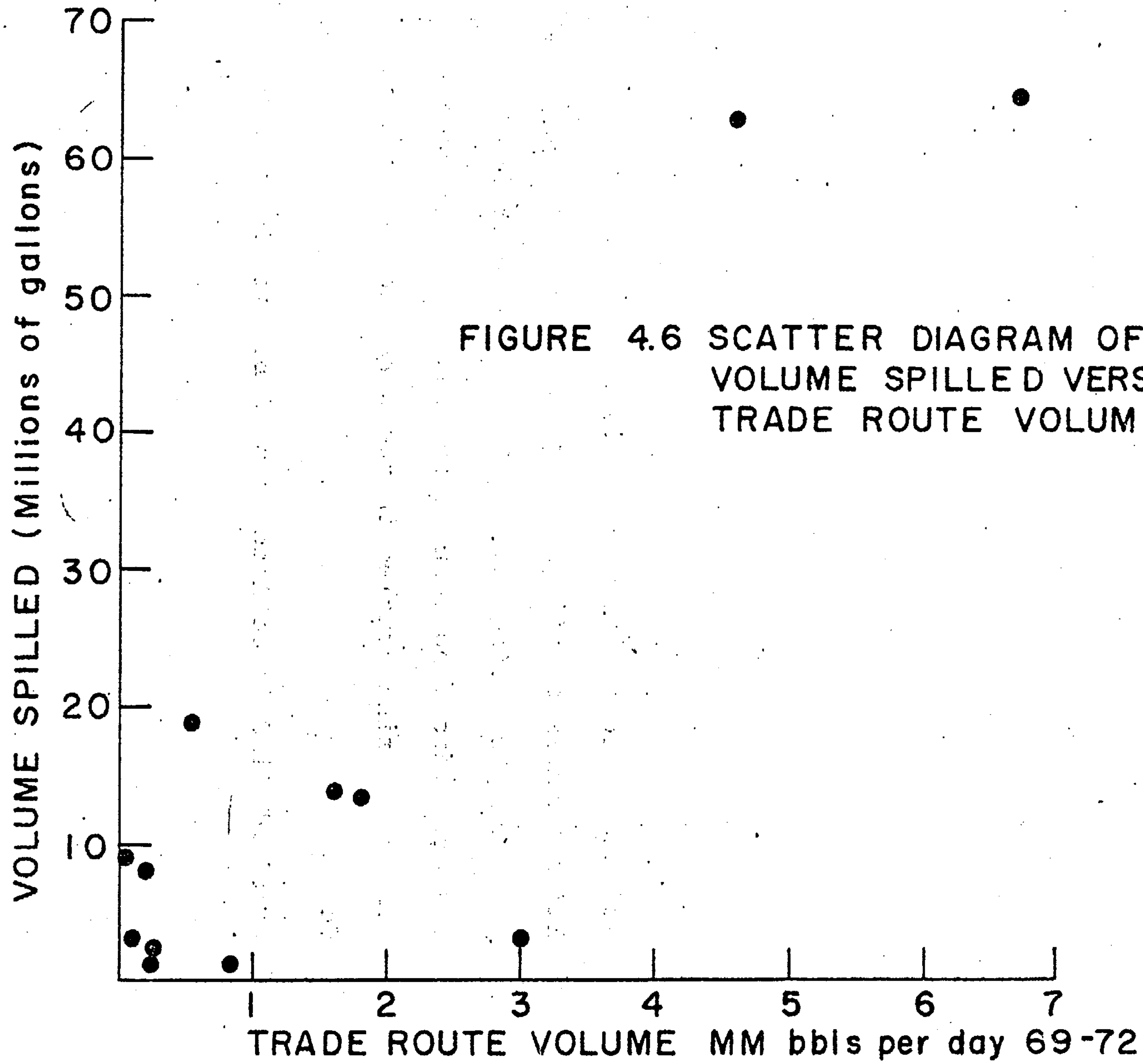

FIGURE 4.6 SCATTER DIAGRAM OF VOLUME SPILLED VERSUS TRADE ROUTE VOLUME