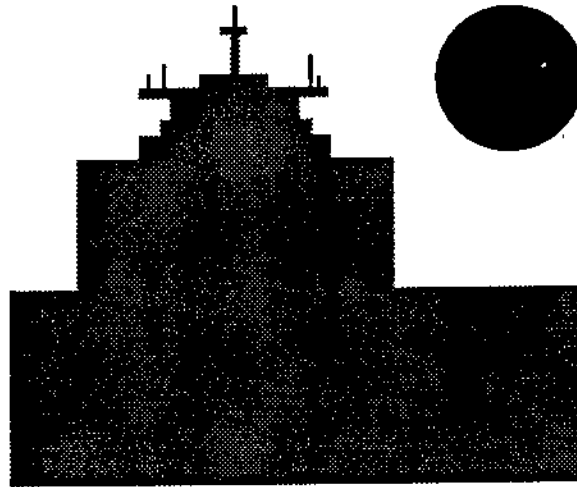


Marine Human and Organization Error: A Data Evaluation

SEA GRANT PROJECT R / OE 28

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October 1994

ABSTRACT

This paper details the strengths and weaknesses of available data and proposes specific expansions to aid studies of Human and Organizational Error (HOE) in the marine environment. Although this paper is closely targeted to the marine oil transportation industry and oil spills, it should be considered relevant to all marine activities involving hazardous materials. Applicability of data to the current research in loading and discharge operations (LDO) is noted; However absence of LDO information does not necessarily imply that the data is not useful for HOE in other operations. We have endeavored to find all possible sources of information though it is possible some have been overlooked. Missed sources are likely to be either of minor importance to oil spills, or are original sources which have been combined into higher level summary reports.

Acknowledgement

This paper is funded by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA36RG0537, project number R/OE-28 through the California Sea Grant College. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its agencies. The U.S. Government is authorized to reproduce and distribute for governmental purposes.

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INTRODUCTION

The marine transportation industry has developed a growing interest in the role of human and organizational error in marine transportation accidents. Many organizations have undertaken measures to reduce the incidence of such error. These measures may be credited in part with the oil & petroleum transportation industry's recent reduction in the rate and quantity of oil spills. Although progress has been made in this and other industries, questions still remain: How much human and organizational error has been eliminated? How much human error remains and what spill potential does this present? How vulnerable is the industry to such incidents? It may also be asked if our model of human error is correct or requires further refinement.

These questions need to be answered. A greater body of knowledge on HOE in the marine environment is important for risk reduction, safe operation and the development of appropriate rules and regulations. This paper pursues the question of how data sources might further advance knowledge of HOE.

What is Human and Organizational Error?

Human and Organizational Error may occur in many ways. Simply put it is "any human activity, or absence of necessary activity, resulting in an oil spill." (Hermanson, 1994) Human error has also been considered "actions and inactions that result in lower than acceptable quality" (Ship Structure Committee, 1994) The essential characteristic of HOE is error is not limited to individuals performing a task improperly. HOE includes broader errors created in complex systems, even

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when people perform their jobs properly.

HOE can be observed in many forms. People may fall asleep, make poor judgements or simply be careless. Such error is truly human error. Organizations may issue conflicting instructions, exert pressure, communicate poorly, assign personnel improperly or react inappropriately to a stimulus. Such system based error is considered organizational. Error may also occur between individuals and equipment, such as ergonomic misfits or easily misread gauges, potentially feeding erroneous information into the organizational system. This error may be considered ergonomic (and perhaps human and organizational). These are only some of the possible errors that have been identified. In short form, Human and Organizational Error can be found in all aspects of marine transport: Errors may enter into specification, design, construction, and operation.

How Does HOE Contribute to Marine Accidents?

Accidents may be viewed as events with many causes. In the case of an oil spill, it is rare that a single cause results in an oil spill. Chains of events are more characteristic, with errors compounding until a spill event occurs. An example LDO error combination could combine the following two contributing causes, leading to an equipment failure as an initiating event, and the absence of a mitigating factor: (1) faulty gasket not checked, (2) pressure is brought up too quickly, (3) a failed gasket results, (4) scuppers have been left open. The spill result is oil leaking from the transfer line, and flowing through the scuppers into a containment boom. In this case the actual spill event (the initiating event) is the gasket failure; however a

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check of the gasket might have revealed the fault or a slow build up of pressure could have revealed the leak at low pressure. Plugged scuppers would have contained the spill to the deck, instead they are open and may be considered a compounding factor. Were the vessel not boomed off (a mitigating factor), the effect and cost of the spill could be greater.

Thus spills are the product of errors. In the above example, absence of contributing causes 1 or 2 would not have resulted in a spill, and presence of the mitigating factor 3 would have limited this event to a deck spill. A conventional, engineering-oriented investigation would reveal the faulty gasket and list it as the spill cause. This is incorrect: the faulty gasket is only a contributing cause. The three preceding events could have HOE roots. The scuppers may have been open for one or more of the following reasons: the operator forgot to plug them (human); because cold impaired his judgement (environment); a deck box was placed to block the operator's view of the single open scupper (system); the scupper plugs had been lost and the request for replacements delayed (organization); the operator was rushed to commence the operation (organization); one of two operators is supposed to plug the scuppers, but they did not check with each other to see if the plugs had actually been placed. These are only hypothetical cases, but they demonstrate the range and complexity of errors that may ultimately be classified as "human error". To study HOE in producing oil spills, it is necessary to go beyond examining initiating events and examine the chain of preceding and following events.

Increased vigilance and awareness of oil transportation safety may reduce error from each of the four source areas (environment, procedures, organization,

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system). Such vigilance, however, is most likely to reduce individual human error by increased attention to procedures and placing more responsibility upon individuals. Phrased differently, vigilance will reduce mistakes. Vigilance however cannot address Organizational error, error produced by systemic interactions between operational or organizational components. Organizational error is more difficult to detect, its role as a background curtain upon which operations occur is not immediately apparent. Organizational error is also more complex than individual sources of error, making it harder to correct if found. System errors may be foreseeable, but may be equally difficult to change. Thus there is reason to suspect that only the easiest and most obvious changes have been made, that the industry has "sucked in its gut" and tightened up operational procedures. This is not an accusation, only a reflection of the difficulty identifying and correcting system and organizational problems. Analysis of HOE data may identify previously unidentified problems in human, organizational, and system areas.

How to Study HOE

There are several ways one could study human and organizational error in a marine environment. Trained observations, professional opinion, and data analysis are options considered. Although each has its strengths, it is concluded that data analysis will generate the most widely useful information.

Observation of operations could identify potential or existing problems. Such an approach is very limited. Operations generate few incidents, occur in a great variety of geographic, temporal and climatic conditions, requiring an impractical

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number of observation hours to cover the scope of operations and conditions. If observation were conducted in depth at one location, a lot could be learned about that particular operation's strengths and weaknesses. Unfortunately application of this site specific information may not be generalizable to other operations and sites.

Professional opinion is very valuable, particularly for initial identification of error potential and probability; however, opinion may not span the entire variety of operations and it cannot produce accurate estimates of error probability. It is also possible that professional opinion will entirely miss critical operational factors that have yet to produce a significant spill (that have not been a salient contributing factor).

