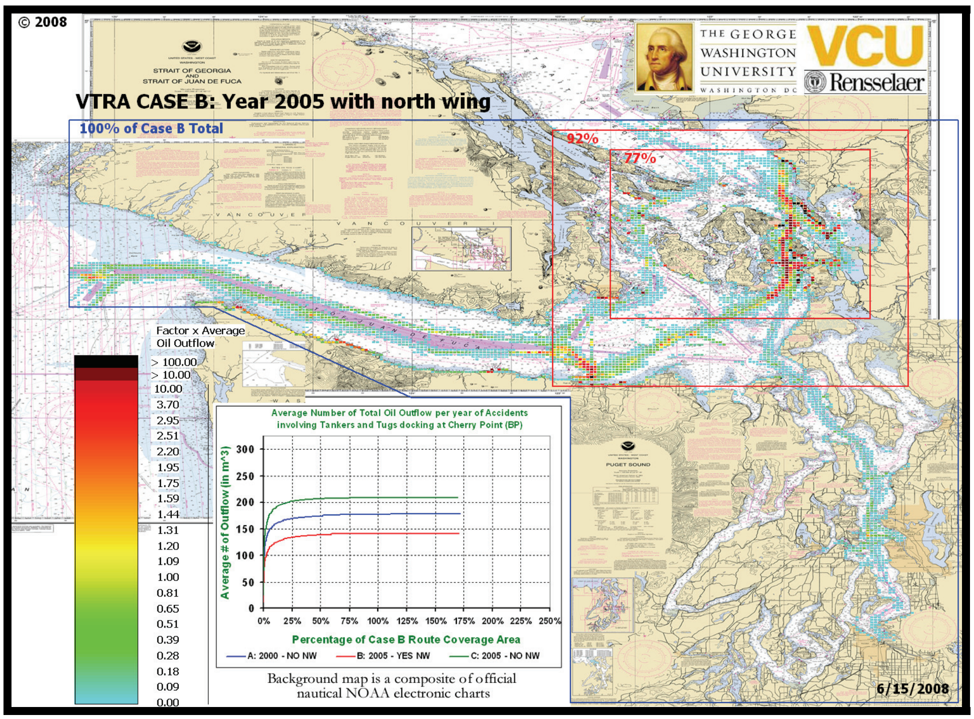
TECHNICAL APPENDIX A:
DATABASE CONSTRUCTION AND ANALYSIS



Assessment of Oil Spill Risk due to Potential Increased Vessel Traffic at Cherry Point, Washington

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Appendix A: Database Construction and Analysis

In order to develop accident and incident frequencies as input to the BP Puget Sound Vessel Traffic Risk Assessment (VTRA) maritime simulation, an analysis of maritime accidents and incidents in Puget Sound from 1995-2005 was undertaken. Accident and incident records for the time period and for the geographic scope of the project were solicited, and an accident-incident database was constructed. The data were analyzed, and the results of that analysis are presented in this report.

A-1. The Puget Sound VTRA Accident-Incident Database

The Puget Sound VTRA accident-incident database is comprised of maritime accident, incident, and unusual event records for tank, tug-barge, cargo, ferry, and fishing vessels over 20 gross tons underway or at anchor, for the years 1995-2005 in Puget Sound, in the State of Washington. The database takes the form of multiple Microsoft EXCEL spreadsheets (Table A-1) with a common format describing various accidents and incidents. The database is the compilation of all accidents, incidents, and unusual events gathered from the project's sources, filtered to include only those relevant records for the waterways of Puget Sound.

Table A-1. Database Files

Tanker Accidents and Incidents
Tug and Barge Accidents and Incidents
Cargo Accidents and Incidents (Public, Freighter, Bulk Carrier, Container, and Passenger Vessel)
WSF (Washington State Ferries) Accidents and Incidents
Fishing Vessel Accidents and Incidents
Unusual Events
Personnel Casualties

The geographic scope of the VTRA project, and of the events recorded in the database, include those listed in Table A-2: the Strait of Georgia (Ferndale southward), Rosario Strait, Haro Strait/Boundary Pass, Guemes Channel, Saddlebag, Puget Sound, and Strait of Juan de Fuca (west to 8 miles west of Buoy "J").

Table A-2. Geographic Locations in Puget Sound VTRA Accident-Incident Database

Location ID	Region Name
1	West Strait of Juan de Fuca
2	East Strait of Juan de Fuca
3	North Puget Sound
4	South Puget Sound
5	Haro Strait/Boundary Pass
6	Rosario Strait
7	Guemes Channel
8	Saddlebag
9	Strait of Georgia/Cherry Point
10	San Juan Islands

Three types of events are captured in the database: accidents, incidents and unusual events.

Accidents are defined as occurrences that cause damage to vessels, facilities, or personnel, such as collisions, allisions, groundings, pollution, fires, explosions, or capsizing/sinking, but do not include personnel casualties alone.

Incidents are defined as undesirable events related to control or system failures which can be detected or corrected in time to prevent accidents; incidents can also be prevented from developing into accidents by the presence of redundant or back up systems. Examples of incidents include propulsion failures, steering failures, navigational equipment failures, electrical equipment failures, structural damage or failure, and near misses.

Unusual events are defined as events of interest to the safety of navigation that are deemed to be unusual by a participant or a reporting organization. In the database, unusual events were provided by the U.S. Coast Guard Vessel Traffic Services (VTS), U.S. Coast Guard Sector Seattle, U.S. Coast Guard Headquarters (MSIS and MISLE data), the Puget Sound Pilot Commission, British Petroleum (Cherry Point), and the Washington State Department of Ecology.

A-2. VTRA Accident-Incident Database Development

Marine casualty and incident data were gathered between June 2006 and June 2007 from the maritime organizations listed in Table A-3. Relevant data were defined as records that fell within the geographic area of study, within the timeframe 1 January 1995 to 31 December 2005, for a vessel greater than 20 gross long tons. Once the data were organized into a common data format, each of the resulting 2705 records was cross-validated with additional data sources to confirm the information in each record. This step was important to establish the accuracy and credibility of the data records and of the resulting database. Each record was assigned a location identification number, following Table A-2, and additional vessel characteristics were obtained from proprietary and open source databases. Once the records were complete, they were analyzed, and the results reported in this document.

Table A-3. Puget Sound VTRA Accident-Incident Database Contributors (Steward, 2007)

United States Coast Guard Headquarters
United States Coast Guard Sector Seattle
United States Coast Guard Sector Portland
United States Coast Guard Vessel Traffic Service Seattle
United States Coast Guard Marine Incident Database (Online)
Washington State Department of Ecology
Lloyd's List Marine Intelligence Unit Portal (Online)
Crowley Maritime Corporation
British Petroleum, Cherry Point Facility
Puget Sound Pilot Commission
Washington State Ferries
Seattle Post – Intelligencer
San Juan Islander

The main source for vessel characteristics in the VTRA database was Lloyd's Marine Intelligence Unit. For tanker vessels, the Clarkson Register was used to identify vessel owner evolution, important because of vessel and industry changes over the time period (1995-2005). Vessels were researched to identify the vessels' gross tonnage (long tons), its flag at the time of the casualty event, the owner at the time of the casualty event, the classification society at the time of the casualty event, its hull type, and vessel type. Records were separated into the following categories: Tanker Accidents and Incidents, Tug and Barge Accidents and Incidents, Cargo (Public, Freighter, Bulk Carrier, Container, and Passenger Vessel) Accidents and Incidents, WSF (Washington State Ferries) Accidents and Incidents, and Fishing Accident and Incidents.

A-3. Challenges with Accident, Incident and Human Factors Data

Accident and Incident Data

Problems with data to support modeling and analysis in marine transportation are well-documented (National Research Council, 1983; 1990; 1994; 2003). Data challenges in marine transportation have grown with the proliferation of electronic data, as the data have a varying storage requirements, exist in various formats, are gathered and collected from various agencies and individuals, with varying degrees of compatibility (National Research Council, 2003). As a result, data validation, compatibility, integration and harmonization are increasingly significant challenges in maritime data and risk assessments. In addition, no standard reliable database for near-miss reporting or exposure data has been developed in marine transportation, although the United States General Accounting Office, Congress and the National Academies/National Research Council have been exploring methods to improve the collection, representation, integration and sharing of accident and incident data (National Research Council, 1994; U.S. Department of Homeland Security, 2005; Transportation Research Board, 2008).

Impact of Data Challenges on Puget Sound VTRA Accident-Incident Database

In marine transportation, as in other domains, event analyses are constrained by the quality of the data gathered, the maturity of the associated reporting system, and the training and background of the investigator and reporter (who may not be the same person). Such constraints place limits on the adequacy and strength of analyses conducted with maritime safety data. These limitations have been characterized and analyzed extensively in reports prepared by the National Academies/National Research Council, the National Transportation Safety Board, and the U.S. General Accounting Office (National Research Council, 1990; 1994; 1999; 2003; National Transportation Safety Board, 1994).

The data records that comprised the VTRA accident-incident database required a significant amount of reconciliation and cross-validation across data sources to ensure that the records were accurate, that they captured the entire event of record, and to reduce redundancy in the final database. Reconciliation and cross-validation was particularly challenging, as the data records from one agency might capture the initial part of an event of record (e.g., an initiating mechanical failure), while the data records from another reporting agency, describing the same event, might capture the initiating event as well as the series of cascading and related events (e.g., other mechanical failures, an eventual accident).

Absent a standard incident and accident coding scheme, common data storage and transmission formats, and a common data dictionary defining accidents, incidents, unusual events and contributory situations, database construction and data record reconciliation encompassed several time-consuming steps: review of all available paper and electronic sources, additional search in many cases to confirm the events, and requests for additional information to ensure that the entire event was captured in the database. Resolution of open items in the database required search and compilation of data sources from maritime safety sources, as well as from vessel, traffic, transit, meteorological, charting and geographic information, as from the sources listed in Table A-4. This required retrieval of archival records from local (Puget Sound), state (Washington State), national (U.S. government) and international (Lloyd's List, Equasis, Clarkson's Register) sources, for several thousand events.

The lack of a standard event coding scheme had impact on the quality of the data collected, as discussed in the following section. For instance, the Coast Guard's MISLE database uses a pre-determined data set (a data dictionary) from which to classify events. Pre-MISLE data dictionaries included more detailed narratives that permitted descriptive root cause analyses, and other current classification schemes, such as that of the Pacific States-British Columbia Task Force (Pacific States/British Columbia Oil Spill Task Force, 1995; 1997; 2007), provide other descriptive classification schemes. Since the data collected at the time of a given event are in large part determined by the questions posed during the evidence gathering process and the data sets used to categorize the events, a standard and comprehensive data dictionary from which to classify and describe events is an essential element of a well-developed safety information system. As will be seen in the following section, the lack of a standard descriptive data dictionary used by all data-gathering organizations to codify events, as well as the lack of international data storage and transmission standards used by federal, state, local and private organizations to capture maritime safety data, occasioned an enormous amount of integration, reconciliation and verification effort during the VTRA accident-incident database construction.

A-4. Data Sources

A variety of organizations provided data as input to the event database, as seen in Table A-4. Since each of these source files was in different formats, of different sizes, and captured different views of safety performance in the Puget Sound marine transportation system, each of the data files was deconstructed, normalized, and integrated into a common database format, utilizing a common data definition language, based on the Pacific States-British Columbia Oil Spill Task Force data dictionary (1995; 1997; 2007). Table A-4 lists the data files received, the size of each of the files received, and the numbers of records received. 97 different data files, comprising over 3.8M records, and more than 1800 megabytes of data were received from 9 organizations as input to the database.

Table A-4 Puget Sound VTRA Accident Incident Database Source Files

Source	Type of Data	Size	# Records
USCG Group Seattle VTS	Incident Reports 2001	964k	54
	Incident Reports 2003	3.64M	20
	Old' Incident Reports	185k	50
	Incident Reports -- Access database	1.3M	646
USCG Website	Marine Casualty Causal Factor Table	751K	2747
	Marine Casualty Collision and Grounding Table	55K	209
	Marine Casualty Event Table	612K	2391
	Marine Casualty Flooding and Capsizing Table	84K	98
	Marine Casualty Fire and Explosion Table	32K	51
	Marine Casualty Facility Supplement Table	307K	869
	Marine Casualty and Pollution Master Table	8.11M	5965
	Marine Casualty Vessel Supplement Table	2.10M	4816
	Marine Casualty Personnel Injury & Death Table	167K	257
	Marine Pollution Substance Table	831K	3096
	Marine Casualty Structure Failure Table	26K	39
	Marine Casualty Weather Supplement Record	88K	68
	Facility Identification Table	8.05M	36980
	Vessel Identification Table	376.06M	>65536
USCG Sector Seattle	Spill Data from 2000-2006	694K	3204
USCG HQ	Closed Incident Investigation reports	8.1M	12,065
	Vessel Identification Table 2001 (vidt.txt)	112.165M	509805
	Facility Identification Table 2001 (fidt.txt)	5.106M	36980
USCG HQ	Marine Casualty and Pollution Master Table (cirt.txt)	56.848M	187812

Source	Type of Data	Size	# Records
	Marine Casualty Vessel Supplement Table (civt.txt)	14.688M	155781
	Marine Casualty Facility Supplement Table (cift.txt)	4.613M	51400
	Marine Casualty Event Table (cevt.txt)	5.724M	108927
	Marine Casualty Causal Factor Table (ccft.txt)	7.199M	116864
	Marine Casualty Collision and Grounding Table (ccgt.txt)	1.073M	26178
	Marine Casualty Structural Failure Table (csft.txt)	101K	2385
	Marine Casualty Flooding and Capsizing Table (cfct.txt)	867K	7677
	Marine Pollution Substance Table (cpdt.txt)	6.589M	84167
	Marine Casualty Personnel Injury Table (cpct.txt)	2.907M	15961
	Marine Casualty Fire and Explosion Table (cfet.txt)	272K	2339
	Marine Casualty Weather Supplement Record (cwxt.txt)	968K	7133
	Pollution Master Table (prit.txt)	11.699M	64421
	Pollution Vessel Supplement Record (pvst.txt)	3.477M	28669
	Pollution Facility Supplement Record (post.txt)	5.157M	36329
	Pre-MIN Pollution Substance Table (psst.txt)	4.922M	66686
	Pollution Substance Table (converta.txt)	18.219M	172683
	Ticket Investigation Master Table (prittk.txt)	2.503M	23434
	Ticket investigation Marine Violation Table (mvcttk.txt)	3.023M	23434
	Ticket Investigation Report Table (mtkt.txt)	2.639M	23434
	Ticket Investigation Casualty Event Table (tcet.txt)	1.714M	22286
	Marine Pollution Substance Table (pssttk.txt)	1.523M	21761
	Personnel Injuries/Deaths (pcas.txt)	3.601M	20752
	Vessel Casualties (vcas.txt)	15.721M	68592
	Master Pollution table (mpir70.txt)	15.79M	98447
	Master Pollution Table (mpir80.txt)	22.269M	127967
	Coast Guard Response Table (mprc70.txt)	667K	6970
	Coast Guard Response Table (mprc80.txt	11.008M	111633
	Non-Coast Guard Response Table (mprn70.txt)	636K	17589
	Non-Coast Guard Response Table (mprn80.txt)	1.308M	33028
	Marine Pollution Facility Table (mpsf70.txt)	3.678M	69921
	Marine Pollution Facility Table (mpsf80.txt)	2.453M	83120
	Marine Pollution Vessel Table (mpsv70.txt)	955K	28527
	Marine Pollution Vessel Table (mpsv80.txt)	1.504M	44580
	Marine Pollution Substance Table (mtl70.txt)	7.499M	98448
	Marine Pollution Substance Table (mtl80.txt)	10.001M	129751
	Marine Violation Table (mv70.txt)	1.664M	32761
	Marine Violation Table (mv80.txt)	3.362M	52635
Washington State Ferry Project	Puget_Sound_VTS_Unusual_Incident_tblUI	548K	1747
	Puget_Sound_VTS_Unusual_Incident_byTypeCode		19
	Puget_Sound_VTS_Unusual_Incident_byVessels		1497
	washdata,_7_Aug_1998/DIM(Sarmis)	269K	30
	washdata,_7_Aug_1998/Waterway		455
Washington State DOE	Multi PDF files	N/A	7
Puget Sound Pilot Commission	Puget Sound Pilot Commission Incident Data	69K	64

