Pipeline spills

The remaining class of OCS spill incidents is pipeline spills. Our data for this class of spills is derived from the USGS Event file as supplemented by the Metairie Pipeline leaks list. The principal source of exposure data is the USGS Pipeline Management System's segment-specific pipeline list. This list is available in a variety of forms. We obtained a copy of the list in "comes from order". Included in this list are the unique segment number, the identities of the structures serving as terminals for the segment, the operator, line size, length (in feet), construction date, and type of service (oil, gas, etc.).

It seems reasonable to expect that this list would serve as the basis for identifying pipeline sources of oil spills, but both the Event file and the leaks list base their pipeline identification on either the nearest structure or on a written account of the spill. Thus, unit-specific analyses such as those made for the platform and tanker spill sources are not possible.

In both the platform and tanker cases, these unit-specific analyses served to validate the form of the incidence model. They were the basis for our objective technique. Since this data is not available, the pipeline model, like the blowout model, must be developed subjectively. For pipelines, we use the assumptions that mile-years is a suitable exposure parameter and that spill number is Poisson distributed.

Summing the length of all 6" and larger diameter pipelines whose service type was "0", we determined there were 248 segments in the Gulf of Mexico with an aggregate length of 1453.4 statute miles as of June 21, 1977. About 144 miles of 6" and larger pipelines were constructed following 1 January 1976. Our estimate of the total pipeline exposure for 1973-1975 is 3700 mile-years. In 1973-1975 there were 110 pipeline and pipeline-related spills. The three largest pipeline spills were 92,946 gallons, 210,000 gallons, and 832,986 gallons. The largest and smallest of these occurred in 1974, the other in 1973. Thirty-four of the remaining 107 spills were associated with gathering nets or fuel transfer and so do not apply to our problem.