Data analysis of oil spills and other accidents presents a third method to determine the role of human and organizational error. This approach is of course only as good as the available data, but it has the advantage of covering wide ranges of activities under diverse environmental and geographic conditions.

Unfortunately, information on human and organizational error in marine accidents and spills is scant. Several federal and state government agencies maintain databases, but human error information is either questionable in its detail and accuracy or is simply not included in the database. Industry sources are not much better. This is not a general critique of these databases, only a recognition that many were not designed to serve this purpose.

Modification of the collection and storage of information in some of these databases would yield improved information on HOE and, in turn, improved prevention. Paradoxically the great improvements recently made by the oil

transportation industry also pose a problem. Simply put, by reducing the number of spills there are fewer data points available to examine. However, this does not mean there is no error left to study. It is possible that many contributing factors are still occurring, only with less probability. Thus the probability of, say, three factors occurring simultaneously is reduced. Fewer spills may indicate reduced error input, not an system that is less prone to errors or accidents. This is particularly true for LDO as an LDO spill is likely too small to be included in some data sources.

CURRENTLY AVAILABLE DATA

Data may be divided into three categories: Federal, State and Industry. The Federal agencies considered here are the Department of the Interior's Minerals Management Service (MMS), the Environmental Protection Agency (EPA), and the United States Coast Guard (USCG) and National Transportation Safety Board (NTSB). Information from California, Oregon and Washington state agencies are considered¹. Industry sources are primarily an assortment of publications, both newsletters and annual publications. Industry sources are the most international of all sources considered. A brief description of each data source follows. The potential use in HOE, particularly LDO, is also considered.

Industry Sources

Golob's *Oil Pollution Bulletin* (OPB) and the Cutter Information Corporation's *Oil Spill Intelligence Report* (OSIR) are regularly published industry newsletters. The scope of these publications is global, the purpose is dissemination of information relevant to the oil shipping industry. Rule changes, spill histories, lawsuits, technology advances and more are reported. The publishers claim to have excellent sources within the oil transportation community. Although spills are reported, neither report places primary focus on cause. Cause may be reported, if known, but it is not investigated. A further weakness from the perspective of this study is the reports are typically limited to spills greater than 10,000 gallons (250bbl).

¹ Other states of the U.S. and Canada may also collect information. Time and resource constraints have prevented a poll of all possible states for information on marine oil spill databases. Interviews with a number of industry and state agency personnel indicated that the state agencies and databases considered here are a representation of the best implementations in this area.

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Loading and discharge operations are unlikely to generate a spill of this size.

Both publishers also make a database available. The database contains limited spill information (date, size of spill, product spilled, vessel and owner, location, and cleanup information). *Oil Spill Intelligence Report* has recently added cause information to the database. Unfortunately cause information is limited to events, not contributing causes (eg. "grounded vessel" is the event that spills oil, but a communication and navigation error causes the grounding). *OSIR's* database has approximately 3250 records.

Though these databases are of little use in an HOE study, the qualitative reports could be coded for information. As these reports are not as detailed as NTSB reports, the quality and utility of such coding is not predictable.

The *Marine Regulatory Bulletin* (MRB) is another industry newsletter. Instead of an international scope, this publication focuses only on Pacific Coast (U.S. and Canada) activity. The primary focus is the reporting of proposals and changes to regulations of interest to the marine industry. Oil spills greater than 250 gallons (?) may be reported, but the cause is again not investigated. If *OPB* and *OSIR* reports are coded, *MRB* should be included².

Another publication serving needs of the marine industry is the *Guide to the Selection of Tankers*. This annual publication ranks all tankers greater than 10,000 metric tons displacement. Each tanker and fleet is given a rating based upon the

² There are also other industry publications targeted to hazardous materials transport (the *Hazardous Materials Intelligence Report*) and other segments of marine transport. These sources have not been evaluated at this time. They may be useful in the future.

accident history of the vessel. The accidents evaluated include oil spills, mechanical damage requiring repair, casualties and other marine incidents³. Though some spill information is provided, the publication is designed as a prevention tool and not an analytical tool. Information provided by Lloyd's and the Salvage Service demonstrate that tankers with a lower rating in this guide are more likely to experience an oil spill. Spill information is obtained from a variety of sources included in this report.

The *Guide* provides a wealth of historical information on large tankers, but it provides no information on barges. Barges are often considered to pose a risk at least as great as tankers for oil spills, particularly in LDO. This and the highly limited spill information does not allow use of the *Guide* as a primary source. The *Guide's* ranking and listing of accidents could be very useful as an additional source of information.

The International Maritime Organization (IMO) has considered or developed several models for the collection of human error⁴. A document was produced in 1993 titled "Role of the Human Element in Maritime Casualties." Although titled a human error study, the IMO report only considers "accidents where fatigue was a contributing factor." Fatigue is certainly a contributing factor of human error, but there are many, many others.

³This information is collected from a variety of sources, public and private. There appears to be no *a priori* size or damage reporting minimum, so the *Guide* may contain information on LDO events.

⁴ Requests for information have been submitted to the IMO. This section on the IMO should be considered incomplete and somewhat speculative at this time.

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An advantage of IMO's tight focus on fatigue is an excellent list to guide an incident investigator. This list appears comprehensive and should produce data that is more accurate and consistent than most sources. Unfortunately the IMO is only an advisory organization with no provisions for conducting its own investigations. Thus there is no actual data associated with these recommendations.

The classification society Det Norske Veritas (DNV) has a program, the Safety and Environmental Protection program, which may yield data. An element of this classification is a requirement that all accidents and near misses be reported to and investigated by the vessel owner. The actual reporting mechanism is left to the discretion of the owner. Though this program may produce excellent information, it may be very difficult to use as data. The information is not reported to a single organization and each owner may conduct the investigations differently, thus collection and assembly of the data into a uniform structure may be costly and ineffective. DNV also produces the well known *World Offshore Accident Databank*. This databank is limited to offshore structures (primarily oil platforms) and seems to contain no human error information.

Many of the large oil shippers and refiners have internal data collection. Spill size and date should be replicated in USCG records, but companies may also conduct an in-depth internal investigation. Near misses may also be investigated by shippers and refiners. Corporate investigations may contain a wealth of information, but as in the DNV SEP case, each company probably conducts investigations differently. In both cases, companies may be reluctant to release information for legal or public affairs reasons. Collection of company data, if

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available, will require large quantities of labor and time.

State Sources

The State of California has two agencies to consider: The California State Lands Commission Marine Facilities Inspection Division and the Department of Fish and Game's Division of Oil Spill Prevention and Response. Both divisions are young organizations, still creating systems and procedures.