Source	Type of Data	Size	# Records
Washington State Dept of Ecology	Washington State Resource Damage Assessment by Date	60K	395
	Past Incidents of Interest	1.03M	10
US Coast Guard Headquarters	Complete accident/incident data up to 2006.		
	Same as data on 08/18/2006(CD1)	370M	
	MisleActivity.txt	3.122M	24970
	MisleFacEvents.txt	1.149M	5708
	MisleFacility.txt	9.159M	40,374
	MisleFacPoll.txt	2.363M	4653
	MisleInjury.txt	435K	3053
	MisleOtherPoll.txt	2.093M	4246
	MisleReadme.doc	69K	
	MisleVessel.txt	382.470M	858,081
	MisleVslEvents.txt	5.059M	23765
	MisleVslPoll.txt	3.429M	6491
British Petroleum	Accident/Incident report in email format (transfer to PDF and saved)	197K	
DOE	Accident/Incident Data		
	Incidents_CPS_1994_present(Center Puget Sound)	304K	718
	Incidents_NPS_Consolidated_Grabowski(North Puget Sound)	234K	426
	Incidents_SPS_1994_present_Grabowski(South Puget Sound)	15K	4
Lloyd's MIU Portal	Vessel Casualty Information	N/A	2
USCG Seattle	Anchoring Database	1,124K	5614
USCG Portland	Portland MSIS & MISLE Data	1551K	4256
USCG Seattle	Intervention and Near Misses(Including Audio files)	225M	25
Washington State DOE	Central and South Puget Sound Accident Files	315K	46
	CPS_all,_9_Feb_2007	1815K	420
	CPS_casualty,_9_Feb_2007	197K	37
	CPS_near_miss,_9_Feb_2007	1064K	226
	CPS_spills,_9_Feb_2007	46K	4
	SPS_all,_9_Feb_2007	95K	90

Because of the large number of records and their various sources, it was necessary to track both the original source of each record and any redundant records from different sources. This information was tracked in the field "event cross-validated" in the database as new, incoming records were inserted and checked for repeats. Figure A-1 provides a breakdown of the various data sources for the events in the VTRA accident-incident database.

The Challenge of Integrating Multiple Data Sources

The development of the Puget Sound VTRA accident-incident database highlighted the complexities inherent in integrating multiple data sources into a coherent information system. One difficulty lay in categorizing the types of events in the database, and in determining whether a series of events that occurred together were incidents or accidents. If an event resulted in an incident (propulsion failure, steering failure, navigation equipment failure, etc.), it was categorized as an incident. If the event resulted in an accident, it was categorized as an accident, and the precipitating incidents or cascading events associated with the accident were captured in the narrative portion of the database.

Another difficulty was occasioned by the varying information contained in the different data sources, which necessitated merging several databases into one accident-incident repository. For instance, of the 2705 events records in the database, 1759 (65%) of the records were unique to USCG records, 478 (17.67%) were unique to Washington DOE, with only 377 (13.94%) represented in both the USCG and DOE databases, as seen in Figure A-1 and Table A-5. Thus, in order to build a comprehensive accident-incident database, both data sets were required. The Coast Guard and Washington Department of Ecology are both charged with maritime data collection, analysis and reporting responsibilities within the Puget Sound marine transportation system; in order to determine the differences in the data sets between two organizations, additional analysis was undertaken, as described in the next section.

Figure A-1 Puget Sound Accident – Incident Data Sources

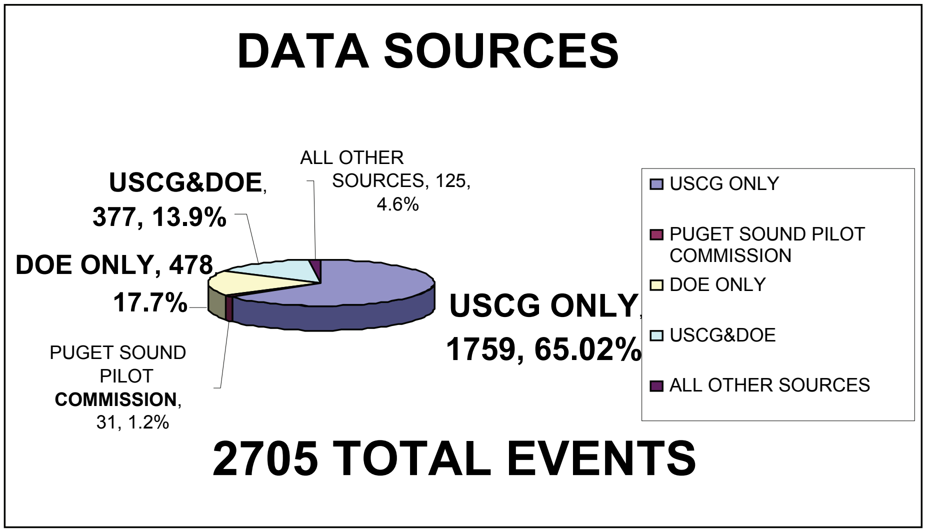


Table A-5 Puget Sound VTRA Accident-Incident Data Sources

Source	Events	% of Events	Accidents	Incidents
USCG only	1759	65.02%	1074 (73.46%)	631 (54.44%)
Wash DOE only	478	17.67%	148 (10.12%)	324 (27.96%)
WSF only	17	6.3%	7	5
Pilots only	31	1.15%	14	3
BP only	4	0.15%	0	3
USCG/DOE	377	13.94%	193 (13.2%)	184 (15.88%)
USCG/WSF	5	0.2%	5	0
USCG/Pilots	4	0.1%	4	0
Pilots/DOE	11	0.41%	7	2
DOE/USCG/Pilots	6	0.22%	5	1
DOE/Seattle Anchor Log	2	007%	0	2
USCG/DOE/WSF	2	0.07%	1	1
Other	9	0.33%	4	3
Total	2705	100%	1462	1159

Other data sources: Seattle P-I, San Juan Islander, Lloyd's List, EQUASIS database, Crowley, Washington Dept of Ecology text, accident files, CG Sector Seattle anchoring log/ database; CG Sector Seattle Watch Supervisor's Log, etc.

Differences between Key Data Sources—USCG and Washington DOE Data

Both the U.S. Coast Guard and Washington State Department of Ecology provided accident, incident and near loss data to the Puget Sound VTRA Accident-Incident database development effort. Both organizations capture data of interest to the database; however, there are several differences between the data provided by these key sources, as seen in Table A-6: these differences center on each organization's definition of a casualty; vessels of interest that are captured in the data records; the nature of in-transit failure data in the records; database and organizational changes that have impacted each organization's data collection and management activities; data used as input to each organization's records; and the nature of oil spill reporting in the data sources. Each of these items is discussed in the following section. The impact of these differences on the development of the Puget Sound VTRA Accident-Incident database is also discussed.

Table A-6 Differences Between Data Sources: USCG vs. Washington State DOE Records

Variable	USCG	DOE
Casualty	• No near miss events in the MISLE database. • Tracks personnel injury information • Tracks all marine event casualties	• No data on deaths, personnel injuries, or events that are not directly linked to spills. • Near miss data
Vessels of Interest	• Tracks all vessel types, including recreational vessels and personal watercraft, of any tonnage.	• Does not track events occurring on or to deck barges, fishing vessels, or vessels less than 300 GT.
In-transit failures	• Reports more small equipment failures leading to anchorage or Captain of the Port (COTP) actions.	• Captures equipment failures if they are reported as likely to precipitate a marine event or are involved in a marine event.
Database and Organizational Changes	• In December 2001, the Coast Guard migrated from the Marine Safety Information System (MSIS) to the Marine Information for Safety and Law Enforcement System (MISLE). MSIS had more detailed narrative reports than does MISLE.	• On July 1, 1997, the State's Office of Marine Safety (OMS) merged with DOE to form the new Spill Prevention, and Preparedness and Response Department (RCW 88.46.421). OMS was dissolved, and responsibility for vessel screening and spill reporting transferred to DOE.
Reporting sources	• Utilizes primary data sources: Coast Guard forms CG-2692 and CG-835, and other auxiliary reporting sources.	• Utilizes secondary data sources, frequently Coast Guard records.
Oil spills	• Uses National Response Center data to report incoming spill information for all kinds of vessels.	• No oil spill events occurring on or to deck barges, fishing vessels, or vessels less than 300 GT.

Definition of Casualty

The first differences between the Coast Guard and DOE casualty reporting systems with impact on the VTRA database were in each organization's definition of a casualty. The Coast Guard uses 46 CFR 4.05 to define a marine casualty as an "Intentional or Unintentional Grounding, Allision, Any loss of equipment that effects a loss of maneuverability, Any materiel deficiency or occurrence of materiality that affects seaworthiness or safety of the vessel (i.e. fire, flooding, loss of installed fire-fighting equipment), Death, Personnel Casualty that results in not fit for duty, Property damage of $25,000 or higher, an Oil Spill that creates a sheen or anything more, or a "Hazardous Condition".

In contrast, DOE uses WAC 317-31-030 and RCW 88.46.100 to define a marine "event" as a "Collision, Allision, Grounding, Near Miss Incident (through non-routine action avoided a collision, allision, grounding, or spill), or anything in CFR 46 4.05-1 EXCEPT Death, Personnel Injuries, and "Hazardous Conditions" not linked to a spill."

The primary difference between these two casualty definitions is that DOE does not collect data about deaths, personnel injuries, or events that are not directly linked to spills, following the organization's direction after the Washington Office of Marine Safety was abolished in 1997; examples of excluded events for DOE include personnel casualties not involved in oil spills, collisions, allisions, and groundings. On the other hand, the Coast Guard does not explicitly track near miss events in the MISLE database. Several reporting differences result: the DOE tracks near miss incidents, but the Coast Guard does not; the Coast Guard regularly tracks deaths, personnel casualties, and property damage events in excess of $25,000, while the DOE does not. However, inspection of the records shows that the Puget Sound VTS watchstanders may record some Near Miss Incidents for larger commercial traffic in their Near Miss or Watch Supervisor's Log. In terms of numbers of records, however, the most notable incongruence is that DOE does not track personnel casualties unrelated to oil spills, while the U.S. Coast Guard does.

Inspection of the data provides further insight. Between 1995 and 2005, 45 Near Miss incidents were reported; 12 were unique to the Coast Guard records, and 26 were unique to DOE records; 3 were reported by both the Coast Guard and DOE, and 4 were reported by other sources. These numbers support the observation that DOE reports contain more near miss events, but the scale is small enough that this explanation alone is insufficient. At the same time, between 1995 and 2005, there were a total of 175 personnel casualties reported, with 174 of those personnel casualties coming from USCG as the sole source. This illustrates that DOE does not track personnel casualties, but the USCG does.

Vessels of Interest to Organizations

Another difference in casualty reporting between USCG and Washington State DOE records lies in the nature of vessels and events of interest to each organization. USCG databases track all vessel types, including recreational vessels and personal watercraft, of any tonnage. However, the Spill Program of DOE uses a database called Marine Information System (MIS), specifically designed for vessels over 300 GT, excluding fishing boats and deck barges. As a result, DOE records do not include events occurring on or to deck barges, fishing vessels, or vessels less than 300 GT, both of which the Coast Guard tracks.

For the Puget Sound VTRA accident-incident database, events occurring to all vessels greater than 20 gross tons were captured; hence, both USCG and DOE data sources were important inputs to the database. Table A-7 shows the nature of the events that are tracked only by the USCG, primarily fishing vessels, public vessels, law enforcement events, deck barges, and vessels < 300GT. These events comprised 65% of the events in the VTRA accident-incident database, or 1759 records.

In-Transit Failures

In-transit failures are another source of data differences between the Coast Guard and DOE records. Coast Guard Seattle VTS captures Captain of the Port (COTP) actions and anchorages due to equipment failures through interaction with vessels and observing their actions at the VTS. DOE captures equipment failures if they are reported as likely to precipitate a marine event or if they are involved in a marine event. The result is that the Coast Guard reports more small equipment failures leading to anchorage or COTP actions, which are logged as part of the VTS watchstander's duties.

Table A-7 Puget Sound VTRA Accident Incident Database Events Tracked only by the USCG

Event Type	N	% of Events	Description
Fishing Accidents	444	25.24%	Fishing Vessel Accidents
Fishing Incidents	37	2.1%	Fishing Vessel Incidents
Other Accidents	174	9.89%	Public vessels
Other Accidents	181	10.29%	Non-Pollution Accidents (excludes Public)
Other Incidents	3	0.17%	Public vessels
Other Incidents	38	2.16%	Sector Seattle Anchor Log
Other Incidents	120	6.82%	Non-Pollution Incidents (excludes Public)
Tanker Incidents	36	2.05%	Sector Seattle Anchor Log
Tug Accidents	226	12.85%	Tugs under 300GT
Unusual Events	27	1.53%	Sector Seattle Anchor Log
Unusual Events	23	1.31%	USCG Law Enforcement (COTP holds, ROTR violations, etc.)
WSF Accidents	73	4.15%	WSF vessels under 300GT
WSF Incidents	377	21.4%	WSF vessels under 300GT
TOTAL	**1759**	**100%**	

Database and Organizational Changes

In addition to differences in reporting requirements, there are also differences in how each agency's reporting culture has evolved. Between 1995 and 2005, both agencies underwent a significant change in their reporting and database systems. In December 2001, the Coast Guard migrated from the Marine Safety Information System (MSIS) to the Marine Information for Safety and Law Enforcement System (MISLE). The transition caused a few months of data processing backlogs, but eventually all casualty records were transferred to the new database. However, the older Coast Guard database, MSIS, had more detailed narrative reports than does MISLE, making cross-referencing records and detailed casualty narratives after 2001 challenging, and changing the granularity of recent (post 2001) casualty information available through Coast Guard records.

Similarly, DOE underwent not only a database and reporting change, but also an organizational change. On July 1, 1997, the State's Office of Marine Safety (OMS) merged with DOE to form the new Spill Prevention, and Preparedness and Response Department (RCW 88.46.421). OMS was dissolved, and responsibility for vessel screening and spill reporting transferred to DOE. The DOE database, MIS, began as a vessel screening tool in OMS, and evolved to an event reporting database in DOE.

As a result of both organizational changes, data sources for the VTRA accident-incident database were of varying granularity and completeness, as each data collection organization evolved and changed its reporting processes and systems during the 1995-2005 time period. Impacts of these changes will be seen in the data analysis reported in Section A-5, particularly in the data available for human and organizational error (HOE) analysis. These are not uncommon challenges in large-scale systems with complex data, but the need to integrate multiple, independent sources into a coherent and common format, and the availability and granularity of data for HOE analysis, had impact on the VTRA accident-incident database development effort.

Primary and Secondary Reporting Sources

A large source of variation in event reporting in Puget Sound lies in the sources used as input by the two organizations. The Coast Guard reporting system uses primary sources as input, mainly the Coast Guard forms CG-2692 and CG-835. The Coast Guard thus develops an enormous repository of primary maritime accident and incident data; however, the varying databases which comprise this rich data resource are not electronically integrated into one common, accessible electronic format. This necessitates considerable knowledge of the existing databases, sources and repositories of information, as well as considerable time to gather, standardize, harmonize and integrate the disparate paper and electronic data sources. The unsuspecting analyst who is looking for a one-stop shopping experience with respect to U.S. maritime accident and incident data, therefore, is often disappointed and consequently forced to examine multiple data sources in order to attain a complete picture of maritime accidents and incidents in a system.