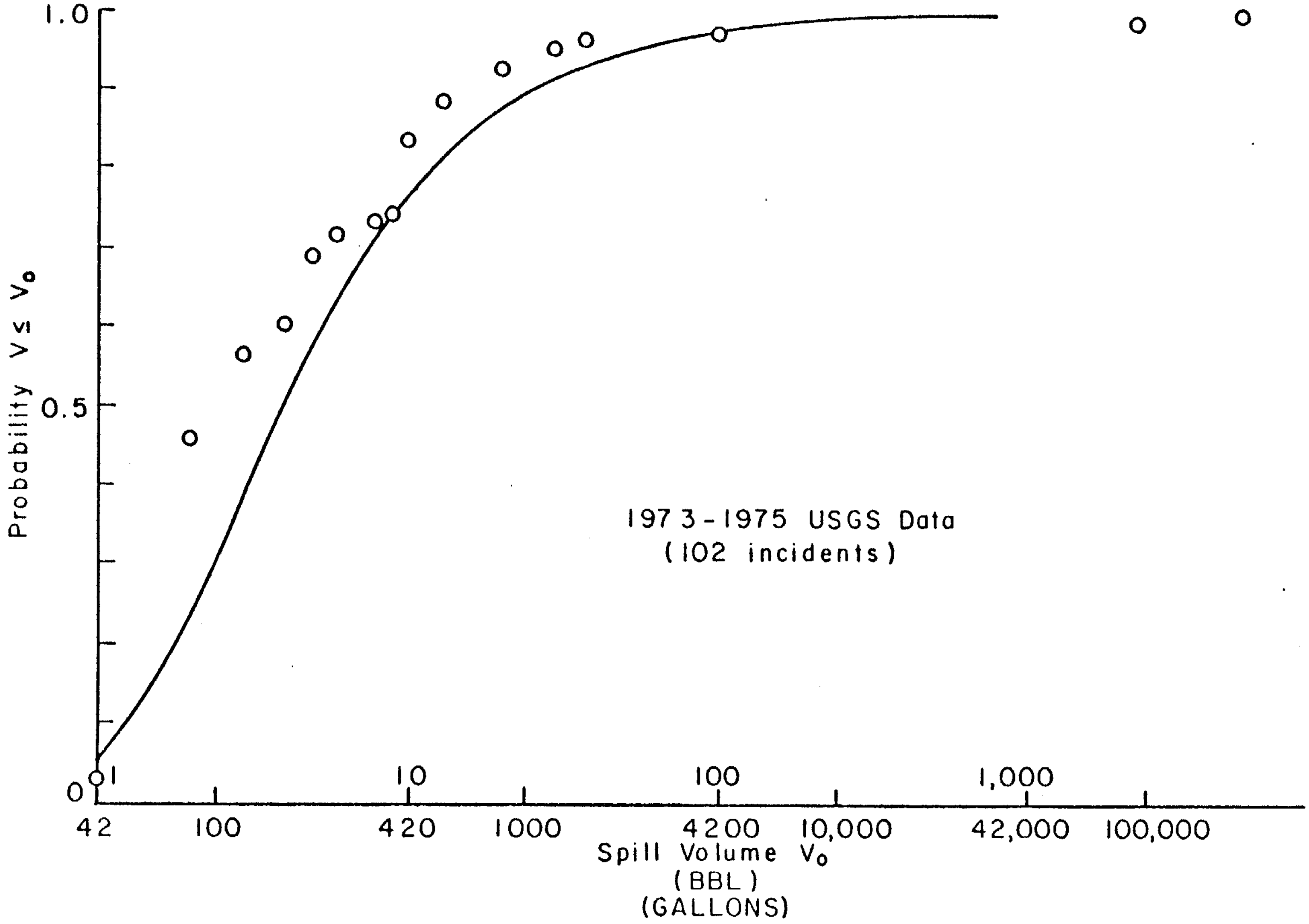
There was a decline in the annual number of pipeline spills from 1973 to 1975, which Danenberger attributes to improved "housekeeping" on the platforms. He foresees an eventual further reduction in pipeline spill numbers as a result of implementation of OCS Order No. 9, but this must await the obsolescence and abandonment of those pipelines constructed prior to OCS Order No. 9. Neglecting this possible improvement and the trend in 1973-1975, we estimate the historical spill record as 76 spill incidents in 3700 pipeline mile-years. These values, when supplemented with estimates for the anticipated number of pipeline mile-years provide the requisite input for the Bayesian spill number algorithm used in the assessment of a prospective OCS petroleum development.

Figure 8 shows the posterior cumulative spill volume distribution for pipeline spills. It is based on 102 incidents, which include gathering net spills. The curve departs from the cumulative histogram in the same way as that observed in Figure 6. This is almost certainly associated with the USGS practice of discarding those spill incidents under one barrel. There is also a rather peculiar series of bumps in the cumulative histogram. The steps preceding the bumps fall at 1, 4, and 8 barrels suggesting spills of this size are rounded up to 2, 5, and 10 barrels.

Comparing the pipeline cumulative histogram to the platform cumulative histogram for nonblowout spills, we can see that the upper tail is much stronger for pipelines than platforms. That is, we have seen many more large spills from pipelines recently than we have from platforms.

It might seem rather peculiar that large pipeline spills can still occur since monitors could obviously be constructed based on the equations of flow for oil in pipelines, which are reasonably well understood even when the oil is mixed with gas and water. However, the existing monitoring schemes are based on very crude high and low pressure shutoffs (pilots) that take no account of the existing load carried by the pipeline. Thus the low pressure pilots must be set for the minimum pipeline load condition while the high pressure must be set slightly above the maximum load. Should a leak occur under conditions of maximum load, the drop in pressure across the

FIGURE 8
POSTERIOR CUMULATIVE PIPELINE SPILL VOLUME DISTRIBUTION



cut in the pipeline is almost certain to be insufficient to activate the low pressure shut-off unless the opening is very sizeable.