The Marine Facilities Inspection Division (MFID) inspects terminals and observes LDOs. MFID collects information on spills of all sizes, from tablespoons to thousands of gallons, occurring in California waters. A new database and collection scheme are under development at this time. As this system is not yet operational, the old data will be considered first. Location, time, product, quantity, source, vessel and terminal are entered into the existing system, though accuracy is questionable (impossibly large spills are documented). A narrative field describes causes of the spill. MFID performs spill investigations and also enters information reported by a variety of agencies and the responsible parties (information accuracy is expected to be higher when MFID performs an investigation). MFID contains spills of all sizes so it does not censor the smaller spills typically generated by LDO. Unfortunately it reports only a single cause. Further, there are no choice lists, no description of activity at spill occurrence, and no information on human factors (other than listing "human error" as a cause) is included. There are approximately 6800 records covering spills from 1988 to the present (Jan 94). The lack of consistent and comprehensive cause and contributing factor information greatly limits the use of MFID historical spill data.

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The new database and collection scheme addresses HOE more comprehensively. In addition to information collected in the old system, events at time of spill are determined. Personnel, mechanical, and organizational causes are presented in choice lists. Causes are further indicated as primary, secondary and tertiary. The 7 types of personnel and 3 types of organizational error are not exhaustive (see section on MSIS) but they capture the basic identity of the error. With improved general accuracy this system may be a very valuable source of HOE data.

MFID also collects information oriented not to spills but to compliance with LDO procedures. MFID regularly visits all terminals during LDO operations. During this visit the inspector completes a checklist detailing compliance with legally mandated procedures. The checklists could be interpreted as the presence or absence of human error (as compliance with established procedures). Taken alone this data is not useful for HOE studies; Combined with terminal spill data it could be very important.

Oil Spill Prevention and Response (OSPR) division of the California Department of Fish & Game does not seem to collect spill and cause information at this time. The division is believed to be developing a database to capture this information.

The Washington State Office of Marine Safety (OMS) recently began collecting a broad range of information on commercial marine activity, including spills. OMS's purpose is the reduction of human and organizational error, making OMS information particularly valuable. Vessel boarding checklists are designed to assess

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the potential for human and organizational error first, and compliance with equipment regulations second. In the case of oil tankers, the boarding officer verifies vessel compliance with company spill prevention policies (submitted directly to OMS). The database constructed to hold this information is very modern in its capabilities and very comprehensive in its scope, containing human factor information, vessel and crew histories and even near misses (the importance of which is explained in Appendix A). Accuracy is expected to be fairly high as OMS uses its own personnel to collect information (by culling industry reports, boarding vessels) while integrating information from the USCG's MSIS.

OMS may conceptually be divided into three segments. The first, and smallest, segment contains violation or incident information investigated by OMS. The second section contains boarding summaries of vessels. International historical information is also entered for all vessels entering Washington waters. Together these three segments feed information into a risk matrix that returns a risk rating for each vessel (in comparison with the *Guide*, OMS bases this rating on more information). Each of these segments must be considered individually for data potential.

Presently an evaluation of incidents in Washington is unlikely to contain enough cases to conduct an analysis. As time passes and more cases are investigated this limitation will erode. On the other hand, OMS incident investigations are likely to contain high quality, accurate human and organizational information on the involved vessels.

By year's end more than 500 vessels will have been boarded. This is

absolutely invaluable data for conducting a human and organizational error analysis. As OMS has background information on incidents (including spills), comparison of boarding ratings and vessel histories would more closely reveal the links between many sources of human and organizational error and incidents. Unfortunately, OMS has not begun to board oil tankers so there will be no data for perhaps a year.

The historical incidents are of interest. These incidents are carefully entered into the database. Indeed, an incident is not officially logged in the system unless all information (date, location, specific violations) is available. Information that cannot be officially logged is entered into a comments field. Because this information has been entered by a single person (a licensed mariner), it should be highly consistent. Unfortunately, most incident information comes from sparse sources that do not provide enough information to accurately code the role of human or organizational error.

Although both the historical and Washington incident reports allow for extensive entry of human and organizational factors, there is no taxonomy to place these errors into. Users of the system may add and delete error categories from the choice list as appropriate. Further, one factor may be flagged as the initiating event while all others are listed only as contributing factors.

The mentioned limitations do not pose serious difficulty for the analysis of HOE, they simply must be considered in the analysis. As will be seen, OMS offers some of the best analysis potential of all sources considered here. One of the greatest strengths of OMS data is the very small size of and high levels of training in the

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organization. All historical incident reports are entered by one person. Presently there are only 3 vessel inspectors, all highly experienced commercial mariners. These characteristics greatly limit the idiosyncrasy of the data, maintaining high standards in all areas of the database. Furthermore the system may be modified to better collect this information.

Washington State's Department of Ecology also records oil spills. This system appears to contain only limited information on spills, recording only date, location, violator, medium, material, source, quantity and "cause." Causes are not elaborated upon, only identified as an event (e.g. equipment failure, operator error) with no elaboration.

The State of Oregon's Department of Environmental Quality (DEQ) compiles information from MSIS. The agency developed plans to collect HOE improved HOE information, unfortunately these plans have not been accepted at this time. Present DEQ databases are duplicates of the

Federal Sources

The Minerals Management Service (MMS) of the Department of the Interior periodically compiles spill information. The most recent report contained 1100 spills since 1974. Information is collected on all tanker and barge spills of greater than 1,000 barrels (42,000 gallons) throughout the world. Adequate information is given to location, size, and vessel identification. MMS also includes other data relevant to understanding and predicting oil spills: year vessel built, vessel size, load size prior to spill, role of heavy weather, and a sequence of casualties leading to

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the spill. Environmental damage assessments are also included.

The great weakness of MMS is the limitation to spills of 1,000 barrels or greater. Human error is likely a factor in spills of this size, though probably no more than in smaller spills. This arbitrary boundary limits the size of the database, and it may also censor causes which tend to result only in small spills. The cause sequence is valuable, but is again limited more to events (e.g. EXPLOSION - FIRE - FOUNDER - SPILL) than the cause of each event leading to a spill. Finally, MMS is collected from many sources including USCG sources and various industry publications (including those evaluated here). Information and accuracy likely suffer in duplication.

The Environmental Protection Agency has limited data collection capability in its PIES system. Data is reported to the EPA as soon as any spill occurs, thus the data will indicate the frequency of spills. Information is typically reported by the responsible organization and contains little more than estimated spill size, location, product and source. Follow-up or investigative information is not collected or entered into the system. This system is almost totally useless for human and organizational error research.

The United States Coast Guard operates the Marine Safety Information System (MSIS). The largest and most complex of the databases considered here, MSIS contains well over 200,000 records on oil spills. Information is collected by the many Marine Safety Offices throughout the United States in completion of its oversight, regulation, inspection and investigation duties. The amount of information collected is truly formidable. MSIS contains qualitative and

quantitative data on the spill, including vessel and terminal histories, historical inspection information (including records of infractions or violations), training information, operation at time of spill, operator information (age, education, time on shift, hours of sleep), responsible party information (may be corporate), initiating cause of spill and contributing factors (including human and organizational error). Any spill creating a sheen on the water is reported (although 1 gallon is the minimum data entry size), regardless of its origin. It is also possible to link spill information from a particular vessel to recorded infractions by that vessel.

MSIS also has an extensive human factor recording capability. An extensive (though not exhaustive) choice of human factors are allowed as causes and contributing factors (as detailed in the CFRs). The system also classifies vessel operation at time of spill, including some of the stages of a loading, discharge, bunkering or lightering.