The Coast Guard utilizes several primary source reports. The CG-2692 form, the Report of Marine Accident, Injury, or Death, must be filled out for every reportable marine casualty as defined by the CFR. The CG-835 Form, the Notice of Merchant Marine Inspection Requirements, is completed when a vessel has materiel deficiencies that must be repaired before sailing. The Coast Guard also uses the Notice of Arrival Information managed by the Coast Guard's National Vessel Movement Center to track commercial vessel transits in major U.S. ports. The Coast Guard also has auxiliary reporting sources, including the VTS Watch Supervisor's Log, the Sector Seattle Anchor Database (also tracked by VTS when vessels arrange for anchoring), the VTS Intervention Log (when VTS must interact with vessels to prevent accidents), the VTS Near Miss Log (similar to the Intervention Log), as well as input from Coast Guard units such as Coast Guard Cutters, small boat stations, and the Sector Prevention and Response personnel.

The data from the Coast Guard data sources, however, is not captured or stored in one electronic integrated enterprise data warehouse, nor can data be easily shared or exchanged between Coast Guard databases. Thus, accident and incident analysts must identify all paper and electronic data sources available from the Coast Guard, in some cases through a Freedom of Information Act (FOIA) request; once identified, the records must be gathered from the archives, standardized, formatted, and integrated into a common electronic data format using a standard data classification scheme. As will be discussed in the next section, additional data were gathered from state, local, industry, non-profit and other sources. These data were also gathered, classified, standardized, integrated and validated with the Coast Guard data records. Thus, the effort to harmonize and integrate event data into a usable electronic format consumed significant effort and time.

The Washington DOE reporting system, in contrast, relies mostly on secondary data sources, frequently the Coast Guard, for its information. DOE uses a vessel screening tool that feeds information to its MIS database for the purpose of monitoring high-interest vessels (WAC 317-31-100). DOE also uses information from the Q-Line of the Coast Guard's Notice of Arrival Reports, and reports from actions taken by the Captain of the Port, Coast Guard Form CG-2692, and WSF Rider Alert Reports (which are not captured in the Coast Guard data). Prior to 2001, when the Office of Marine Safety existed, Washington DOE collected primary data in the form of boarding and risk evaluation reports. This primary data is contained in the pre-2001 DOE records, and in the VTRA accident-incident database for events that occurred prior to 2001.

Review of the DOE data shows that DOE has electronically captured records that specifically list the Coast Guard and WSF as sources in the written comments of the records; however, much of the Coast Guard data used in DOE data sources is not integrated into the primary Coast Guard marine casualty database, MISLE. Table A-8 lists the sources of the unique DOE records. Analysis of the DOE records shows that DOE databases contain records from the Coast Guard that the Coast Guard does not have available in the MSIS or MISLE databases. Integration of all available maritime safety data into a standard format electronic data warehouse would greatly enhance analysis, reporting and data maintenance activities.

Table A-8 Unique Data Sources in Washington DOE Records, 1995-2005, (Records Not Duplicated in Other Data Sources)

Source	# of Records	% of Records
CG Form CG-2692	89	32%
ANE Q-Line	17	6%
COTP Directives	36	13%
MSO Data Reports	36	13%
NRC Fax	1	0.1%
Pilot Reports	30	11%
VTS	11	4%
Unspecified USCG	5	2%
Shipping Company Reports	5	2%
WSF Rider Alert or Reports	47	17%
Total	**277**	

Oil Spill Reporting

A final source of difference between the Coast Guard and DOE records lies in the data sources used for oil spill data. The primary source of oil spill reporting for the Coast Guard is the Coast Guard's own National Response Center. The U.S. National Response Center is a Federally-funded, Federally-mandated "one-stop" reporting source for all the Coast Guard's incoming spill information, meeting the Federal requirements for spill reporting with one (800)-number phone call. VHF, UHF, and HF radio watchstanders also monitor communications for emergency response as well.

Washington State requires reporting to the State of Washington beyond the Federal standards (RCW 88.46.100). The U.S. National Response Center also sends the State of Washington a copy of reports of oil spills upon report of an accident in the state of Washington. Any differences in oil spill reporting between USCG and DOE are usually, but not always, related to the fishing, deck barge and 300 GT vessel record differences already discussed.

Impact of Data Sources on Puget Sound VTRA Accident-Incident Database

Examination of the differences between the data sources used to construct the Puget Sound VTRA Accident-Incident database underscores the importance of using multiple data sources when constructing databases that describe complex event sequences. However, the use of multiple data sources also requires extensive validation efforts and data checking. A common data dictionary was developed to standardize data entry and analysis, following the British Columbia/Pacific States Task Force oil spill reporting data dictionary, and validation activities comprised a significant work effort.

In contrast to other studies (Merrick, et al., 1992; Harrald, et al., 1998; Grabowski, et al., 2000; van Dorp, et al., 2001), there was considerably less proprietary data provided in the Puget Sound VTRA study. Perhaps this was the result of a study borne of litigation. However, perhaps because of the limited proprietary data sources, incident report rates are much lower (43%) in this study, compared to levels of 60-80% in other marine risk assessments. Accident rates appear higher, in contrast to incident rates, although the true reporting effect may be the lack of incident data. Computing mean time between failures (MTBF) and mean time to repair (MTTR) by vessel types was possible in earlier studies; this was not possible in this study because of the absence of sufficient, often proprietary, data. Each of these items impacted the data that was available for the accident-incident database analysis.

A-5. Database Analysis

Input to the accident-incident database was closed on June 1, 2007, in order to provide adequate time for analysis within the scope of the project. However, when new data sources were identified, they were incorporated into the database and the analysis, including U.S. Coast Guard 2692 and 835 accident reports provided by U.S. Coast Guard Headquarters. Descriptive statistics were developed using SAS version 9.0. Normalization was effected using transit data by vessel types for 1996-2005 provided by the U.S. Coast Guard Sector Seattle Vessel Traffic Service and the Puget Sound Marine Exchange. Transit data for the year 1995 was not available. Event frequencies were adjusted to the differing time periods captured in the database (1995-2005) and used for normalization (1996-2005). Although some of the data did not fail normality tests, both normal and non-parametric methods were used because of small sample sizes.

The Wilcoxon test, a non-parametric alternative to the paired Student's t-test for the case of two related samples or repeated measurements, is used to verify whether population means were equal. The test is used when the data are not normally distributed and when there are two levels for the factor. The Kruskal-Wallis test is also a non-parametric method used to verify whether the population means are equal when there are three or more levels for the factor. The test is also used when the normality test for the data fails. The Chi-square distribution assumption for the test statistic is valid when the sample size at each level is greater than or equal to 5. However, since the Kruskal-Wallis test was not able to give the direction of the test results, Tukey's HSD (Honestly Significant Differences) test was used to infer the difference of several means and also to construct simultaneous confidence intervals for these differences. The Tukey's HSD assumes that the displayed variables are independent and normally distributed with identical variance and it can rank means from different levels, which is important for the statistical analysis. The Kruskal-Wallis test was primarily used since it does not require the normality assumption. However, in this report, we found that both the Kruskal-Wallis and Tukey's HSC tests on Puget Sound VTRA data had similar results.

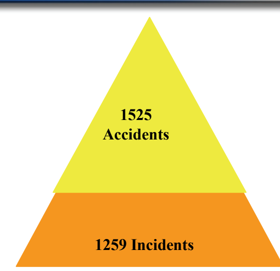
Maritime Events in Puget Sound, 1995-2005

The Puget Sound VTRA Accident-Incident database contains 2705 records of Puget Sound maritime events that occurred between 1995-2005, of which 54% (1462 events) were accidents, 43% (1159 events) were incidents, and 3.1% (84 events) were unusual events, as seen in Figure A-2. As described in the previous section, the proportion of accidents to incidents in the VTRA database is different from proportions observed in other risk assessment studies. For instance, in the 1988-1998 Washington State Ferries risk assessment, 25% of the 1229 events in the accident-incident database were accidents, and 75% of the events were incidents (Van Dorp, et al., 2001).

The proportional difference in the 1995-2005 VTRA database is attributed to a lack of available incident data, and the predominance of public, rather than proprietary, data in the database. In contrast, the 1988-1998 Washington State Ferries accident-incident database contained a great deal of proprietary machinery history data. No machinery history data and very little proprietary data were available for inclusion in the VTRA Accident-Incident database, which resulted in the accident-incident proportion illustrated in Figure A-2.

VTRA Events by Event Type, 1995-2005

Accidents	1462	54%
Incidents	1159	43%
Unusual events	84	3%
Total	2705	



- 1 accident : 0.8 incidents
- Typically, 1 accident : ~4 incidents

Figure 2

7

Figure A-3 shows these percentages in the form of an accident-incident pyramid, a representation commonly used to depict proportional relationships between accidents and incidents. Typically, the number and percentage of accidents in a safety-critical system is small, compared to the percentage of incidents; in marine transportation, a ratio of 1 accident for every 2-5 incidents is not unusual. Figure A-3 shows a greater percentage of accidents compared to incidents in the VTRA database; as just discussed, this may be related to the large number of accident records in the VTRA accident-incident database, and the absence of machinery history and proprietary incident data, as discussed previously.

An analysis of 1995-2005 accident-incident proportions by vessel type (Figure A-3) shows that ratios differ by vessel type: the ratio of accidents: incidents was greatest for fishing vessels, followed by tug-barges. These proportions were shown to be significantly different than the rest of the vessel types using the paired Wilcoxon Sign Rank Test at the 95% confidence interval (fishing>tug/barge>cargo>tanker=WSF).

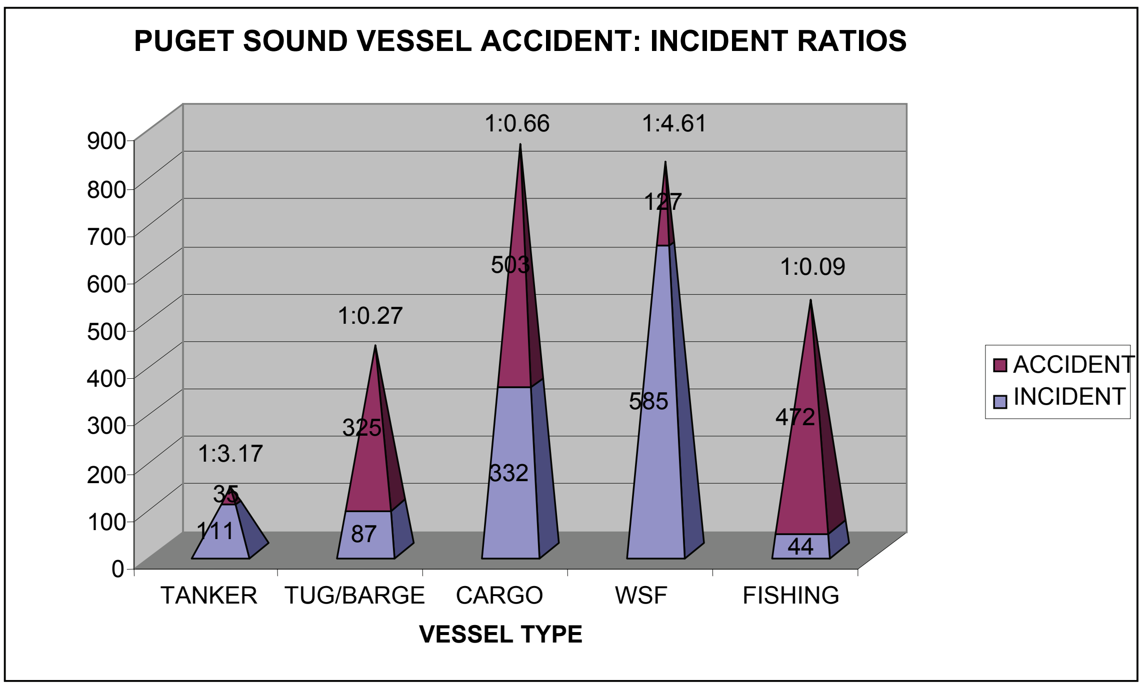


Figure A-3 Puget Sound Accident-Incident Ratios by Vessel Type, 1995-2005

Events by Year

Event frequencies varied over the time period, as seen in Figure A-4. Overall, the number of accidents and incidents has fallen dramatically since 2001; prior to 2001, the numbers of accidents and incidents were rising. As described earlier, up to and in 2001, several organizational changes occurred in the regulatory and reporting organizations, information technology and database changes occurred within those agencies, and heightened awareness and reporting was observed as a result of the events in the United States on September 11, 2001.

The event frequencies were first tested for normality. Since the normality test didn't fail, Tukey's HSD test was used, showing that years 1997-2002 had a significantly higher number of events than other years, and year 2005 had the lowest means of events. Anomalies with the accident and incident frequencies can also be noted in Figure A-4: in 1996, for instance, the number of incidents was greater than the number of accidents; similarly, in 2001, the number of accidents and incidents was identical. Analysis of the accidents shows that the year 2005 had the lowest frequency than other years in the 1995-2005 time frame; analysis of incidents using the same tests shows that the years 1996-2002 (with no differences among years 1996-2002) had significantly higher numbers of incidents than other years.

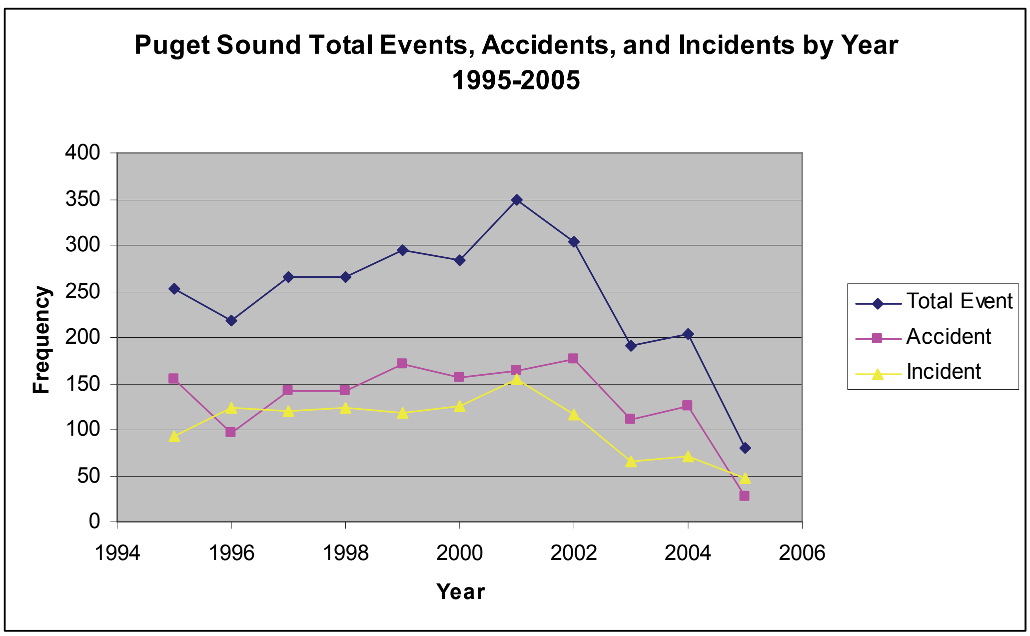


Figure A-4 Puget Sound Events and Event Types over Time, 1995-2005

Table A-9 shows the transit data from year 1996-2005 for each vessel type in Puget Sound. Note that transit data for 1995 was not available. Figure A-5 graphically illustrates the Table 9 data, and the predominance of Washington State Ferries transits, which comprised approximately 80% of all transits in Puget Sound between 1996 and 2005.

When the event data were normalized by the transit data, the results were slightly different from those obtained with the raw data, as shown in Table A-10. The normalized data test results show that years 1998-2002 had statistically higher event means than other years; for incidents, years 1996-2002 had significantly higher numbers of incidents than other years. Both raw data and normalization data test results are presented in the Table A-10.