Another way to say this is that in order to detect small leaks using pressure sensors, it is necessary to know the load conditions fully including both quantity and type of fluid being put into the pipeline. This in turn implies a requirement for some kind of continuous communication between all the platforms feeding into the pipeline and some central data processor that analyzes this data based on the equation of pipeline flow. This is not done at present. Consequently, pipeline spills are still usually detected by visual observation of a surface oil slick. To our knowledge, in fact, no pipeline spill has been discovered or prevented by the existing sensors. In frontier areas where visual observation of the pipeline route is sporadic, as opposed to the Gulf of Mexico where it is nearly continuous, this technological deficiency could be important.

Use of models

We have shown that spills from tankers and production platforms occur in a Poisson fashion. We assumed that pipeline spills also occurred in this fashion. The posterior distribution for Poisson-distributed variates, assuming a non-informative prior, is the negative binomial (c.f. Devanney and Stewart, 1974). By combining the known properties of this distribution function with the posterior distributions we have determined for spill volume, it is possible to determine a number of interesting descriptors of the spillage associated with hypothetical petroleum developments.

To illustrate some of the mathematical tools available to us, we will consider the problem of determining the cumulative distribution function of the largest spill that might occur in a hypothetical tanker transport system. The scenario for this example is as follows. Crude oil is to be shipped from A to B, a distance of 1,800 nautical miles. The crude arrives at Point A at a rate of 150,000 long tons daily. Due to draft limitation, the average tanker on this route is 123,000 DWT. This average tanker has an economical cruising speed of 15 knots. Allowing four days (22%) down time for periodic maintenance and hauling, two days to load, and two days to offload, the average round trip is 18 days. The system has an expected life of six years. Based on the route and throughput values, we can readily calculate that 22 tankers will be required to carry the crude. Combining this value with the expected life, the total lifetime exposure will be 132 tanker-years.

We wish to determine the probability that the largest spill that occurs over the six-year life of the transport system is less than V_o gallons. We will interpret this probability as follows. If the probability is .5 that the largest spill is less than V(.5), then we will expect (in the long run, for many such tanker systems) that about half the time the largest spill will be less than V(.5) gallons. We can't count on being so lucky in any particular realization, so we will also want to know how this volume varies for different probabilities, V(.9) for example being the expected value for the volume of the largest spill in 9 out of 10 developments.

If the probability that any one spill is less than V_o gallons is $P(V_o)$, then the probability that n spills will all be less than V_o is $[P(V_o)]^n$. When n is a random variable, the probability that the largest spill will be less than V_o gallons is given by summing over all the mutually exclusive, collectively exhaustive outcomes, or

$$P(V \leq V_o) = \sum_{n=0}^{\infty} P(n)[P(V_o)]^n .$$

In general, the spills will be generated by more than one random process. In this tanker problem, for example, hull rupture and non-hull-rupture spills occur independently and at different rates. Because the two processes are independent, the probability that both processes will have spills smaller than V_o gallons is

$$P(V_{max} \leq V_o) = \left\{ \sum_{n=0}^{\infty} P_1(n)\,[P_1(V_o)]^n \right\} \cdot \left\{ \sum_{n=0}^{\infty} P_2(n)\,[P_2(V_o)]^n \right\}$$

where index 1 corresponds to the hull rupture spills and 2 corresponds to all other tanker spills. The equation may be generalized to any number of independent spill sources.

It is readily seen that the summations in the brackets are simply the z transforms of the probability mass functions, $P_1(n)$ and $P_2(n)$, where z takes the value of $P_j(V_o)$. The z transform of the negative binomial is:

$$P^T_{jn}(z) = \frac{\left(z \dfrac{\tau_j}{t_j + \tau_j}\right)^{n_j}}{\left[1 - z \dfrac{t_j}{t_j + \tau_j}\right]^{n_j}} \qquad j = 1,2 \quad .$$