Although it would seem that the size, geographic scope and depth of detail make MSIS the ideal database, there are many problems to be considered. These problems are access, orientation, consistency, accuracy.

Access to MSIS is difficult, primarily because the legal nature of many Coast Guard investigations is not compatible with public access. Direct, terminal access to the system is difficult to gain. Reports and data files can only be constructed at headquarters and may require filing under the Freedom of Information Act. The complexity and scope of MSIS make it difficult to assemble an information request. Terminal access to MSIS could alleviate this difficulty.

MSIS also poses problems for the entry of spill data, not just retrieval. The

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system is divided into many different modules. Each module is devoted to an MSO activity area (Pollution, Investigation, Inspection, etc) and information does not automatically map across all modules (e.g. an event description may need to be entered once in each of two modules). System fragmentation makes spill entry very time consuming, as much as two hours or more of computer time to enter a basic case. This is expected to reduce the entry of information that may be considered spurious to the Coast Guard's investigation.

MSO pollution investigations are oriented towards identifying the source of the spill. In this case, "source" is not the root cause of the spill but an identification of the physical source of the spill, and thus the responsible party. Busy and short staffed MSO offices thus cannot engage in the luxury of pursuing causal investigations once a spill is linked to its physical source. Thus even for spills in which human error is clearly a major contributing factor, human factor information may not be collected, analyzed or entered. If human error is the cause (the initiating event) this information will be investigated and recorded.

The accuracy of MSIS is expected to be as good as any information reported. That is, identifying data on spill size, location, material, date, vessel, etc will be very accurate (as is necessary for the prosecution of pollution and violation cases). However cause information, particularly human factors (if reported), has little or no consistency. This lack may be traced to several factors. First, investigators are not trained in human factors. Second, the military billet and career structure hinders development of investigators into highly experienced "experts." Third, a lack of definitions and a clear taxonomy further compounds the problem, reducing

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determination of the causal factor code to a near random process. Each individual may report an incident differently, choosing or neglecting to complete "supplementary" information as human factors. The idiosyncratic nature of the information is increased by turnover of personnel, the large number of personnel involved and the geographic diversity of the Coast Guard offices.

A further limitation of MSIS are the huge number of "source unknown" sheens that are entered. Many entries address sheens or spills generated by from sources ranging from the recreational boater, storm drains, and underground pipelines to natural seepage, commercial vessels and shore facility fires. This will greatly deflate the number of cases relevant to commercial HOE. A review of one MSO's current cases (totalling perhaps 450 cases for an eight month period) found approximately 20 cases relevant to commercial shipping and even fewer cases related to oil carriers and terminals.

The above limitations of MSIS lead us to the unfortunate conclusion that despite its many attributes the HOE data is neither consistent nor reliable enough to use as a sample. Other information contained in MSIS, as violation information, could be very useful if combined with other sources of HOE data.

The USCG does maintain a publicly available database, the Port Safety Information Exchange (PSIX). PSIX allows access to some public information contained in MSIS. Coast Guard transactions, inspections and equipment violations are listed. Because pollution and accident case information is not public, PSIX contains no information on spills, accidents or other casualties.

The National Transportation Safety Board of the Department of

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Transportation examines marine accidents. The NTSB does not maintain a database, but produces highly detailed analytical reports. An attractive feature of NTSB reports is the common use of human factors specialists (who may also work on airplane, train or highway accident reports). These specialists consider and analyze human and organizational error, placing NTSB reports at the top of available human and organizational error data sources. Though qualitative, these reports could be coded to produce highly consistent data.

NTSB reports do however present some drawbacks. The NTSB investigates accidents involving the loss of 5 lives or more, vessels over 100 gross tons, accidents of a recurring nature, or accidents involving Coast Guard vessels. Discretion is used, so not all accidents fitting the above conditions are investigated. There are not a sufficient number of reports done (or there are not enough accidents fitting the NTSB investigation criteria) to generate a sample for study: From 1985 to present there are 62 reports available, 25 of which pertain to tank vessels, tank barges, chemical carriers or offshore oil drilling and pumping equipment. There appears to be but one report during these years directly related to loading and discharge operations.

Summary Evaluation

None of the current sources of data contains the full range of HOE information necessary for a comprehensive study. The data sources can provide excellent information on the frequency, size and location of spills. Only MFID, OMS, NTSB reports and the USCG's MSIS are designed to capture HOE information.

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However, MFID has not activated the new system and OMS is still developing collection procedures. It may be some time before either system contains enough data to permit analysis. NTSB reports are highly detailed, but they detail only actual accidents not near misses. NTSB reports are further limited by lack of established HOE similarity between large and small accidents; there may be distinct differences in type and number of causes in large and small accidents. The potential lack of similarity is important for LDO analysis. MSIS contains fields for recording HOE though department priorities, a difficult computer system and lack of training in HOE inhibit collection and recording of HOE.

Computer systems can generally be characterized as deficient in accuracy, taxonomies and completion of information. Accuracy is questionable, if only because many systems rely upon initial report information only. This initial information may be erroneous or inaccurate, and is often not corrected or checked by an investigation. The systems have unclear taxonomies (particularly for human factors), allowing contradictory or incompatible information to be entered. Finally, completion of some information (specifically human contributing factors) is not required to enter a case.

It is possible that MFID or OMS will overcome these inherent problems. If so, they will be a valuable source of data in future years.

Beyond these factors associated with computer based systems, there is a greater weakness with all information sources: a spill must actually occur to notice

the event. "Near spills"⁵ are not included (excepting information required under DNV's SEP, OMS and possibly related information collected by MFID facility inspections). Other highly safety sensitive industries, particularly the nuclear power industry and most classes of aviation, are required to report and investigate near misses. The importance of near spill information is discussed in Appendix A.

The lack of near spill information in these data bases is not a fault of the responsible agencies. Rather, it reflects that maritime and oil industries are not required to report near misses and spills. It is also a reflection of the absence of an accepted definition of a near miss/spill in the marine environment (see appendix). Both reasons may be attributed to a historical orientation towards response and citation, not prevention.

All of these systems are also artifacts of the legal, commercial, social and engineering histories of marine transport. These histories have led us to focus on the ship as an entity unto itself: crew belong to a ship, a ship spills oil, ships represent large amounts of capital and earnings potential. When we speak of a ship we may mean not only the vessel, but also its complement and cargo. Of course a ship and its name are enduring while the crew are temporary. A ship's age is considered a more important risk factor than the current crew levels or crew training. Crew are considered interchangeable, though some are better than others.

The problem of this conception is that information is collected only on

⁵ "Near spill" as used here includes navigational or other "near misses" of maritime accidents (e.g. grounding, collision) that have the potential to produce a spill, and narrowly avoided spills (e.g. a contained deck spill).

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vessels and facilities, while the personnel are ignored for the most part⁶. In none of these systems (excepting OMS) can information on relevant individuals be entered or recalled. HOE evaluation would be more effective if information on crew composition, experience, violations and incidents were recorded. Although identification of known offenders may be very interesting for prevention, it also serves a role in understanding how crew characteristics, in addition to ship and company characteristics, explain HOE.