Table A-9 Puget Sound Transit Data by Vessel Type, 1996-2005

	Tankers	%	Tug-Barge	%	Cargo	%	WSF	%	Other	%	Total
1996	2001	*1%*	24477	*10%*	12429	*5%*	196620	*81%*	7446	*3%*	**242973**
1997	2289	*1%*	30969	*13%*	16209	*7%*	176160	*76%*	7134	*3%*	**232761**
1998	2107	*1%*	25769	*11%*	13065	*6%*	180875	*80%*	3083	*1%*	**224899**
1999	2095	*1%*	27016	*12%*	9608	*4%*	194977	*83%*	801	*0%*	**234497**
2000	2557	*1%*	27553	*13%*	9551	*4%*	176567	*81%*	802	*0%*	**217030**
2001	2145	*1%*	24941	*11%*	9930	*5%*	179108	*82%*	1204	*1%*	**217328**
2002	1848	*1%*	24776	*11%*	9359	*4%*	176846	*79%*	12286	*5%*	**225115**
2003	1889	*1%*	26342	*12%*	9001	*4%*	176230	*77%*	14254	*6%*	**227716**
2004	2031	*1%*	24456	*12%*	8464	*4%*	167628	*82%*	1662	*1%*	**204241**
2005	2103	*1%*	24139	*12%*	8588	*4%*	166178	*82%*	1816	*1%*	**202824**
Total	**21065**	*1%*	**260438**	*12%*	**106204**	*5%*	**1791189**	*80%*	**50488**	*2%*	**2229384**

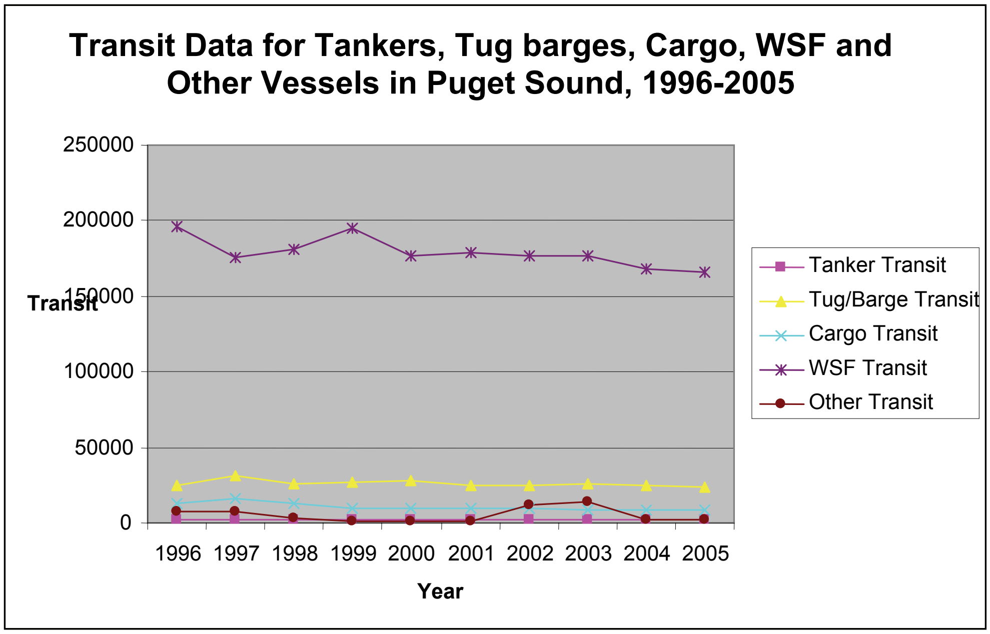


Figure A-5 Puget Sound Vessel Transits by Vessel Type, 1996-2005

Table A-10 Kruskal-Wallis and Tukey's HSD Tests Results of Raw and Normalized Total Events, Accidents and Incidents, 1995-2005

Variable		DF	Test Statistics	Test Result (Means with the same letter are not significantly different)
Raw Data (1995-2005)	Total Events	**10**	**Kruskal-Wallis: Chi-square statistic 60.1687, Pr > Chi-square <0.0001** **Tukey's HSD: F-value=11.27, Pr > F<0.0001**	**A:2001 2002 1999 2000 1997 1998 1995 B:2002 1999 2000 1997 1998 1995 1996 C: 1999 2000 1997 1998 1995 1996 2004 D: 2000 1997 1995 1996 2004 2003 E:2005** A>B>C>D>E
	Accidents	**10**	**Kruskal-Wallis: Chi-square statistic 51.6289, Pr > Chi-square <0.0001** **Tukey's HSD: F-value=8.88, Pr >F <0.0001**	**A:2002 1999 2001 2000 1995 1997 1998 2004 2003 B:2000 1995 1997 1998 2004 2003 1996 C: 2005** A>B>C
	Incidents	**10**	**Kruskal-Wallis: Chi-square statistic 56.7266, Pr> Chi-square < 0.0001,** **Tukey's HSD: F-value=8.61, Pr >F <0.0001**	**A:2001 2000 1998 1996 1997 1999 2002 B: 2000 1998 1996 1997 1999 2002 1995 C:1997 1999 2002 1995 2004 D: 1995 2004 2003 2005** A>B>C>D
Normalized Data (1996-2005)	Total Events	**9**	**Kruskal-Wallis: Chi-square statistic 59.0563, Pr > Chi-square <0.0001** **Tukey's HSD: F-value=13.40, Pr >F <0.0001**	**A:2001 2002 2000 1999 1998 B:2002 2000 1999 1998 1997 2004 C:2000 1999 1998 1997 2004 1996 D:1999 1998 1997 2004 1996 2003 E:2005** A>B>C>D>E
	Accidents	**9**	**Kruskal-Wallis: Chi-square statistic 51.1032, Pr > Chi-square =0.0017** **Tukey's HSD: F-value=9.94, Pr >F <0.0001**	**A:2002 2001 2000 1999 1998 2004 1997 B: 2001 2000 1999 1998 2004 1997 2003 C: 1998 2004 1997 2003 1996 D: 1996 2005** A>B>C>D
	Incidents	**9**	**Kruskal-Wallis: Chi-square statistic 51.1060, Pr> Chi-square < 0.0001** **Tukey's HSD: F-value=8.97, Pr >F <0.0001**	**A: 2001 2000 1998 2002 1997 1996 1999 B: 1998 2002 1997 1996 1999 2004 C: 1999 2004 C:1999 2004 2003 D: 2004 2003 2005** A>B>C>D

Bold results are statistically significant

Events by Vessel Type

Between 1995 and 2005, events in Puget Sound occurred to different vessels, as seen in Table A-11 and Figure A-6. The bulk of accidents between 1995 and 2005 occurred to cargo vessels (34%) and fishing vessels (32%). A paired Wilcoxon test shows that the proportion of accidents to total accidents occurring to cargo and fishing vessels was statistically higher over the time period than other vessels at the 95% confidence level. In contrast, most incidents between 1995 and 2005 occurred to Washington State Ferries (WSF) (50%) and cargo vessels (29%). A Wilcoxon test of proportions of the WSF incident frequencies shows the proportions to be statistically significant at the 95% confidence level, followed by cargo vessels. Finally, cargo vessels experienced the most (56%) of the 84 unusual events recorded in the database between 1995 and 2005. Thus, proportionally, cargo vessels experienced significantly more accidents, the 2nd-most level of incidents, and significantly more unusual events during the reporting period. Note that some of the data in Table A-11 are limited by small sample sizes.

Table A-11 Puget Sound Events by Vessel Type, 1995-2005

Event Type	Tankers	%	Tug-Barge	%	Cargo	%	WSF	%	Fishing	%	Total
Accidents	35*	*2%*	325	*22%*	**503**	*34%*	127	*9%*	**472**	*32%*	1462
Incidents	111	*10%*	87	*8%*	**332**	*29%*	**585**	*50%*	44	*4%*	1159
Unusual Events	25*	*30%*	9*	*11%*	**47**	*56%*	1*	*1%*	2*	*2%*	84
Total Events	171		421		882		713		518		2705

Bold results are statistically significant *** = small sample size**

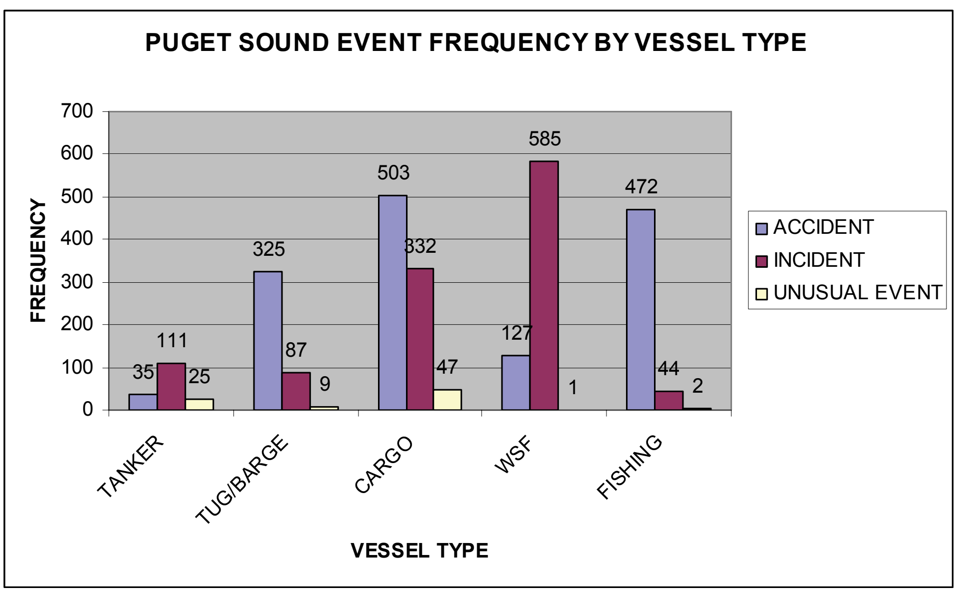


Figure A-6 Puget Sound Events by Vessel Type, 1995-2005

Normalizing the Table A-11 accident and incident data with the Table A-9 transit data provides normalized accident and incident rates by vessel types for the period 1996-2005, shown in Tables A-12 and A-13, which allows comparison of accident and incident rates for different vessel types using numbers of transits as a surrogate for exposure. Transit data for the year 1995 was not available from the U.S. Coast Guard.

Table A-12 Normalized Events by Transits, 1996-2005

	Tankers	Tug-Barge	Cargo	WSF	Fishing	Total
Accidents	0.001662*	0.001248	**0.004736**	7.09E-05	0.009349	0.000656
Incidents	**0.005269**	0.000334	**0.003126**	0.000327	0.000871	0.00052
Unusual Events	0.001187*	3.46E-05*	0.000443	5.58E-06*	3.96E-05*	3.77E-05
Total Events	**0.008118**	0.001617	**0.008305**	0.000398	0.01026	0.001213

*** = small sample size** **Bold results are statistically significant**

Results of the Kruskal-Wallis test showed that there were statistical differences for the normalized events, accidents, and incidents among the different vessel types. By using both Kruskal-Wallis and Tukey's HSD tests, cargo and tanker vessels were found to have significantly higher numbers of normalized events, compared to tug-barges and Washington State Ferries, over the period 1996-2005, as shown in Table A-13. Cargo vessels were shown to have significantly higher numbers of normalized accidents over the time period, compared to the other vessel types. Tanker vessels were shown to have significantly higher numbers of normalized incidents over the time period, compared to the other vessel types. The normalized results are statistically different from the raw data results, as raw tanker incidents and total events were not statistically significant, while the normalized incidents for tankers are.

Table A-13 Kruskal-Wallis and Tukey's HSD Test Result, Raw and Normalized Events Types by Vessel Types, 1995-2005

Variable		DF	Test Statistics	Direction
Raw Data 1995-2005	Total Event	4	Kruskal-Wallis: Chi-square statistic 34.2814, Pr > Chi-square <0.0001 Tukey's HSD: F value= 19.24, Pr>F <0.0001	**A: Cargo = WSF B: WSF Fishing C: Fishing Tug/barge D: Tanker A>B>C>D**
	Accident	4	Kruskal-Wallis: Chi-square statistic 39.0843, Pr > Chi-square <0.0001 Tukey's HSD: F Value =26.82, Pr>F <0.0001	**A: Cargo Fishing B: Fishing Tug/barge C: WSF Tanker* A>B>C**
	Incident	4	Kruskal-Wallis: Chi-square statistic 40.7493, Pr > Chi-square <0.0001 Tukey's HSD: F Value= 39.92, Pr>F <0.0001	**WSF> Cargo> Tanker= Tug/barge = Fishing**
Normalized Data 1996-2005	Total Event	3	Kruskal-Wallis: Chi-square statistic 32.9020, Pr > Chi-square <0.0001 Tukey's HSD: F value= 19.17, Pr>F <0.0001	**Cargo=Tanker>Tug/barge=WSF**
	Accident	3	Kruskal-Wallis: Chi-square statistic 27.3205, Pr > Chi-square <0.0001 Tukey's HSD: F Value =26.53, Pr>F <0.0001	**A: Cargo B: Tanker* Tug/barge C: Tug/barge WSF A>B>C**
	Incident	3	Kruskal-Wallis: Chi-square statistic 24.1537, Pr > Chi-square <0.0001 Tukey's HSD: F Value= 20.99, Pr>F <0.0001	**Tanker>Cargo>Tug/barge=WSF**

Bold results are statistically significant *** = small sample size**

Additional analysis was undertaken to determine whether there were statistically significant differences between raw and normalized accident and incident frequencies for all vessel types (Table A-14). Comparing the raw and normalized accident:incident frequencies using a Wilcoxon test shows that for both raw and normalized events, tankers and WSF had significantly higher incident frequencies than accident frequencies; and tug-barges and cargo ships had significantly higher accident frequencies than incident frequencies (Table A-14). Note that the results for tanker accidents were limited by small sample sizes.

Table A-14 Wilcoxon Test and P-value of Normalized and Raw Accidents and Incidents, 1995-2005, Tankers, Tug-Barges, Cargo Ships, WSF, and Fishing Vessels

Variable		N	Test statistic	Normal approximate Z	Two-sided Pr> $\lvert Z \rvert$	Direction
Raw Data (1995-2005)	Tanker	11	81.5000	-2.9760	**0.0029**	Incident>Accident*
	Tug/barge	11	178.5000	3.4184	**0.0006**	Accident>Incident
	Cargo	11	166.0000	2.5938	**0.0095**	Accident>Incident
	WSF	11	70.5000	-3.6856	**0.0014**	Incident>Accident
	Fishing	11	184.5000	3.8237	**0.0001**	Accident>Incident
Normalized Data (1996-2005)	Tanker	10	70.5000	-2.6089	**0.0173**	Incident>Accident*
	Tug/barge	10	148.0000	3.2505	**0.0012**	Accident>Incident
	Cargo	10	132.0000	2.0410	**0.0413**	Accident>Incident
	WSF	10	59.0000	-3.4773	**0.0005**	Incident>Accident

* = small sample size **Bold results are statistically significant**

Events by Location

Events in Puget Sound occurred in different geographical areas, as can be seen in Table A-15 and Figure A-7. South Puget Sound had the most events from 1995 to 2005. Kruskal-Wallis and Tukey's HSD tests were used to analyze the differences between the frequency of events, accidents, and incidents in the different zones; the number of events occurring in South Puget Sound was significantly higher than those occurring in other areas at the 95% confidence level (Table A-16). Events by location were not able to be normalized by transits because transit data by location was not available. Note that the data in Tables A-15 and A-16 are limited by small sample sizes.