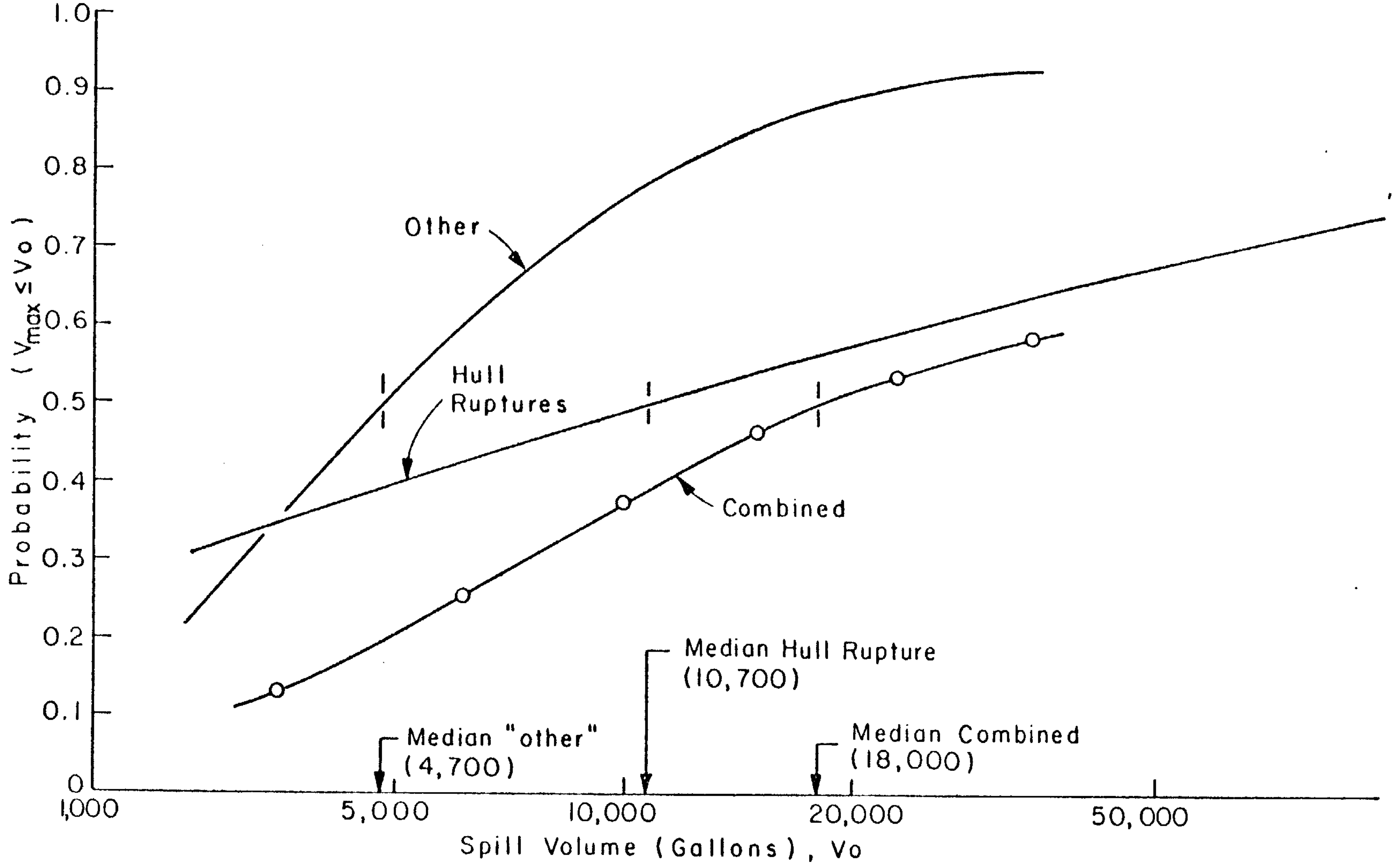
In our example, t is 132 tanker-years, and the volume of n and τ were seen to be:

	hull rupture, j=1	other, j=2
n	15	76
τ	235	235

Utilizing the z transform equation and the offsets of the cumulative posterior volume distribution of Appendix B, we have constructed the curves shown in Figure 9 for the hull system, other, and combined spill sources for this example. Note that the "other" category determines the behavior of the combined cumulative for small volumes. This is a consequence of the large number of spills to be expected in this category. Conversely, the large-volume behavior is dictated by the hull rupture category. For large volumes, the "other" category cumulative distribution becomes very much like unity, and the effect of raising this number even to a power of 40 or 50 is negligible compared to that of raising the hull rupture cumulative to a power of 7 or 3. In the example at hand, the median lifetime spill is 18,000 gallons when we consider both spill sources. Remarkably, the ninetieth percentile spill for the combined sources was found to be on the order of 2.8 million gallons. An exact estimate is not possible for such large volumes due to the accuracy that would be required for the offsets of the tail of the "other" cumulative. Our uncertainty in this case is perhaps ± .5 million gallons. We are, nevertheless, dealing with a rather large spill.

It is also possible to calculate average total spillage over the life of the development using estimates of the average number of spills and average volume of any particular spill. Since these formulas are well known, we

FIGURE 9
CUMULATIVE PROBABILITES FOR LARGEST SPILL IN THE HYPOTHETICAL TANKER TRANSPORT SCENARIO



will not discuss them. However, it should be noted that most of the posterior cumulative volume distributions based on the inverse-gamma had no mean.* That is, the behavior of the tail was such that the integral

$$\int_0^\infty v\, f(v)\, dv$$

failed to converge. The probability density function, f(v), was nevertheless well behaved.

If this is judged to be of critical importance, then a mean value can be calculated by truncating the distribution f(v) at some large but finite value like 100 million gallons. It is our preference, however, to avoid such ad hoc procedures. Since the total volume spilled is likely to be closely related to the largest spill observed, our calculations determining the cumulative distribution of the largest spill have good interpretive value for total spill volume estimates. Thus, we can assign a probability of about .5 that the total spill volume will be on the order of 18,000 gallons or less. Likewise, the probability is about .9 that the total spillage will be less than 2.8 million gallons.

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*The expectation is not defined for inverse gamma distributions with a shape factor(r) less than or equal to 2. The asymptotic (large volume) behavior of the following distributions is inverse gamma distributed(the platform blowout's distribution has as one of its components an inverse gamma distribution). The following shape factors hold.

Hull Ruptures	Platform Blowouts	Platform Other	Pipeline
1.37	1.29	2.87	2.01

Data collection recommendations

The information requirements for supervisory programs and for long-term spill assessments are not as dissimilar as one might at first think. Both require a knowledge of the normal spillage expectation (in terms of, say, number and volume distributions), and both require a knowledge of special conditions that may account for deviations from the pattern. The differences lie in the use made of this information. The supervisor wants to identify units that have either very good or very bad records. The assessment program manager needs to identify the central tendencies of contemporary technology in order to make extrapolations into the future.

Despite this similarity in information requirements, there is no guarantee that independent supervision and assessment programs will in fact generate reports and summaries that are compatible with each other's requirements. This is the present case. The principal reason for this situation is that field supervision by both the Geological Survey and the Coast Guard relies almost exclusively on the personal knowledge of local inspectors and MEP officers. In general, these people are long on experience, but rather short on the skills of abstract analysis required to distill their substantial experience into transferable information. The Coast Guard's MEP officers in Boston, for example, were aware that the *Argo Merchant* had an oil spill history that qualified her for additional attention, and an overflight had been scheduled for the morning she went aground. Likewise, the Geological Survey field inspectors in Metairie appeared highly knowledgeable of the special trouble spots in the offshore region. Neither group, however, had written quantitative summaries of their conclusions and expectations.