Also conspicuously absent from an HOE perspective is information on the relevant organization. Company procedures and policies are not found in any of the systems⁷. Again this is not a criticism of any of the systems, only a limitation that must be understood in advance of analysis. Organizational features are difficult to categorize in meaningful ways, change frequently and may have little relation to actual operations.

⁶ This is not necessarily the case when legal action is taken: Captain Hazelwood was tried in court for his purported negligence leading to the Exxon Valdez spill.

⁷ MFID requires procedure manuals from all terminals. OMS requires spill prevention and management plans from all tanker operators. In both cases this information is kept in paper form and not entered into a computer system.

UTILITY OF CURRENT DATA

How could the current information be used to examine human error in oil loading and discharge operations? The discussed available databases could have limited use. It may be possible to analyze the data as is, accepting the discussed limitations, or by combining data sets to generate proxies for HOE risk.

Proxies for human error present four basic analyses. The assumption could be made that training levels are negatively related to human error and thus spills. Examination of vessel flag or classification society requirements could yield differences in training standards that might be related to spill frequency. Another possibility is a comparison of the frequency of cargo transfers (indicative of familiarity and competence) with the number of spills per transfer⁸. Weather records could be correlated with spill data to find possible links between time of day, temperature, rainfall, etc. A final option is identifying procedures that are organizationally or technically complex, and perhaps more prone to human and organizational error. The number of spills occurring during such procedures could be examined.

The problem with each of these make shift approaches is the lack of new information provided. It is already established that human error plays a large role in oil spills, transforming the questions from "Does it play a role?" to "What role does human error play?" These methods may also be considered as demonstrating correlations, not causation. An analysis of training requirements and topics may

⁸ Such an analysis would require assembly of transfer frequency and size information as it is not included in any of the databases addressed here. Company and port arrival records contain this information.

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reveal a negative correlation between training and spills, but it is too coarse a measurement to indicate the topics that are effective at preventing spills or the topics that are ineffective as prevention. A training analysis also does not address the individual level of training a causal individual may have. A transfer frequency analysis limits itself to simple correlational results because it cannot control for causes, complexity of equipment, and perhaps not the size of transfer. Weather analysis does not describe the mechanism nor is it likely to go beyond common knowledge of human performance in adverse conditions. An examination of high risk procedures is probably the best of these options though it faces two problems. First, it is not clear that there is sufficient data available on the activity at time of spill to conduct such an analysis. Second, there would be no indication as to which part of the activity presents the highest risk of human error.

Limited analysis may be more useful than use of proxies. NTSB reports may be limited to high cost accidents and rarely involve spills but they contain a wealth of information. Coding these reports could reveal consistent similarities in causal factors. LDO or other operations could then be examined (by observation for instance) for evidence of these factors. MSIS data could be analyzed with the caution that results are statistically meaningless, although there may be emergent patterns to investigate in the field. Of these approaches, the NTSB coding is more reliable and more likely to produce relevant results.

SOLUTIONS

One must ask if the currently available data could not be fixed, or if existing systems could be amended or improved to provide better information in the future. Failure of these options suggests the need to develop a new system.

Retroactively fixing data is improbable. The primary deficiency in existing databases is a lack of human factor information, information that would be nearly impossible to accurately and consistently investigate months to years after an event. Advancing knowledge of HOE in marine operations additionally requires precise identification of the procedure and the error. Intensive interviews could reconstruct some of this information at great cost. Accuracy, particularly for small spills with low saliency, will be low. Near spills would also be completely missed as there are no records of such events to reconstruct.

Database modification could improve the ability of systems to record information; however the problems of collection (primarily trained investigators) are not overcome by the addition of fields to a database. MSIS is an example of this problem.

A third possibility is the development of a new database. This database could be wholly independent of the sources considered here, independent with ties to information in other databases, or an integral part of another database. However, the same collection problems facing a modified database will confront a new database. The ultimate placement of a new database will require an analysis of collection methods for the proposed human error information. Links with existing databases may ease the burden of collecting background information (company and

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crew information for instance).

It is much easier to state what HOE information should be included in a modified or new database. Don Hermanson of the Marine Facilities Inspection and Management Division, California State Lands Commission has suggested an improved oil spill database as part of his *Marine Oil Pollution Prevention Strategies*. In addition to information concerning the time and date, location, product and quantity of a spill he suggests the following minimal information be collected:

Process at time of spill	Injuries incurred
Equipment involved	A Specific and complete narrative of the spill cause
Employees involved and-experience	Contributing factors
-training	An assessment of spill costs (lost product, overtime, injuries, cleanup, repairs, liability, etc).
-tenure	
-time on duty	
-physical condition	
Environmental conditions (including physical and work environment)	

The availability of this information would greatly enhance human error analysis. We would go further and suggest the following general additions: Number of people present at event, stop and mitigating factors limiting the spills and near spills, potential spill size if the stop or mitigating factor fails (see Appendix B), and description of human error. It is also preferable to not just name contributing factors, but also to determine the conditions under which each contributing factor occurred (as an error leading directly to a spill).

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Difficulties Implementing a New Marine HOE Database

Recording HOE in a computer database is a simple task many inexpensive computers and programs are capable of today. The computer difficulty is found in maintaining an HOE system with other databases (witness the USCG's MSIS) and devising an easy entry system (again, witness MSIS). Merging HOE information with regulatory and legal information may pose collection problems, though there are no technical reasons rendering this impossible.

The greatest difficulty is collecting the information. The marine industry poses several challenges to collection. It is a diffuse industry with many countries, organizations and locations, without a strong unifying organization. It is a diverse industry, transporting many goods through a wide, and extreme, variety of conditions using a multitude of vessel and terminal designs mated with a multitude of personnel, utilizing a multitude of vessels (tugs, barges, tankers). It is also an industry that has, with diminishing success, maintained relative freedom from regulation. These factors alone make it difficult to collect meaningful information.

Accuracy in HOE reporting requires the assistance of companies and individuals. This assistance may be difficult to obtain in the United States' legal environment, particularly if HOE investigation is conducted simultaneously with legal or regulatory investigations. At the same time, the investigators must be associated with an organization powerful enough to command assistance and cooperation of a company.

If individual crew level information is to be collected an entire new approach

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to identification will be required. The present norm is to classify incidents by the legally definable entities of company, ship or terminal. There is no precedent for recording the identification of crew so an approach will need to be developed.

Resistance to such an effort is likely to be very high.

Further collection complications arise when trying to classify HOE information. HOE is not necessarily easy to determine in simple systems, in the complex system just described determination will almost always be difficult. The NTSB requires 9 months⁹ to research and write its reports. Development of a clear and easy to use taxonomy (discussed below) will simplify this process.