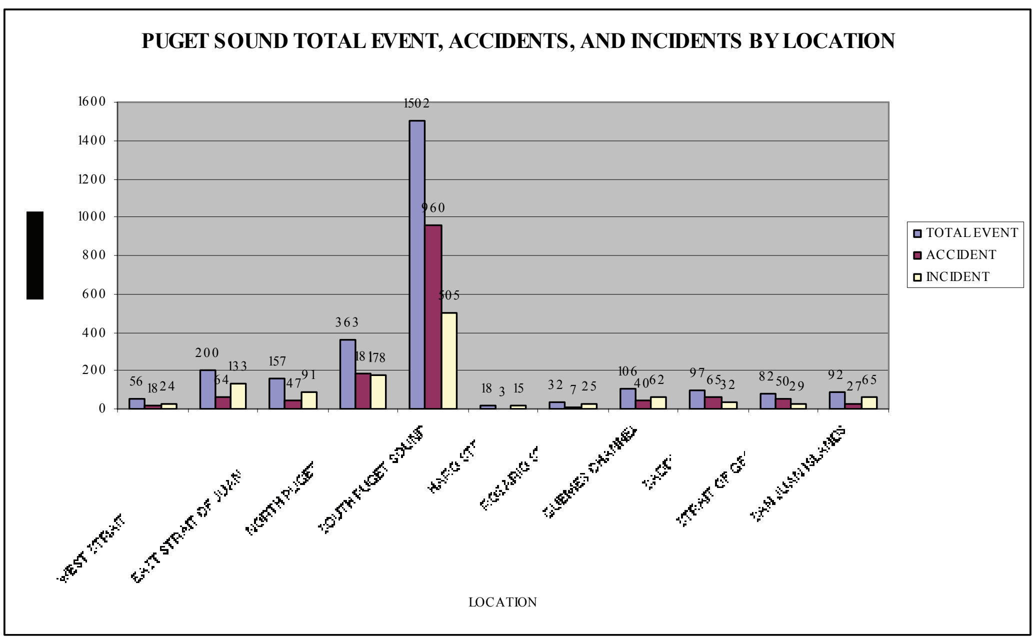


Figure A-7 Puget Sound Event Types by Location, 1995-2005

Table A-15 Puget Sound Events, Accidents, Incidents and Unusual Events by Location, 1995 – 2005

Zone	Total Events		Accident		Incident		Unusual Event	
	N	%	N	%	N	%	N	%
West Strait of Juan de Fuca	200	7.4%	64	4.4%	133	11.5%	3*	3.6%
East Strait of Juan de Fuca	157	5.8%	47	3.2%	91	7.9%	19*	22.6%
North Puget Sound	363	13.4%	181	12.4%	178	15.4%	4*	4.8%
South Puget Sound	**1502**	**55.5%**	**960**	**65.7%**	**505**	**43.6%**	**37**	**44.0%**
Haro Strait / /Boundary Pass	18*	0.7%	3*	0.2%	15*	1.3%	0	0.0%
Rosario Strait	32*	1.2%	7*	0.5%	25*	2.2%	0	0.0%
Guemes Channel	106	3.9%	40	2.7%	62	5.3%	4*	4.8%
Saddlebag	97	3.6%	65	4.4%	32*	2.8%	0	0.0%
Strait of Georgia /Cherry Point	82	3.0%	50	3.4%	29*	2.5%	3*	3.6%
San Juan Islands	92	3.4%	27*	1.8%	65	5.6%	0*	0%
Unknown	56	2.1%	18*	1.2%	24*	2.1%	14*	16.7%
Total	**2705**		**1462**		**1159**		**84**	

*** = small sample size** **Bold results are statistically significant**

Table A-16 Kruskal-Wallis and Tukey's HSD Test Results for Raw Events by Locations, 1995-2005

Variable	DF	Test Statistics	Direction
Total Events	**9**	Kruskal-Wallis: Chi-square statistic 80.7694, Pr>Chi-square<0.0001 Tukey's HSD: F-value= 81.20, Pr >F <0.0001	**Location South Puget Sound had higher number of events than other locations***
Accidents	**9**	Kruskal-Wallis: Chi-square statistic 79.5272, Pr > Chi-square <0.0001 Tukey's HSD: F-value =79.24, Pr >F <0.0001	**Location South Puget Sound had higher number of accident frequency than other locations***
Incidents	**9**	Kruskal-Wallis: Chi-square statistic 79.2347, Pr > Chi-square <0.0001 Tukey's HSD: F-value= 44.79, Pr >F <0.0001	**Location South Puget Sound had higher number of incident frequency than other locations***

*** = small sample size** **Bold results are statistically significant**

Events by Season

Events in Puget Sound between 1995-2005 varied by season, as seen in Tables A-17 and A-18. Per input from Puget Sound experts, summer was defined as the months from May to September; winter was defined as the months from November to March. As can be seen in Table A-17, most of the events between 1995 and 2005 occurred in the summer and winter seasons (39.9% and 37.7%, respectively). Accidents occurred most often in the summer (42.4%) and in the winter (39.1%). Incidents occurred most often in the summer (36.5%) and winter (35.5%) as well. For raw numbers of events, a Tukey's HSD test showed that summer and winter had significantly higher number of events, accidents, and incidents than autumn and spring did, and summer was the most significant event period for all event types (Table A-19).

However, when the data were normalized by transits, spring and autumn had a significantly higher number of normalized total events and incidents, compared to winter and summer, and no differences for the normalized accidents were noted among the four seasons. This is another example of the importance of normalizing results by transits. The differing results for the normalized data may be because for the raw data, summer and winter have many more events than spring and autumn since summer was assumed from May to September and winter from November to March, while spring and autumn had just one month, April and October separately. For the normalized data, the transits are higher because there are five months in those seasons. Therefore, there is no statistically significant difference for normalized total events and accidents.

Table A-17 Puget Sound Events by Season, 1995-2005

Year	Total			Spring			Summer			Autumn			Winter		
	Event	Accident	Incident	Event	Accident	Incident	Event	Accident	Incident	Event	Accident	Incident	Event	Accident	Incident
1995	253	154	93	26*	12*	14*	94	64	28*	26*	11*	15*	107	67	36*
1996	219	96	123	26*	6*	20*	91	46	45	44	17*	27*	58	27*	31*
1997	265	142	120	33*	14*	19*	86	51	35*	40	19*	21*	106	58	45
1998	265	141	124	42	10*	32*	91	54	37*	34*	15*	19*	98	62	36*
1999	294	171	118	30*	16*	14*	130	81	48	40	18*	22*	94	56	34*
2000	283	156	126	31*	9*	22*	120	67	52	27*	12*	15*	105	68	37*
2001	349	164	154	35*	14*	21*	151	76	60	40	14*	20*	123	60	53
2002	303	176	117	34*	21*	13*	126	79	44	20*	10*	7*	123	66	53
2003	191	110	66	15*	13*	2*	69	38*	23*	16*	9*	7*	91	50	34*
2004	203	125	71	21*	11*	10*	85	53	29*	17*	13*	1*	80	48	31*
2005	80	27	47	6*	4*	2*	36*	11*	22*	4*	2*	2*	34*	10*	21*
Total	**2705**	**1462**	**1159**	**299**	**130**	**169**	**1079**	**620**	**423**	**308**	**140**	**156**	**1019**	**572**	**411**

* = small sample size

Table A-18 Puget Sound Normalized Events by Season (Normalized by Transits), 1996-2005

Year	Spring	Normalized data			Summer	Normalized data			Autumn	Normalized data			Winter	Normalized data		
	Transits	Event	Accident	Incident	Transits	Event	Accident	Incident	Transits	Event	Accident	Incident	Transits	Event	Accident	Incident
1996	21776	0.0012	0.0006	0.0006	107320	0.0009	0.0006	0.0003	17944	0.0014	0.0006	0.0008	95933	0.0011	0.0007	0.0004
1997	17839	0.0015	0.0003	0.0011	92696	0.0010	0.0005	0.0005	21457	0.0021	0.0008	0.0013	100769	0.0006	0.0003	0.0003
1998	17395	0.0019	0.0008	0.0011	96358	0.0009	0.0005	0.0004	17639	**0.0023**	0.0011	0.0012	93507	0.0011	0.0006	0.0005
1999	17556	0.0024	0.0006	0.0018	104966	0.0009	0.0005	0.0004	19686	**0.0017**	0.0008	0.0010	92289	0.0011	0.0007	0.0004
2000	18589	0.0016	0.0009	0.0008	95194	0.0014	0.0009	0.0005	17090	0.0023	0.0011	0.0013	86157	0.0011	0.0007	0.0004
2001	17738	**0.0017**	0.0005	0.0012	95379	0.0013	0.0007	0.0005	20066	**0.0013**	0.0006	0.0007	84145	0.0012	0.0008	0.0004
2002	18319	**0.0019**	0.0008	0.0011	95534	0.0016	0.0008	0.0006	18303	0.0022	0.0008	0.0011	92959	0.0013	0.0006	0.0006
2003	19458	0.0017	0.0011	0.0007	97023	0.0013	0.0008	0.0005	18303	0.0011	0.0005	0.0004	92932	0.0013	0.0007	0.0006
2004	16346	0.0009	0.0008	0.0001	87806	0.0008	0.0004	0.0003	17458	0.0009	0.0005	0.0004	82631	0.0011	0.0006	0.0004
2005	16409	0.0013	0.0007	0.0006	87421	0.0010	0.0003	0.0003	16839	0.0010	0.0008	0.0001	82155	0.0010	0.0006	0.0004

Bold results are statistically significant

Table A-19 Kruskal-Wallis and Tukey's HSD tests of Raw and Normalized Events, Accidents, and Incidents by Season, 1996-2005

Variable		DF	Test statistic	Direction
Raw	Total Events	3	Kruskal-Wallis: Chi-square statistic 29.3489, Pr>Chi-square <0.0001 Tukey's HSD: F-value=56.31, Pr >F <0.0001	**Summer=Winter>Autumn =Spring***
	Accidents	3	Kruskal-Wallis: Chi-square statistic 29.4899, P>Chi-square <0.0001 Tukey's HSD: F-value=69.62, Pr >F <0.0001	**Summer=Winter > Autumn = Spring***
	Incidents	3	Kruskal-Wallis: Chi-square statistic 27.5853, P>Chi-square < 0.0001 Tukey's HSD: F-value=21.83, Pr >F <0.0001	**Summer=Winter > Spring= Autumn***
Normalized	Total Events	3	Kruskal-Wallis: Chi-square statistic 13.2963, P>Chi-square =0.0040 Tukey's HSD: F-value=6.71, Pr >F =0.0012	**Autumn=Spring> Winter =Summer***
	Accidents	3	Kruskal-Wallis: Chi-square statistic 1.0841, P>Chi-square =0.7809 Tukey's HSD: F-value=0.78, Pr >F =0.5154	**N/A**
	Incidents	3	Kruskal-Wallis: Chi-square statistic 14.9298, P>Chi-square =0.0019 Tukey's HSD: F-value=8.07, Pr >F =0.0004	**Spring=Autumn> Winter =Summer***

*** = small sample size** **Bold results are statistically significant**

When a seasonality index was constructed to assess the likelihood of events, accidents, and incidents in Puget Sound by season between 1995 and 2005, this analysis (Table A-20) showed that events occurred more often in summer and winter than in the spring and autumn, due to the longer periods; for normalized events, spring and autumn had slightly more events than summer and winter. Note again that these data are also limited by small sample sizes.

Table A-20 Raw and Normalized Seasonal Index for Total Events, Accidents, and Incidents, 1996-2005

Season	Raw Seasonal Index		
	Total Events	Accidents	Incidents
Spring	0.444	0.350	0.590
Summer	1.585	1.679	1.460
Autumn	0.450	0.375	0.555
Winter	1.536	1.591	1.408
	Normalized Seasonal Index		
Spring	1.190477	1.048649	1.399870
Summer	0.801881	0.931193	0.666871
Autumn	1.194303	1.091444	1.260790
Winter	0.813435	0.9281	0.67253

Events by Time of Day

Events that occurred in the Puget Sound VTRA area between 1995 and 2005 were characterized as occurring during the day or night. Per input from Puget Sound maritime experts, day was defined from 6am to 8pm in the spring and summer and 7am to 7pm in the autumn and winter. The data collected are shown in the Table A-21.

Table A-21 Total Events, Accidents, and Incidents by Day and Night
N: Number of Frequency; %: Percent of Frequency, 1995-2005

Time of Day	Total Events		Accidents		Incidents	
	N	%	N	%	N	%
Day	1317	48.7	771	52.7	526	45.4
Night	510	18.9	208	14.2	293	25.3
Null	878	32.4	483	33.0	340	29.3
Total	**2705**	**100**	**1462**	**100**	**1159**	**100**

From Table A-21, it can be seen most total events, accidents, and incidents occurred during the day. One of the obvious reasons is that there are more transits, particularly for WSF vessels, which comprise 80% of all transits, during the day than at night. A Wilcoxon test (Table A-22) on the raw data showed no statistical differences between total events and accident frequencies between day and night. However, vessels had a statistically higher number of incidents during the day than the night. Caution is noted with the results in Table A-22, however, because of the high proportion of null values for day and night. In addition, normalization by transit data was not available by time of day.

Table A-22 Wilcoxon Test on the Total Events, Accidents, and Incidents Frequencies by Time of Day, 1995-2005

Variable	N	Test statistic	Normal approximate Z	Two-sided Pr> $\|Z\|$	Direction
Total Events	**11**	153.5000	1.7735	0.0762	N/A
Accidents	**11**	152.5000	1.7087	0.0875	N/A
Incidents	**11**	156.5000	1.9739	**0.0484**	**Day>Night**

Bold results are statistically significant

Events by Vessel Flag

Events of interest that occurred in the Puget Sound VTRA area between 1995 and 2005 occurred aboard vessels of varying flags, as seen in Figure A-8 and in Table A-24. More events occurred to U.S. flag vessels during the reporting period than to non-U.S. flag vessels; these differences were significant at the 95% confidence level using the Wilcoxon test (Table A-23).

Similarly, significantly more accidents (1028, 70.3%) occurred to U.S. flag vessels than to non-U.S. flag vessels; these differences were found to be significant at the 95% level, using the Wilcoxon test. A similar pattern was observed in total numbers of incidents over the time period, with 72.9% of the incidents occurring to U.S.-flag vessels. These differences were found to be significant at the 95% level using the Wilcoxon test. Unfortunately, transit data was not available by vessel flags to compare normalized results.

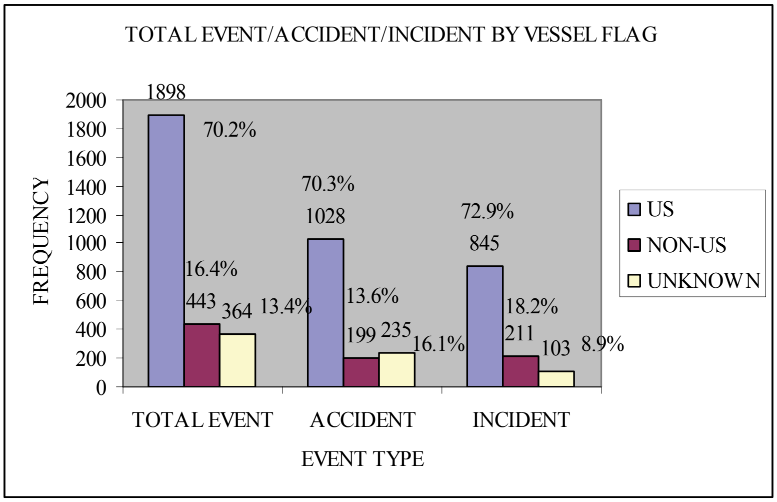


Figure A-8 Puget Sound Accident and Incident Frequencies by Vessel Flag, 1995-2005

Table A-23 Wilcoxon Test on Total Events, Accidents, Incidents by Vessel Flag, 1995-2005

Variable	N	Test statistic	Normal approximate Z	Two-sided Pr> $\|Z\|$	Direction
Total Events	**11**	184.0000	3.7768	**0.0002**	**U.S.>Non U.S.**
Accidents	**11**	179.5000	3.4871	**0.0005**	**U.S.>Non U.S.**
Incidents	**11**	187.0000	3.9795	**<0.0001**	**U.S.>Non U.S.**

Bold results are statistically significant

Events occurred to vessels of various flags, as seen in Table A-24.

Table A-24 Puget Sound Total Events, Accidents and Incidents by Vessel Flag, 1995-2005

Vessel Flag	Total Events		Accidents		Incidents	
	N	%	N	%	N	%
U.S.	1898	70.2	1028	70.3	845	72.9
Bahamas	34*	1.25	11*	0.75	23*	1.98
Canada	34*	1.25	28*	1.92	6*	0.52
Cyprus	21*	0.78	10*	0.68	11*	0.95
Liberia	40	1.48	15*	1.03	20*	1.72
Panama	84	3.10	30*	2.05	45	3.88
Russia	37*	1.37	31*	2.12	6*	0.52
Singapore	25*	0.9	5*	0.34	18*	1.55
Other	168	6.2	69	4.72	82	7.1
Unknown	364	13.4	235	16.1	103	8.9
Total	**2705**	**100**	**1462**	**100**	**1159**	**100**

*** = small sample size**

A subset of Table A-24, events that occurred to non-U.S. flag vessels between 1995 and 2005, is shown in Table A-25.