Presumably, the USCG PIRS and the USGS Event files are intended to remedy this difficulty. They fail to do so primarily because the data requested at present is incomplete. Much of this report, for example, has been devoted to the difficulties of bringing together the many and diverse additional data sources required to close the problem. Our experience in this attempt prompts the following recommendations for modification of the existing data-collection system. Our objective is mainly to simplify the assessment manager's task, although these measures may also aid supervisory personnel.

1. The data must emphasize the identity of the spill source and provide redundancy, so that no question can arise regarding who did what. This is particularly important since we have found for both tankers and offshore platforms that unit years is a reasonable exposure parameter. The PIRS system is particularly deficient in this regard, and immediate efforts should be made to include new data fields that could be used to validate the source identifier. For offshore platforms and pipelines in federal waters, the PIRS identifier should be based on the Geological Survey's pipeline and structure files, backed up with an operator name. A special system of identifiers must be created for state

waters. For ships, the inclusion of call sign, registration number, and country of registry would be desirable.

2. The PIRS operation and cause codes must be revised so that they provide an exhaustive but nonoverlapping set of alternatives. The usefulness of the USGS Event file would be increased if it also contained such a coding. The operation and cause code selections need not be the same for different kinds of source. Ships could have one set of operation and cause codes, offshore platforms another. The USGS should play a major role in defining the coding choices for the platform spill. Since the USCG gets most of its offshore platform spill notifications from the USGS, commonality of source identifier and operation and cause codes would materially assist in cross-referencing spill data bases.

3. The USGS Event file must be made more easily accessible and transferable. We had considerable difficulty getting the file in a form other than printed listings. In fact, rather than obtain a tape or card listing of the file, we ended up ordering a number of special runs through the Conservation Division, as this was easier and quicker. Our impression was that the file was a sort of hostage held by the private group maintaining it. This needlessly restricts access to the file, which reduces the amount of experimentation that can be performed. Both the Coast Guard and the Geological Survey have fallen into this data-management problem. Both have opted for very expensive data-management

and display systems which have tended to impose a rather formidable barrier between the raw numbers and the manager. This is unfortunate, because as we saw above for the PIRS data, the raw numbers need considerably greater scrutiny than they are now receiving.

4. Monthly or annual tabulations of unit specific spill histories should be instituted on a routine basis for both the event and PIRS files. This is computationally trivial, and such a tabulation would help identify both systematic errors within the data-collection system and unusual trends of importance to local supervisors. Such tabulations should also be classified along the lines we have found important above. Ship spill data would therefore be categorized on the basis of vessel age and flag, as well as number of U.S. port calls annually. Offshore production platform spill data should be categorized by age and volume of production. Pipeline spill data should be categorized by water depth and segment length. Since several of these parameters are not available within the present data format, some additional information will have to be collected for each spill event and incorporated into subsequent spill records.

5. Spills from major categories of spill sources (i.e. American-flag tankers, Exxon pipelines, etc.) should be examined annually for variations in either volume characteristics or frequency of incidence. The existing models and analytical techniques provided to the Offshore Risk

Assessment Group give a basis for such comparison. Attempts to use the PIRS and Event file data in this fashion will help provide feedback to the data-collection system. Time requirements for such analytical work are very small, especially in view of the overall data-collection and management costs. A few person-months a year should suffice.

6. MarAd's efforts to determine the use of U.S. waters and harbors by foreign and U.S.-flag tankers should be closely monitored, as this data will eventually be quite useful to the Offshore Risk Analysis Group. The problem is not entirely trivial, so great care should be exercised in reviewing MarAd's assumptions and techniques. If possible, unit-specific data should be obtained to compare with PIRS data. This will necessitate cross-referencing, which will require tables linking vessel name (the MarAd classifier) to call sign or registration number (the PIRS identifier).

7. The USGS Event file should be modified so as to include <u>all</u> reported spills and to include segment number identifiers for pipeline spills. The absence of small spill data needlessly complicates the analysis of the spill volume distribution and the absence of pipeline segment identifiers thwarts validation of pipeline incidence models.