Difficulties in Design of a New Marine HOE Database

Marine transportation is also an industry with a wide range of technologies, matching computer controls with essentially primitive machinery and a wide range of operations (e.g. petroleum transport presents different operational procedures for different cargoes). This range creates special considerations for recording accurate information of each operation in marine transportation. For example, an accompanying paper (Hart & Bea, 1994) details the many complexities of LDO: LDO may be characterized as a seven step process, with each process requiring a multitude of tasks that must be performed correctly to prevent a spill. A database designed to capture LDO information (possibly in addition to other activities) would have to accept spill information from each of the seven steps. Of course there will be simplifying similarities across tasks, procedures and operations. The

⁹ From start to finish. This is a time frame, not a count of labor.

complication comes from developing a system that can accept the unique or idiosyncratic tasks, procedures and operations.

A thorough computer design will flow from a thorough taxonomy. Clear taxonomy, choice lists and decision trees will be necessary to develop the database, produce usable forms, and train personnel. The more developed the taxonomy, the easier collection (considered above as a difficult task) will be. A well developed taxonomy may also require less investigation training, increasing the likelihood of industry adoption.

Taxonomy development will be the first major step in developing a collection and recording program. Years of marine casualty investigation have identified most, if not all, physical initiating events. The next stage is identifying possible sequences of events in error chains. Knowledge of such sequences is necessary to develop a reliable entry program. For instance, a spill occurs when the tanks of a barge are overfilled during topping off. If the spill initiating event is determined as "overfill" the taxonomy will need to prompt for more information on procedure (topping off or steady rate?), source of error (sounded wrong tank, sounding reading misinterpreted, failure to shut off pump, miscalculation of fill time, etc), contributing factors and compounding factors (misunderstanding of the DOI, scuppers not closed, flow rate increased or not decreased, etc). Such a system will not only make HOE classification simple, consistent and reliable, it will also highlight unidentified sources of error. When implemented in a computer system the taxonomy will result in easy, fast entry of information.

Taxonomy development is already underway. HOE taxonomies have been

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developed for design and construction of marine structures (Ship Structure Committee, 1994). These taxonomies are a good starting place for the development of an LDO specific system. Coding of NTSB reports and filed research will aid the refinement of existing taxonomies for application in LDO.

CONCLUSION

If our understanding of Marine HOE is to advance, it will be necessary to collect improved HOE information. Unfortunately existing data is neither sufficient for a general survey of HOE nor for any specific operation. Study and prevention of HOE require collection of more accurate data. This collection may require the modification of an existing database or the creation of a new database. Collection will also require wide ranging changes in public agency orientation, industry support and participation, collection methods and regulations.

The changes necessary for effective collection of data are beyond the scope of this paper; however it is possible to conclude with recommendations for developing the taxonomy that must guide the development of a database and collection system. Continued study through observation and professional opinion is warranted at all stages of development. Focus groups might be added to the methods used to collect professional opinion.

Analysis of existing data will also aide development. In particular NTSB reports should be coded and analyzed. The NTSB reports should help delimit possible HOE errors and, more importantly, begin to demonstrate the sequence in which these events may occur. NTSB report coding should not be limited to marine reports. Air, Railroad and Pipeline accidents occur in complex systems not unlike marine accidents, although in different physical, technical and regulatory environments. NTSB reports will not directly further knowledge of HOE in LDO, but indirectly through a contribution to the knowledge of HOE in complex systems.

HOE is an important cause of accidents in the marine transportation industry

with environmental, commercial and personal costs. Its reduction could have a profound impact on marine operations. The best way to reduce HOE is to understand it thoroughly. A comprehensive understanding may be obtained only through increased study that requires improved data.

APPENDICES

APPENDIX A: Attempting to Define Spills & Near Spills

It is difficult to define an "accident." We tend to think of accidents as both single events and the resulting combination of events. Examining the oil spill example introduced earlier in this paper (pg 2), where does the "accident" occur? Is the "accident" created when a crew member fails to close the scuppers or fails to notice the faulty gasket when coupling hoses? Is the "accident" caused by bringing the pressure up too quickly? If the scuppers were plugged and the oil was contained on the deck, is this series of events even considered an "accident?" If the replacement scupper plugs were not ordered in time is this part of the accident? We can further complicate the issue by adding organizational variables such as pressure to complete work quickly. If time pressure were the cause of any of the events preceding the spill was it an "accident" for the company to exert these pressures?

Accidents then can be considered as the application of an arbitrary standard. Is it an accident if the oil escapes deck containment but is captured in the boom with a 90% recovery rate? A common definition of a spill is contact of oil and a body of water. This is as arbitrary as defining it as a deck spill, an uncontained spill or in the category of "a spill would result if one more valve were open." Thus an "accident" is not bounded by time or a single event. The question may then become not "Is this an accident?" but "Is this close to an accident?" The latter can be considered a near spill.

If the oil spill example is placed on a time continuum, the classification of each cause may change. Using the contact of oil and water as our spill definition,

the open scuppers, improper connection, and improper start-up flow are contributing causes. The initiating event is the gasket breaking. The containment boom is a mitigating factor. We can suppose a stop factor in the attention of the crew member that observed the oil flowing from the hose connection and shutoff the pump.

The classification is very different if the scuppers are closed. The contributing and stop factors are the same except the scuppers are now a mitigating, perhaps a stop, factor. If we redefine a spill as "loss of flow" the closed scuppers are still a mitigating factor. If the scuppers are open, they become a compounding error. The incorrect hose coupling could also be considered the initiating event, with all other events classified as compounding factors.

Using "contact with a water body" definition we can also see that many errors can occur without creating a spill. These errors may be sequential and propagate until the chain is broken (e.g. the closed scuppers), or they may accumulate until an initiating event releases the chain. (e.g. bringing pressure up too quickly). A spill may not occur, but has an accident occurred if all of the events *except* bringing pressure up too quickly occur?

Although accidents are not bounded by time, it may bound the categorization of factors. Once an initiating factor has been fixed, events preceding and following may be classified using the following definitions. *Contributing factors* clearly precede in time the initiating event, while the placement of compounding and mitigating factors is not as apparent. It makes sense to define *mitigating factors* as events prior to the initiating event that have the effect of restricting the chain of

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events. *Compounding factors* are events occurring after the initiating event that actively advance the chain of events. *Stop factors* are events that occur after the initiating event that halt the advancing chain.

These classifications suggest a theoretical definition for the near spill. A near spill will have a set of contributing factors that allow an initiating event to occur. The difference between the near spill and an actual spill is then the presence of mitigating factors and the absence of compounding factors. Today it is not expected that there would be no mitigating factors at work, however there may not be enough present in all circumstances. By definition a compounding factor would rarely be found in a near spill (*in LDO*). An operational definition of a near spill *in LDO* could then be "the last mitigating factor worked." Technically this could be converted to considerations of containment (if one valve were opened...). It might be more correct to consider cases in which the first, second and third mitigating factors operated properly; however such an extensive approach applied to human error would severely test cognitive limits.

Near spills may also occur during non-LDO. The definition may be different in such cases, possibly involving compounding factors, because it is not the failure of a piece of the LDO system, but perhaps the total failure of a larger system. For instance tankers underway may suffer mechanical problems that result in grounding. In this case the concept of an open valve or even a double hull may not adequately describe the risk, so it may be more appropriate to consider the near miss of grounding.

Simplicity requires that we make a firm, though perhaps arbitrary, judgement

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about initiating effects and "accidents." While sliding a definition along a time line highlights the temporal quality of causes and demonstrates the nature of error chains it does not help a general classification of such events.