Table A-25 Puget Sound Non U.S. Flag Events, 1995-2005

Vessel Flag	Total Events		Accidents		Incidents	
	N	%	N	%	N	%
Bahamas	34*	7.7	11*	5.5	23*	10.9
Canada	34*	7.7	**28***	**14.1**	6*	2.8
Cyprus	21*	4.7	10*	5	11*	5.2
Liberia	40	9.0	15*	7.5	20*	9.5
Panama	**84**	**19.0**	**30***	**15.1**	**45**	**21.3**
Russia	37*	8.4	**31***	**15.3**	6*	2.8
Singapore	25*	5.6	5*	2.5	18*	8.5
Other	168	37.9	69	34.7	82	38.9
Total	443	100	199	100	211	100

*** = small sample size** **Bold results are statistically significant**

Table A-25 shows that, of the non-U.S. flag events that occurred between 1995 and 2005, 19% of events, 15.1% of accidents, and 21.3% of incidents occurred to Panamanian flag vessels. A group of 'other' non U.S. flag vessels—other than Bahamian, Canadian, Cypriot, Liberian, Panamanian, Russian and Singapore—comprised the largest group of non U.S.-flag events (37.9% of events, 34.7% of accidents, and 38.9% of incidents). Using the Kruskal-Wallis and Tukey's HSD tests upon raw data, the results show that Panamanian flag vessels had significantly higher total events and incident frequencies then vessels from other flags. In addition, Canadian, Panamanian and Russian flag vessels had significantly higher accident frequencies than vessels from other flags (Table A-26). Note that these data are limited by small sample sizes, and transit data by flag was not available to normalize the data.

Table A-26 Kruskal-Wallis and Tukey's HSD tests of Raw Events, Accidents, and Incidents Frequencies by Foreign Vessel Flag, 1995-2005

Variable	DF	Test Statistics	Direction
Total Events	**6**	Kruskal-Wallis: Chi-square statistic 21.0342, P>Chi-square =0.0026 Tukey's HSD: F-value= 32.65, Pr >F <0.0001	**Panama> Bahamas= Canada =Cyprus =Liberia = Russia =Singapore**
Accidents	**6**	Kruskal-Wallis: Chi-square statistic 21.5897, P>Chi-square =0.0014	**Panama= Canada= Russia> Bahamas =Cyprus =Singapore**
Incidents	**6**	Kruskal-Wallis: Chi-square statistic 23.0145, P>Chi-square =0.0011 Tukey's HSD: F-value =17.20, Pr >F <0.0001	**Panama> Bahamas= Canada =Cyprus =Liberia = Russia =Singapore**

*** = small sample size**

Events by Owner

An analysis of events by vessel owner is presented in Table A-27. Note that vessel owner data is dynamic, as some vessel owners may no longer exist, or some vessels may have changed their operators during the period for which the database captures information. Table A-27 presents event information for owners that have more than 30 events between 1995 and 2005, excluding the Washington State Ferries.

Table A-27 Puget Sound Events by Vessel Owners, 1995-2005

OWNER	Total Events		Accidents		Incidents	
	N	%	N	%	N	%
Foss	68	100	54	79.4	10*	14.7
U.S. Navy	56	100	44	78.6	9*	16.1
Crowley	56	100	46	82.1	10*	17.9
U.S. Coast Guard	44	100	44	100	0	0
Clipper Navigation, Inc.	36*	100	12*	33.3	22*	61.1
Olympic Tug and Barge, Inc.	30*	100	23*	76.7	7*	23.3

N: Number of total events, accidents, incidents; %: Percent of accidents or incidents of total events

*** = small sample size**

In Table A-27, it can be seen that most of the vessel owners in the table have higher accident frequencies than incident frequencies, except Clipper Navigation, Inc. There are differences between different owners with respect to accident and incident frequencies, as seen in Table A-28; however, a Kruskal-Wallis and Tukey's HSD analysis on the raw data show no significant differences for total events among the vessel owners. Transit data by owner was not available to normalize this data.

Table A-28 Kruskal-Wallis and Tukey's HSD tests of Raw Events, Accidents, and Incidents by Vessel Owner, 1995-2005

Variable	DF	Test Statistics	Direction
Total Events	**5**	Kruskal-Wallis: Chi-square statistic 8.3655, P>Chi-square =0.1390	N/A
Accidents	**5**	Kruskal-Wallis: Chi-square statistic 20.9822, P>Chi-square =0.0010 Tukey's HSD: F-value=4.60, Pr >F=0.0016	**A: Foss Crowley US Navy USCG Olympic Tug and Barge B: Olympic Tug and Barge, Clipper A>B ***
Incidents	**5**	Kruskal-Wallis: Chi-square statistic 11.6234, P>Chi-square =0.0440 Tukey's HSD: F value 2.56, Pr>F 0.0445	**A: Clipper, Crowley, Foss, US Navy, Olympic Tug and Barge B: Crowley, Foss, US Navy, Olympic Tug and Barge, USCG A>B ***

*** = small sample size** **Bold results are statistically significant**

Events by Classification Society

Class society information for the VTRA accident-incident records were obtained from Lloyd's List. Although the classification society for vessels can vary over time, the classification society for the vessel at the time of the recorded event was captured in the database. The major classification societies include the American Bureau of Shipping (ABS), Det Norske Veritas Classification A/S (DNV), Nippon Kaiji Kyokai (NK), and Lloyd's Register (LR). Total events, accidents, incidents, and unusual events by vessel registered with various class societies are found in the Table A-29. Note that much of the data in Table A-29 and the results in Table A-30 are limited by small sample sizes.

Table A-29 Puget Sound Event Types by Classification Society, 1995-2005

Class Society	Total Events	Accidents	Incidents	Unusual Events
ABS	318	166	131	21*
Bureau Veritas (BV)	20*	12*	5*	3*
China Classification Society (CS)	8*	1*	3*	4*
China Corp. Register of Shipping (CR)	2*	0	1*	1*
Croatian Register of Shipping (HV)	1*	0	1*	0
Germanischer Lloyd (GL)	24*	7*	12*	5*
Korean Register of Shipping (KR)	12*	4*	4*	4*
Lloyd's Register (LR)	27*	15*	10*	2*
Nippon Kaiji Kyokai (NK)	70	19*	36*	15*
Det Norske Veritas Classification A/S (DNV)	83	36*	40	7*
Registro Italiano Navale (RINA)(RI)	5*	2*	2*	1*
Russian Maritime Register of Shipping (RS)	20*	14*	6*	1*
Null	2115	1186	908	20
Total	**2705**	**1462**	**1159**	**84**

*** = small sample size**

Kruskal-Wallis and Tukey's HSD tests on the class society data showed that ABS class vessels had a statistically higher number of total events, accidents, and incidents than those belonging to other classification societies (Table A-30). Normalization data by vessel class was not available for this analysis.

Table A-30 Kruskal-Wallis and Tukey's HSD tests of Raw Events, Accidents and Incidents by Class Society

Variable	DF	Test Statistics	Direction
Total Events	3	Kruskal-Wallis: Chi-square statistic 30.4518, P>Chi-square <0.0001 Tukey's HSD: F-value=34.16, Pr >F <0.0001	**ABS>DNV=NK=LR***
Accidents	3	Kruskal-Wallis: Chi-square statistic 26.6617, P>Chi-square <0.0001 Tukey's HSD: F-value= 54.05, Pr >F <0.0001	**ABS>DNV*=NK*=LR***
Incidents	3	Kruskal-Wallis: Chi-square statistic 28.0562, P>Chi-square <0.0001 Tukey's HSD: F-value= 20.21, Pr >F <0.0001	**ABS>DNV*=NK*=LR***

*** = small sample size** **Bold results are statistically significant**

Events by Weather Conditions

Weather condition information for every record in the VTRA database was not available.

Events by Direction (Inbound/Outbound)

Information about the direction in which the vessel was traveling was available for some events from CG 2692 and 835 reports. Note that of the 2705 events in the database, directional information was only available for 110 of those events. Of the 110, 92 events occurred to inbound vessels and 18 events occurred to outbound vessels. The accident, incident and unusual event records are shown in Table A-32. Note that the data in Tables A-31 and A-32 are limited by small sample sizes.

Table A-31 Puget Sound Events by Direction, 1995-2005

DIRECTION	Total Events		Accidents		Incidents		Unusual Events	
	N	%	N	%	N	%	N	%
Inbound	92	100	5*	5.4	86	93.5	1*	1.1
Outbound	18*	100	0*	0	14*	77.8	4*	22.2
Total	**110**	**100**	**5***	**4.5**	**100**	**90.9**	**5***	**4.5**

*** = small sample size**

In Table A-31, both inbound and outbound vessels have many more incidents than accidents. A Wilcoxon test on the data in Table A-32 shows that inbound vessels had significantly higher numbers of total event and incident frequencies than did outbound vessels. No significant differences were found for accident frequencies for inbound vessels and outbound vessels. Note that the small percentage of records with directionality information suggest that these results may or may not be representative of data for the entire VTRA area.

Table A-32 Wilcoxon tests on total event/accident/incident frequency by Direction

Variable	N	Test statistic	Normal approximate Z	Two-sided Pr> $\|Z\|$	Direction
Total Events	**11**	172.500	3.0474	**0.0023**	**Inbound>Outbound***
Accidents	**11**	143.000	1.8166	0.0693	N/A
Incidents	**11**	170.500	2.9421	**0.0033**	**Inbound>Outbound ***

*** = small sample size** **Bold results are statistically significant**

Events by Accident/Incident Type

Ten types of accidents were captured in the Puget Sound VTRA accident-incident database: pollution, allisions, breakaways, capsizings, collisions, fire and/or explosions, flooding, groundings, salvage, and sinkings (Table A-33). Six types of incidents were also captured:

equipment failures, loss of power, loss of propulsion, loss of steering, near misses, and structural failure and/or damage (Table A-34). Note that much of the data, and the results in Table A-35, are limited by small sample sizes.

Table A-33 Puget Sound Accident Frequency by Accident Type, 1995-2005

Accident Type	Allision	Breakaway	Capsize	Collision	Fire/explosion
Frequency	204	8 *	12 *	50	55
Accident Type	**Flooding**	**Grounding**	**Pollution**	**Salvage**	**Sinking**
Frequency	25 *	65	1005	0 *	38 *

***= small sample size**

Table A-34 Puget Sound Incident Frequency by Incident Type, 1995-2005

Incident Type	Equipment Failure	Loss of power	Loss of propulsion	Loss of steering	Near miss	Structural failure/damage	Loss of anchor
Frequency	744	30 *	227	67	40	42	9*

- **= small sample size**

Tables A-33 and A-34 show that the predominant accident type is pollution, and the leading incident type is equipment failure. Kruskal-Wallis and Tukey's HSD tests also showed that there were statistical differences among accident and incident types (Table A-35), although the results were limited by small sample sizes.

Table A-35 Kruskal-Wallis and Tukey's HSD test results on Accident and Incident types, 1995-2005

Variable	DF	Test Statistics	Direction
Accident Type	**9**	Kruskal-Wallis: Chi-square statistic 69.4233, P>Chi-square <0.0001 Tukey's HSD: F-value= 78.22, Pr >F <0.0001	**A:Pollution B:Allision, Grounding Fire, Collision C:Grounding Fire, Collision, Sinking, Flooding, Capsize, Breakaway A>B>C**
Incident Type	**3**	Kruskal-Wallis: Chi-square statistic 58.1122, P>Chi-square <0.0001 Tukey's HSD: F-value= 81.11, Pr >F <0.0001	**A:Equipment failure B:Loss of Propulsion, C:Loss of steering, Structural Failure, Near miss, Loss of Power, Loss of Anchor A>B>C**

*** = small sample size** **Bold results are statistically significant**

Events by Error Type

Events were initially categorized according to their causes, using Reason's (1997) human error framework. Confirmation of the event analysis was undertaken by requesting additional records from the U.S. Coast Guard and the Washington Department of Ecology. Even with the additional records, however, 47% (1279 events) contained insufficient information to make an error determination. Of the remaining 1426 events, 1181 were found to be due to mechanical failure and 213 were attributable to human error (Figure A-9).

Accidents were found to be caused significantly by human and organizational error (HOE), rather than mechanical failures (MF) (Table A-36); at the same time, incidents were significantly caused by mechanical failures (MF), rather than by human and organizational error (Table A-36).

A breakdown of the 1394 records with sufficient causal information is shown in Table A-37. The predominance of mechanical failures is partially a reflection of the paucity of detailed human and organizational error (HOE) and root cause data available in public data records. Note especially the drop off in HOE events after 2003, which is again though to reflect changes in reporting systems and requirements, as discussed in Section A-3.

Table A-37 shows the results of tests of the proportion of events caused by human and organizational error (HOE) compared to mechanical failure (MF): for tankers, tug-barges, cargo, WSF and fishing vessels, mechanical errors caused significantly more events than did human error at the 95% confidence level. The data and test results are shown in the Tables A-37 and A-38. Note that all of the vessel-type results are limited by small sample sizes, and by the availability of confirmatory HOE information in the public data records.

Table A-36 Wilcoxon Tests on Puget Sound Total Events, Accidents and Incidents by Error Type, 1995-2005

Variable	N	Test statistic	Normal approximate Z	Two-sided Pr> |Z|	Direction
Total Events	**11**	66.0000	-3.9410	**<0.0001**	**MF>HOE**
Accidents	**11**	163.0000	2.3733	**0.0176**	**HOE>MF**
Incidents	**11**	66.0000	-3.9533	**<0.0001**	**MF>HOE**

*** = small sample size**

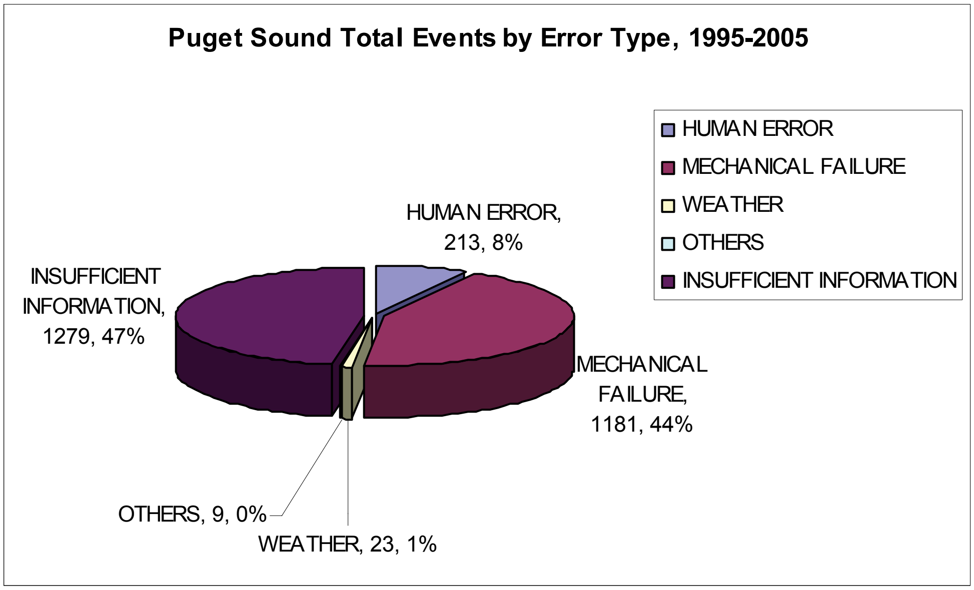


Figure A-9 Puget Sound Error Types, 1995-2005

Table A-37 Puget Sound Accidents and Incidents caused by Human and Organizational Error (HOE) and Mechanical Failure (MF); Wilcoxon test results for Tankers, Tug-Barges, Cargo Ships, WSF, and Fishing Vessels, 1995-2005

*** = small sample size** **Bold results are statistically significant**

Year	Total		Tanker		Tug-Barge		Cargo		WSF		Fishing	
	HOE	MF	HOE	MF	HOE	MF	HOE	MF	HOE	MF	HOE	MF
1995	15*	99	1*	12*	0	2*	7*	23*	0	55	7*	7*
1996	18*	124	2*	8*	2*	5*	9*	33*	2*	72	3*	6*
1997	27*	125	3*	9*	7*	6*	10*	46	5*	60	2*	4*
1998	21*	130	2*	3*	4*	3*	7*	31*	5*	87	3*	6*
1999	12*	118	1*	8*	4*	7*	4*	31*	1*	62	2*	10*
2000	13*	123	2*	11*	4*	23*	5*	36*	2*	50	0	3*
2001	18*	155	7*	21*	5*	21*	10*	41	1*	67	0	5*
2002	21*	117	2*	14*	0	9*	7*	43	4*	44	3*	7*
2003	15*	65	2*	10*	4*	1*	6*	15*	3*	36*	0	3*
2004	5*	74	1*	12*	0	5*	3*	15*	1*	42	0	0
2005	6*	48	0*	5*	2*	9*	2*	20*	1*	14*	1*	0
Total	171	1178	23[a]	113	32[b]	91	70[c]	334	25*	589	21*[d]	51
Test Result (Direction)	**MF>HOE**		**MF>HOE**		**MF>HOE**		**MF>HOE**		**MF>HOE**		**MF > HOE**	
Wilcoxon Test Statistics	**Statistic 66.0000, Normal Approximate z= -3.9432, Pr> |z|<0.0001**		**Statistic 68.50, Normal Approximate z= -3.8049, Pr> |z|< 0.0001**		**Statistic 91.5000, Normal Approximate z= -2.2810, Pr> |z|=0.0226**		**Statistic 66.000, Normal Approximate= -3.9477, Pr> |z|< 0.0001**		**Statistic 66.0000, Normal Approximation z= -3.9533, Pr> |z|<0.0001**		**Statistic 93.00, Normal Approximate z= -2.2008, Pr> |z|=0.0278**	

[a] 23 additional events were caused by weather and 9 events were caused by 'other' reasons

[b] 42 additional events are unusual events.