APPENDIX B: The Importance of Studying Near Spills

Unfortunately the accepted definition of a spill does not capture all relevant information. Borrowing the engineering method Probabilistic Risk Assessment demonstrates this. Assume Event A occurs with a probability of .8, Event B with .7 and Event C with probability of .2. The chance of A,B&C occurring to create a spill is .112. If we relate only C to the spill, we accept its probability as .112 and perhaps attempt to reduce this probability, most likely by reducing the true probability of .2 If we instead observe the relation between A,B &C, we notice the high probability of A or B occurring. What is observed is a stage set (with probability .56) awaiting event C to cause a spill. If these contributing factors can be reduced in probability, the chance of a spill will be greatly reduced.

Near spill reporting may capture events A&B. Near spill investigation is important because there is as much to learn, if not more, from near spills as from actual spills. This is true even with an arbitrary definition of a spill. Evaluation of actual spills yields only the negative factors (contributing, compounding and initiating factors), while evaluation of near spills yields positive factors (mitigating and stop factors). Thus near spill investigations can reveal not only causes of potential spills, but comparisons to actual spills highlights preventive factors. This allows study not only of potential human errors, but also of improved stop and mitigating factors. Such prevention factors can then become part of the wider knowledge on oil spill prevention.

Near spill reporting could also aid in predicting sizes of spills, an important component of spill response planning. More accurate spill prediction may

emphasize the need for prevention.

The temporal nature of accidents suggests that mitigating and stop factors should also be collected for actual spills (not just near spills). These are probably the factors that prevent a minor spill from escalating into a major spill. The value of such information is again the study of the positive "stop" mechanisms, potentially highlighting the most effective and least effective responses to spills. It is possible that some "stop" mechanisms actually increase the length and magnitude of the error chain in events under different conditions. Only by studying the positive and negative effects of each mechanism can prevention be improved.

APPENDIX C: Proposed List of Fields

The above evaluation of databases concluded no sources contain enough information, accurate information and HOE information to conduct a thorough analysis of HOE in LDO specifically, much less for marine transport generally. It was then proposed that some sources could be reconfigured or a new database and collection system designed. The following fields are suggestions for information that would be helpful in studying HOE. The collection system and feasibility of collection are not the purpose of this paper and are not addressed.

Although not specifically listed here, categories of human and organizational underlie these fields and particularly the causal factor assessments. These categories are part of an HOE taxonomy. It should also be expected that this suggested list of fields may change as the HOE taxonomy is further developed.

BACKGROUND

Facility Information

Barge, Terminal, Tanker, Commercial Cargo, Other
Name
Age (Code built to)
Flag (if applicable)
Classification Society (if applicable)
Size
Equipment/Design
Personnel Policies & Procedures
Maintenance Policies & Procedures
Training Policies & Procedures (continuing & drills)
Transfer/ Navigation Policies (as applicable)

Facility History

Violations, Citations by regulatory and class agencies
Accidents, spills, casualties, near misses, near spills
Major events (ownership change, rebuild, reclassification, etc)

Personnel Information

Name

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Age
Training
Tenure
Experience (types and amount)
Physical, Mental Condition
Time on shift, in week
Sex
Nationality
Language skills

Personnel History

Recorded violations, citations of regulatory code
Violations of facility policy
Accidents, spills, casualties, near misses, near spills (even if not at fault)

SPILL INFORMATION

Spill Identification

Quantity
Material
Near Spill Potential Quantity

Evolution & Procedure Information

Evolution
Procedure
Point of Procedure
Frequency of inspection
Time since last inspection
Communication method & network
Equipment Involved

Crew Composition

Crew engaged in task
Crew in previous shift (if applicable)

Spill Factors

Contributing
Initiating
Compounding
Mitigating
Stop

APPENDIX D: Data Source Comparisons

A comprehensive set of tables follows, comparing the sources of data considered in this paper. The EPA's PIES, USCG's PSIX system, DNV's SEP and corporate sources have been excluded from these comparisons as they are not directly applicable to studies of Marine HOE. No information on OSPR's proposed system were available at the time of writing, so it is also excluded from the tables. All systems considered are actual data recording systems, excepting IMO which is a recommended format.

The source abbreviations used are as follows :

Proposed The proposed Marine HOE database.

MSIS U.S. Coast Guard, Marine Safety Information System

MMS U.S. Department of the Interior, Minerals and Management Service,
World Wide Tanker Spill Database

NTSB U.S. Department of Transportation, National Transportation Safety
Board, Marine Accident Investigations

MFID California State Lands Commission, Oil Spill Database

OMS Washington Office of Marine Safety, Vessel Screening Database

DEQ Oregon Department of Environmental Quality

IMO International Maritime Organization

OPB World Information System's *Golob's Oil Pollution Bulletin*

OSIR Cutter Information Corporation's *Oil Spill Intelligence Report*

MRB Marine Publishing's *Marine Regulatory Bulletin*

Guide Tanker Advisory Center's *Guide for the Selection of Tankers*

Presence of information is indicated by "Yes" ; In primarily quantitative systems this indicates that a field exists for this information or that the information may be found in the system; In primarily qualitative reports this indicates that the information is reported. Qualitative Reports (or portions) may also be indicated "Possibly." This indicates the idiosyncratic as opposed to systematic reporting of information. "N/A" is used to indicate that the type of information is outside the scope of the source.

In the working draft of this paper question marks indicate the information is not yet known. In the case of OSPR and DEQ this is because the systems are under development.

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Database Parameters

	Min. Spill Size	Location	Materials	Tankers/ Barges	Terminals	Platforms	Near Spill
Proposed							
USCG/ MSIS	Sheen	U.S. Navigable Waters	All	Spills from any source entering to navigable waters; includes inshore facilities.			No†
MMS	42,000 gallons (1,000bbl)	World-wide	Oils	Yes	No	No	No
NTSB	Not a criteria	US waters/ vessels	Not a criteria	Yes	No‡	Yes	No
MFID	Tablespoon	CA waters	All	Yes	Yes		No
OMS	Not a criterion	WA (+Worldwide*)	All	Yes	No	No	Yes**
DEQ	Sheen	OR waters	All	Spills from any source entering OR waters			No
IMO	Not a criterion	International	Not a criterion	Yes	No	No	No
OPB OSIR	10,000 gallons	World-wide	Oils***	Yes			No
MRB	250 gallons	Pacific Coast U.S., Canada	All				No
Guide	Not a criterion	World wide	Not a criterion	Yes/ No	No	No	No

†The Coast Guard does record some accidents as "potential spills"; however this is limited to damaged vessels that could discharge hazardous material - typically from fuel tanks.

‡If a vessel accident occurs at a shore facility, the facility will be included in the investigation.

* A unique feature of OMS is vessel screening . This process captures international historical information on all vessels entering Washington waters.

**OMS collects Near Miss information. Presently this is defined as a navigational near miss only.

*** The publishers also produce newsletters for other products, as World Information Systems *Hazardous Material Intelligence Report*.

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Spill Identification

	Size	Material	Location†	Weather	Date	Time
Proposed						
USCG/ MSIS	Yes	Yes (highly detailed)	Yes	Yes (if a factor)	Yes	Yes
MMS	Yes	Yes	Yes	Yes (if a factor)	Yes	No
NTSB	Yes	Yes	Yes	Yes	Yes	Yes
MFID	Yes	Yes	Yes	No	Yes	Yes‡
OMS	Yes	Yes	Yes	Yes (extensive)	Yes	Yes
DEQ	Yes	Yes	Yes	Yes	Yes	Yes
IMO	Yes	Yes*	Yes	Yes	Yes	Yes
OPB	Yes	Yes	Yes	Possibly (if a factor)	Yes	?
OSIR						
MRB						
Guide	Yes	Yes	Yes	No	Yes	No

†Each database reports locations to varying degrees of precision.

‡Time reported. This may differ greatly from the time of the spill.

* Limited to oil or chemical designation.

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Vessel Information

	Name	Flag	Size	Year Built	Type	Owner-ship	Class Society	Equip-ment	Design
Proposed									
USCG/MSIS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Possibly	Possibly
MMS	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
NTSB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes [†]	Yes
MFID	Yes	No	No	No	No	No	No	No	No
OMS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes (extensive)	Yes
DEQ	Yes	No	No	No	No	No	No	No	No
IMO	Yes	Yes	Yes	Yes	Yes	No	Yes	Limited	Yes
OPB	Yes		Possibly		Yes	Possibly			
OSIR									
MRB									
Guide	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

[†]Affected or involved equipment is described in great detail, often down to the model number

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Vessel/ Facility/Crew History

	Vessel		Facility		Crew		
	Viola- tions	Acci- dents	Viola- tions	Acci- dents	Deck Crew	Dock Crew	Violations/ Accidents
Pro- posed							
USCG/ MSIS	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MMS	No	No	N/A	N/A	No	N/A	No
NTSB	If the history is relevant to the accident investigation.						
MFID	No	No	No†	No	No	No	No
OMS	Yes	Yes	Yes	Yes	Yes	No	No
DEQ	No	No	No	No	No	No	No
IMO	Possibly						
OPB							
OSIR							
MRB							
Guide	Yes	Yes	N/A	N/A	No	N/A	No

† MFID field visit checklists may detail procedural violations, but not violations cited under law.

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Cause/Investigation

			Cause Factors				
	Proce- dure	Load Level	Human	Con- tributing	Com- pounding	Physical events	Mitigating/ Stopping
Proposed							
USCG/ MSIS	Possibly	Possibly	Yes	Yes	Yes	Yes	No
MMS	No	No	No	Yes†	No	Yes	No
NTSB	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MFID	Possibly	No	No	No	No	Yes	Possibly
OMS	Possibly	Possibly	Yes	Yes	Yes	Yes	Possibly
DEQ	Possibly	Possibly	No	No	No	No	No
IMO	No	No	Yes	Yes	Yes	Yes	Yes‡
OPB	Possibly						
OSIR							
MRB							
Guide	No	No	No	No	No	No	No

† Limited to a chain of initiating events leading to a spill.

‡ Limited to use of safety equipment - life saving, fire fighting, communications.

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Response

	How/ When noticed	How Contained	Damages	Minimizing Actions
Proposed				
USCG/ MSIS	Possibly	Possibly	Possibly	Possibly
MMS	No	No	No	No
NTSB	Yes	Yes	Yes	No
MFID	No	Possibly	Yes	Possibly
OMS	No	No	No	No
DEQ	Yes	Possibly	No	Possibly
IMO	No	Yes	Yes†	No
OPB	Possibly			
OSIR				
MRB				
Guide	No	No	No	No

† Limited primarily to equipment or structural damage and individual injury or death.

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User Concerns

	Sources	Number of Records	Year Coverage Begun	Type of Info	Computer based
Pro-posed					
USCG/MSIS	Primary, Secondary, Legal	≈210,000	≈1973	Quantitative with limited Qualitative	Yes
MMS	Tertiary Public, Industry	≈1,100	1955	Quantitative	Yes
NTSB	Primary	≈180	1973	Qualitative	No
MFID	Secondary Legal	≈7,000	1988	Quantitative with limited Qualitative	Yes
OMS	Primary, Secondary, Tertiary	≈1,200	1993*	Quantitative with limited Qualitative	Yes
DEQ	Primary, Secondary,	≈700	1995 (new system)	Qualitative with Quantitative summary	Yes
IMO	Primary	N/A	N/A	Quantitative with limited Qualitative	N/A
OPB	Secondary	≈80	1978	Qualitative with Quantitative summary	Yes†
OSIR	Secondary	≈3250	1978		
MRB	Secondary	N/A	1991	Qualitative	No
Guide	Secondary, Tertiary	≈3,400	≈1984	Quantitative with limited Qualitative	Yes

* Information on self-reported tanker incidents from approximately 1988 have also been entered for all tankers operating in Washington waters.

†The databases offered by these organizations provide only the quantitative information.

APPENDIX E - Method

The information presented in this paper was obtained from a variety of sources. When possible actual data was examined, failing this we used printouts or samples of the data. Complete lists of fields were also requested, though the complexity of some systems did not make this a feasible request. Interviews were conducted with a variety of people, both the custodians of the databases as well as users in and outside of the parent organization. Publicly available newsletters and reports were reviewed for content. Not all information was verified so there exists the possibility that some information is incorrect. At the time of this writing information had still not been collected from California's Department of Fish and Game, Oil Spill Prevention and Response.

All interviews are listed in the references, as are all publications. Informal publications, printouts, etc that are not titled are not referenced as they were effectively part of the interview process.

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Interviews

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Lou Burris, Information System Manager, Washington Office of Marine Safety

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Nina Carter, Director of Operations, Washington Office of Marine Safety

Bob Diaz, Investigator, Washington Office of Marine Safety

Lt. Cmdr T. G. Falkenstein, Marine Safety Office San Francisco Bay

Ray Fayles, Classifications, Det Norske Veritas

Mike Gobal, Senior Vetting Officer, Sea River Maritime

Dexter Halligan, Management Information Services, Oregon Department of
Environmental Quality

Don Hermanson, Marine Terminal Safety Specialist, California State Lands
Commission

Rick Holly, Marine Terminal Safety Specialist, California State Lands Commission

Ron Holton, Safety Specialist, Chevron Shipping

Mike Hughes, W.P.I. Coordinator - Richmond Refinery, Chevron Products

Ronald Kelleher, Safety Specialist, Chemical Tankers of America

Dodge Kenyon, Vessel Inspector, Washington Office of Marine Safety

Cora McCauley, Database Manager, California State Lands Commission

Arthur McKenzie, Director, Tanker Advisory Center

Lt. Rick Naccara, USCG, Marine Safety Office San Francisco Bay

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Laura Stratton, Vessel Screening Specialist, Washington Office of Marine Safety

Paul Slyman, Oil Spill Specialist, Oregon Department of Environmental Quality

Donald Tyrell, National Transportation Safety Board Marine Accident Investigation,

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Bernie Weber, Inland Structures, Det Norske Veritas

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