.

Table A-38 Puget Sound Error Types by Vessel Types, Event Types, 1995-2005

Year	Tanker Accident		Tanker Incident		Tug Accident		Tug Incident		Cargo Accident		Cargo Incident		WSF Accident		WSF Incident		Fishing Accident		Fishing Incident	
	HOE	MF	HOE	MF	HOE	MF	HOE	MF	HOE	MF	HOE	MF	HOE	MF	HOE	MF	HOE	MF	HOE	MF
1995	1*	1*	0	11*	0	0	0	2*	7*	1*	0	22*	0	0	0	55	7*	4*	0	3*
1996	1*	1*	1*	7*	2*	1*	0	4*	6*	5*	3*	28*	2*	0	0	72	3*	0	0	6*
1997	3*	1*	0	8*	7*	2*	0	4*	9*	9*	1*	37*	2*	1*	3*	59	2*	0	0	4*
1998	2*	3*	0	0	4*	1*	0	2*	6*	2*	1*	29*	4*	4*	1*	83	3*	0	0	6*
1999	0*	1*	1*	7*	4*	0	0	7*	1*	2*	3	29*	1*	1*	0	61	2*	1*	0	9*
2000	1*	0	1*	11*	4*	2*	0	21*	5*	3*	0	33*	1*	0	1*	50	0	0	0	3*
2001	1*	2*	1*	19*	4*	0	1*	21*	6*	3*	4*	38*	1*	6*	0	61	0	0	0	5*
2002	5*	3*	2*	11*	0	0	0	9*	4*	2*	3*	41	4*	2*	0	42	3*	1*	0	6*
2003	1*	1*	1*	9*	2*	0	2*	1*	6*	1*	0	14*	2*	2*	1*	34*	0	1*	0	2*
2004	0	0	1*	12*	0	2*	0	3*	1*	4*	2*	11*	1*	0	0	42	0	0	0	0
2005	0	0	0	5*	2*	1*	0	8*	2*	1*	0	19*	1*	0	0	14*	1*	0	0	0
Total	**15***	**13***	**8***	**100**	**29***	**9***	**3***	**82**	**53**	**33***	**17***	**301**	**19***	**16***	**6***	**573**	**21***	**7***	**0**	**44**

Normalizing the data by transits provided contrasting results (Table A-39). In contrast to the raw data, which showed cargo ships and tug-barges with the largest proportion of accidents by HOE, the normalized data showed tankers and cargo ships, followed by tug-barges and WSF, having the highest proportion of accidents caused by HOE. In other words, tug-barge accidents by HOE were proportionally less frequent when the normalized data were considered; similarly, tanker accidents by HOE were proportionally more frequent when the normalized data were considered. It should be noted, however, that in both the raw and normalized data, tanker accidents were characterized by small sample sizes, and because of the limited detailed accident information available, caution is advised with these results.

In the raw data, accidents due to mechanical failure occurred most frequently to cargo ships, tankers and WSF vessels. Normalizing the accidents caused by mechanical failure data dropped WSF from the most frequently occurring group; tankers and cargo ships continued to have the most frequent normalized numbers of accidents by mechanical failure over the period 1995-2005. Again, all accident data caused by mechanical failure in this analysis were characterized by a small sample size.

Raw data for incidents caused by HOE showed that cargo ships, tankers, and WSF vessels showed the highest frequency; the normalized data showed different results, as tankers alone showed the most frequency, followed by cargo vessels, tug-barges and WSF vessels. These data were also characterized by small sample sizes.

Finally, the raw data for incidents due to mechanical failure showed that these events happened most frequently to WSF vessels over the period 1995-2005, then cargo vessels, then tankers and tug-barges and fishing vessels. The normalized data again showed significant differences, with tankers and cargo ships having the highest frequency, followed by tug-barges and WSF. Note that the incidents by mechanical failure data were not characterized by small sample sizes, in contrast to the other data sets.

Normalizing the data, therefore, accounted not only for differences in transits between vessel types, but also showed that tanker events occurred most frequently for all categories, compared to the other vessel types. However, caution is advised with these results as they are all characterized by small sample sizes. Thus, whether accident or incident, HOE or mechanical cause, tanker accidents and incidents occurred most frequently, compared to other vessel types, when the accident and incident data were normalized by numbers of transits over the period 1996 – 2005.

These results may be related to the quality and availability of the nature of the data gathered, as described earlier, as well as to trends in events that occurred over the time period. Overall, it is interesting to note that even in the absence of machinery history data for any vessels, tankers and cargo ships experienced significantly more normalized incidents due to mechanical failure than did tug-barge and fishing vessels between 1995 to 2005.

Table A-39 Kruksal-Wallis and Tukey's HSD Tests on Puget Sound Error Types by Vessel Types, 1995-2005

Variable		DF	Test statistic	Direction
Raw Data	**Accident by HOE**	**4**	Kruksal-Wallis: Chi-square statistic = 12.6629, Pr > Chi-square=0.0130 Tukey's HSD: F-value=5.30, Pr >F =0.0012	**A: Cargo Tug-Barge B: Tug-Barge Fishing WSF Tanker* A>B**
	Accident by MF	**4**	Kruksal-Wallis: Chi-square statistic = 13.7505, Pr > Chi-square = 0.0081 Tukey's HSD: F-value=3.78, Pr >F =0.0093	**A: Cargo WSF Tanker B: WSF Tanker Tug-Barge Fishing A>B**
	Incidents by HOE	**4**	Kruksal-Wallis: Chi-square statistic = 14.9217, Pr > Chi-square= 0.0049 Tukey's HSD: F-value=4.76, Pr >F =0.0025	**A: Cargo Tanker WSF B: Tanker WSF Tug-Barge Fishing A>B**
	Incidents by MF	**4**	Kruksal-Wallis: Chi-square statistic = 40.6812, Pr > Chi-square<0.0001 Tukey's HSD: F-value=41.58, Pr >F <0.0001	**WSF > Cargo > Tanker= Tug-Barge= Fishing**
Normalized Data	**Accident by HOE**	**3**	Kruksal-Wallis: Chi-square statistic = 15.3552, Pr > Chi-square=0.0015 Tukey's HSD: F-value=5.18, Pr >F =0.0044	**A: Tanker Cargo B: Tug-Barge WSF A>B**
	Accident by MF	**3**	Kruksal-Wallis: Chi-square statistic = 17.8668, Pr > Chi-square = 0.0005 Tukey's HSD: F-value=8.33, Pr >F 0.0002	**A: Tanker Cargo B: Tug-Barge WSF A>B**
	Incidents by HOE	**3**	Kruksal-Wallis: Chi-square statistic = 13.3240, Pr > Chi-square=0.0040 Tukey's HSD: F-value=9.93, Pr >F <0.0001	**Tanker>Cargo=Tug-Barge=WSF**
	Incidents by MF	**3**	Kruksal-Wallis: Chi-square statistic = 24.3000, Pr > Chi-square<0.0001 Tukey's HSD: F-value=22.31, Pr >F <0.0001	**Tanker= Cargo > Tug-Barge = WSF**

*** = small sample size** **Bold results are statistically significant**

Human and Organizational Error Analysis

Detailed event records were requested from the Coast Guard and DOE to supplement the public event records. These records included CG 2692 and 835 archives from Coast Guard Headquarters and DOE accident investigation reports. Once the detailed event records were compiled and incorporated into the accident-incident database, Reason's human error framework and Shappell and Weigemann's performance shaping factors were used for analysis, as discussed in this section. Influence diagrams to illustrate BP Cherry Point tanker and ITB/ATB fleet collisions, allisions and groundings were developed (Appendix A-3). Finally, calibration events for the VTRA simulation were identified: these events included collisions, allisions and groundings for the BP Cherry Point tanker and ITB/ATB calling fleet, as described earlier.

Reason's (1997) cognitive framework of human error classifies unsafe acts into two types of activities: *errors*, which are unintended actions; and *violations*, which are intended actions (Figure A-10). Shappell and Weigemann (1997, 2001) identified errors as being of three types: *rule-based errors*, *skill-based errors*, and *knowledge-based errors*, based on Rasmussen's (1983, 1986) model of cognitive information processing. Violations can be either of two types: routine, which are common place abrogation of policies, rules or procedures that are condoned by management, or exceptional violations, which are not condoned by management.

Skill-based errors are those errors associated with failures to execute well-rehearsed actions, where there is little need for conscious decision-making (Rasmussen, 1986). Skill-based performance relies on skills that a person acquires over time and stores in memory. Skill-based errors, therefore, are largely errors of execution. Examples of skill-based errors include failures to execute a task, or to apply the correct skills to complete an assignment.

Two types of decision errors were identified by Shappell and Weigemann: rule-based and knowledge-based errors. Rule-based errors are similar to skill-based errors in that they represent failures to follow procedures, and are generally routines in nature (Rasmussen, 1986). A central difference is that people consciously fail to follow rules and procedures with which they are very familiar. Examples of rule-based errors include failures to maintain a

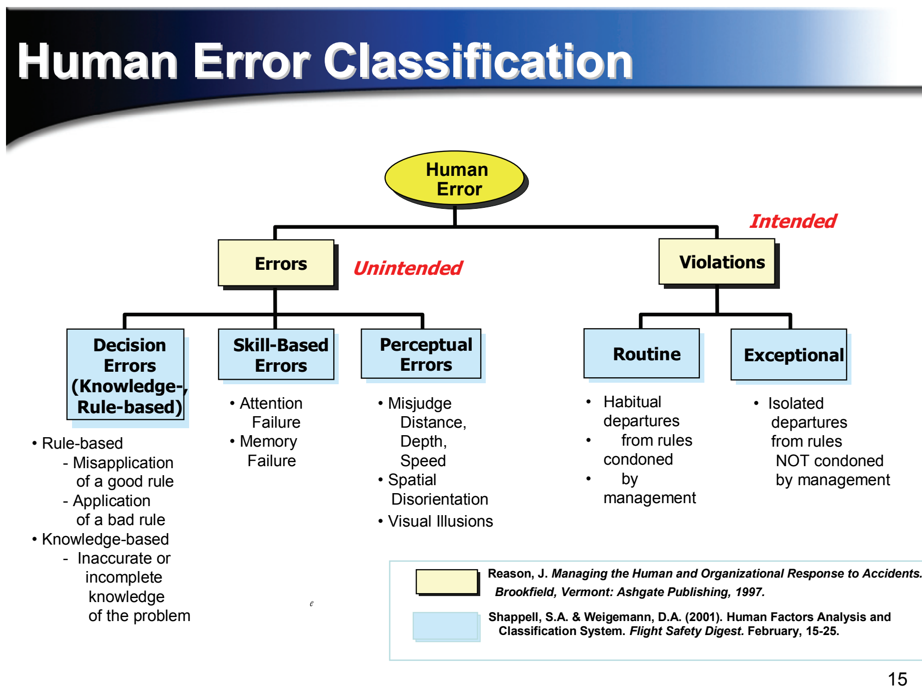


Figure A-10 Human Error Classification

piece of equipment as required, failure to follow well known company rules, and failures to follow mandatory inspection guidelines.

Errors at the knowledge level involve failures in conscious problem-solving directed towards attaining a goal (Rasmussen, 1986). Knowledge-based errors represent non-procedural behavior involving reasoning and computation, rather than rule-following (Rasmussen, 1986). Examples of knowledge-based errors include failures to reason properly, failures to utilize available information appropriately, or failures to make appropriate decisions with available information.

Perceptual errors are those that relate to failures to notice important cues or information, or to perceive information critical to decision-making. Examples of perceptual errors include failures to recognize dangerous situations, or approaches to dangerous situations; failures to recognize patterns of events that could lead to failures; or a lack of awareness of surroundings, situations or behavior that could led to adverse events.

As noted in the previous section, the human error analysis was limited by a lack of available information. Of the 2705 database events, only 53% (1426) had sufficient information to make an error determination; 47% (1279 events) had insufficient information (Figure A-9). Of the 1426 events with sufficient information for detailed error analyses, 213 of those events could be attributed to human error, while 1181 events were due to mechanical failure. In addition, 23 other events were attributed to weather conditions and 9 events were attributed to other reasons. On one hand, the proportion of human error events is a surprising result, given the often-quoted statistic that 80% of all events are due to human error; the proportion is a reflection of the paucity of detailed human error information in the event records, compared to the more available mechanical error information.

Breaking down the 213 human error events further shows that 79% (168) were unintended errors, rather than violations (32 events). Another 13 events that were characterized as due to human error in the accident records could not be described further, due to a lack of supporting or detailed information. These 13 events are counted in the HOE total of 213 events (Figure A-11), but are not counted in either of the 168 errors or 32 violations shown in Figure A-11. Of the 168 unintended errors, significantly more events (87, or 52%) were due to perceptual errors (Chi-square = 8.87, **$p = 0.012$)**, compared to decision- (36 events, 21%) or skill-based errors (45 events, 27%). As can be seen in Figure A-11, none of the error subtype data (decision error data, perceptual error data, skill-based error data) were characterized by small sample sizes.

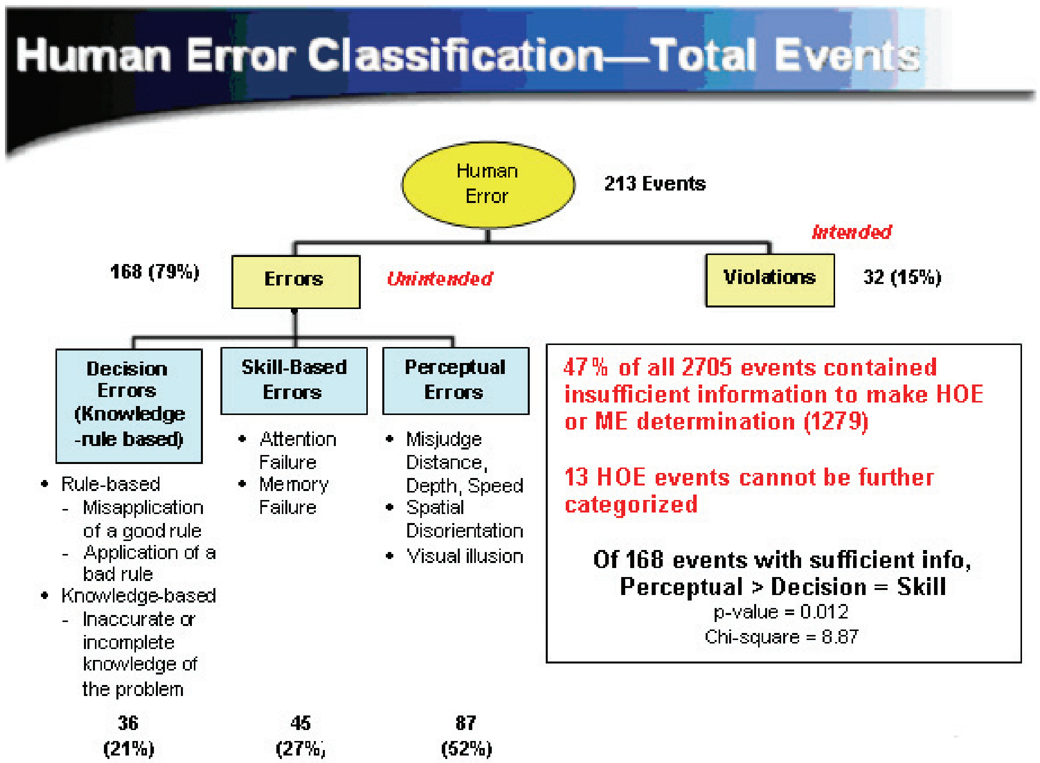


Figure A-11 Human Error Classification – Total Events in Puget Sound, 1995-2005

These trends were echoed in the accident (Figures A-12 and A-14) and incident analyses (Figures A-13 and A-15). For instance, of the 1462 accidents in Puget Sound that occurred between 1995 and 2005, only 230 accidents (15%) had sufficient information to make an error determination; 85% (1232 events) had insufficient information (Figure A-12). Of the 230 accidents with sufficient information, 137 of those accidents were due to human error, 78 were due to mechanical failure, 12 were due to weather, and 3 were due to other causes (Figure A-12). This 60:34 proportion of human error to mechanical failures for accidents is consistent with earlier accident analyses, but is inconsistent with the total event results in Figures A-9 and A-11. The inconsistency could be explained by the degree of attention paid to accident records, which typically contain more detailed analyses of human errors than incident records; however, that argument is relatively weak, given that both accident and incident data were characterized by substantial amounts of missing and insufficient data for error analyses.

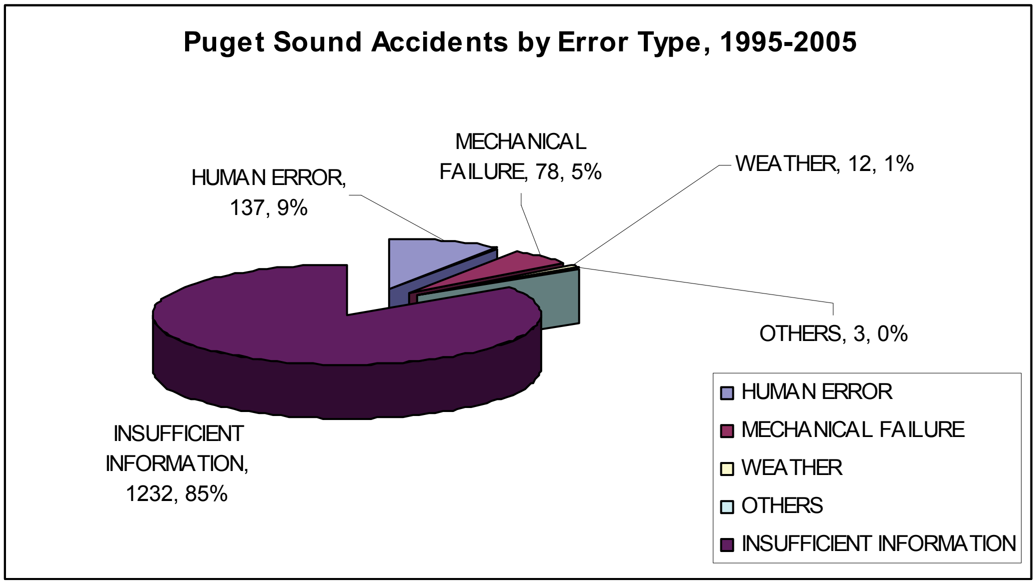


Figure A-12 Puget Sound Accident Error Types, 1995-2005

Analyzing the accidents further shows that of the 137 with sufficient information to make an error determination of human error, 85% (117 accidents) were due to unintended errors, rather than to violations (10 accidents, or 7%). 10 accident records indicated that they were due to human error, but no other supporting or descriptive information was provided in the accident record (Figure A-14). Of the 117 accidents caused by unintended errors, perceptual errors were again significantly more frequent than were accidents caused by decision- or skill-based errors (56%, Chi-square = 9.94, **p = 0.007**). However, in this analysis, the decision- and skill-based error data were characterized by small sample sizes (n = 27, 25, respectively).

The incident error analyses exhibited other trends (Figures A-13 and A-15), and were characterized by small sample sizes. In contrast to the pattern seen in the total event and accident analyses, 99% of the 1159 incidents in Puget Sound that occurred between 1995 and 2005 had sufficient information to make an error determination; only 1% did not. Thus, of the 1147 incident reports with sufficient information, 3% (34 incidents) were due to human error, while 95% (1100 incidents) were due to mechanical failure (Figure A-13). This 3:96 proportion of human error to mechanical failure accidents is consistent with the total event results in Figure A-9, and consistent with expectations associated with incidents, which are primarily equipment-related. The level of reporting detail provided in the incident records showed that mechanical failure determinations were easily identified with the available records. Few incident records reported that the mechanical failure was due to human error. This could be a reflection of the causes of incidents in Puget Sound during the reporting period, or it could be a reflection of training and reporting standards, which often emphasize identifying the broken or failing equipment or systems when filling out an incident report. In the available data, however, incidents with sufficient reported information for error analysis showed significantly more incidents due to mechanical failures, rather than caused by human error.

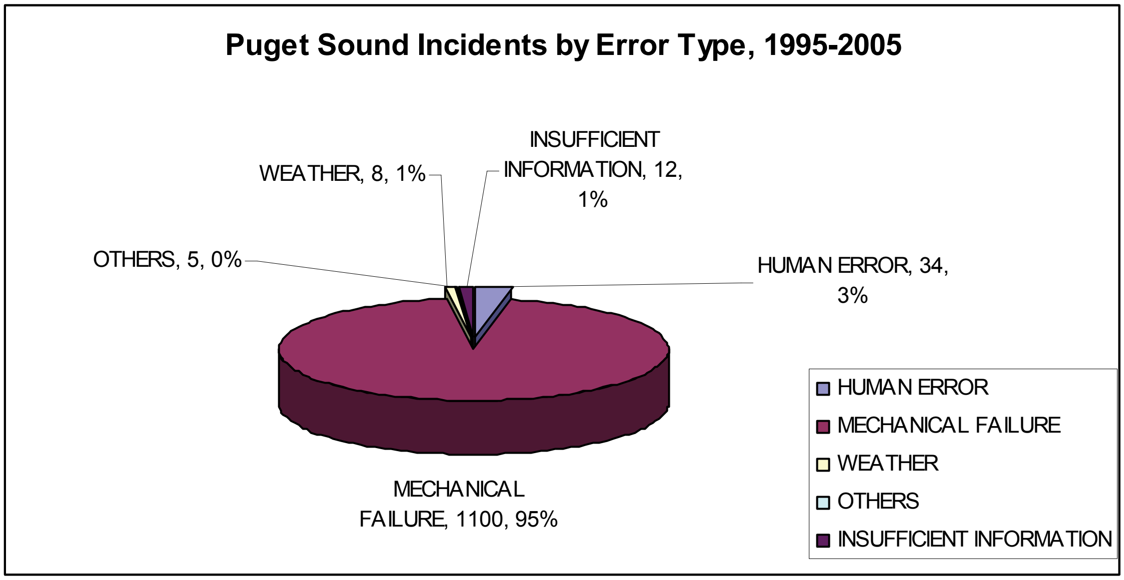


Figure A-13 Puget Sound Incidents Error Types, 1995-2005

Following Figure A-15, of the 34 incidents due to human error, most (31) had sufficient information to conduct further analysis. The pattern of error subtypes was consistent with that of events and accidents, with significantly more incidents due to perceptual errors (58%, or 18 incidents), rather than decision- (23% or 7 incidents) or skill-based errors (19%, or 6 incidents). As was noted with the accident data, however, all of the incident error subtype data were characterized by small sample sizes. This analysis, hampered as it was by insufficient information and small sample sizes, does suggest the primacy of perceptual errors as a root cause of both accidents and incidents in Puget Sound during 1995-2005.

Further investigation of accidents and incidents occurring to the BP Cherry Point calling fleet (tankers, integrated tug-barges (ITB's) and articulated tug-barges (ATB's)) during the reporting period was then undertaken. These events are of particular interest in the VTRA study, as they represent the calibration events for the vessel traffic simulation. Influence diagrams for the calibration accidents in Table A-40 are shown in Appendix A-3. A discussion of the sequence of events illustrated in the influence diagrams follows in the next section.

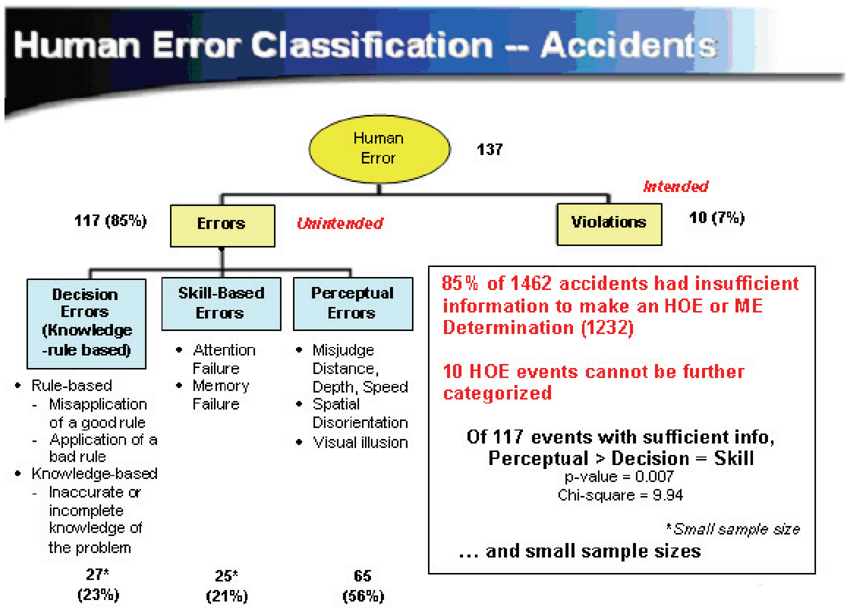


Figure A-14 Human Error Classification – Accidents in Puget Sound, 1995-2005

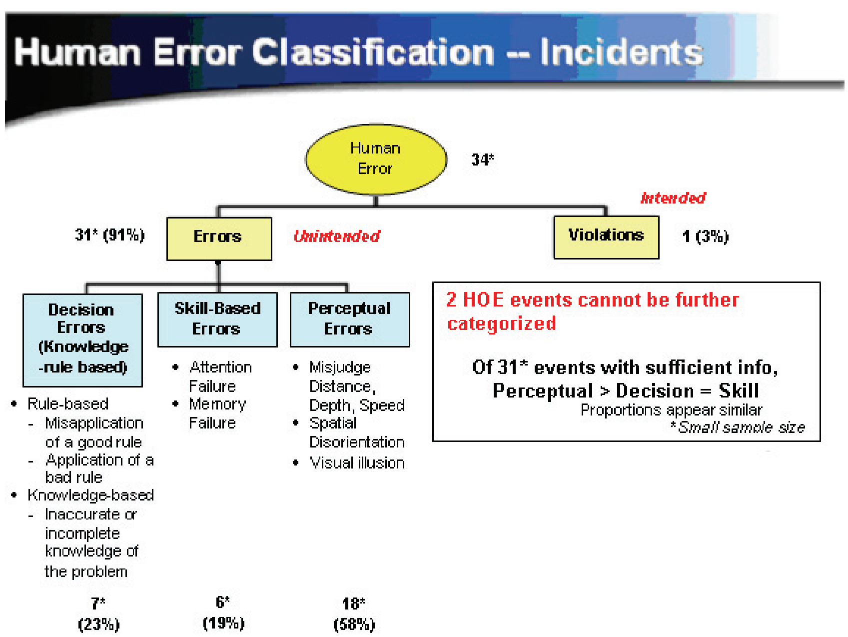


Figure A-15 Human Error Classification – Incidents in Puget Sound, 1995-2005

Error Analysis – BP Cherry Point Calling Fleet Accidents and Incidents

In order to calibrate the vessel traffic simulation, accidents and incidents occurring to tankers, ITB's and ATB's calling on BP Cherry Point between 1995-2005 were identified (Tables A-40, A-41). Calibration events for the simulation were a subset of events captured in the database—collisions, allisions and groundings. Pollution events, structural failures, capsizing, and fire and explosion accidents were not included in the calibration events or in the error analysis. Similarly, calibration incidents for the simulation included propulsion failures, steering failures and navigational equipment failures; other types of failures, and/or unusual events were not included in the calibration events or in the error analysis.

Table A-40 Calibration Accidents for Puget Sound Tankers, ITB's/ATB's, 1995-2005

Event Date	Event Time	Vessel Type	Vessel Name	Event Type	Event Type Description	Event Summary
24 Jan 1998	Null	**Tanker**	*Overseas Arctic*	**Accident**	**Allision**	Docking US Oil, hit piling bracket
14 Dec 2001	0900	**Tanker**	*Leyte Spirit*	**Accident**	**Allision**	Heavy weather, getting off dock at Ferndale; hit dock, scrape
19 Jan 2002	2140	**Tanker**	*Allegiance*	**Accident**	**Collision**	
5 Dec 1999	2035	**ITB**	*ITB New York*	**Accident**	**Grounding**	55 knot wind, anchor drag off March Point, pilot aboard Anacortes, Garth Foss respond

Table A-41 Calibration Incidents for Puget Sound Tankers, ITB's/ATB's, 1995-2005

Event Date	Event Time	Event Year	Vessel Type	Vessel Name	Event Type	Event Type Description
17 Mar 2002		2002	Tanker	Allegiance	Incident	Propulsion failure
13 Oct 1999		1999	Tanker	Angelo D'Amato	Incident	Propulsion failure
13 Dec 1999		1999	Tanker	Antiparos	Incident	Propulsion failure
25 Sept 2001		2001	Tanker	British Hawk	Incident	Propulsion failure
20 April 97		1997	Tanker	Chevron Mississippi	Incident	Propulsion failure
29 Dec 2000		2000	Tanker	Chevron Mississippi	Incident	Propulsion failure
17 Oct 2001		2001	Tanker	Great Promise	Incident	Propulsion failure
18 Oct 2001		2001	Tanker	Great Promise	Incident	Propulsion failure
18 July 2004		2004	Tanker	Gulf Scandic	Incident	Propulsion failure
12 Nov 2004	0010	2004	Tanker	Gulf Scandic/British Harrier	Incident	Propulsion failure
21 Jan 2001		2001	Tanker	HMI Brenton Reef	Incident	Propulsion failure
30 April 01		2001	Tanker	JoBrevik	Incident	Propulsion failure
11 July 1996		1996	Tanker	Kenai	Incident	Propulsion failure
13 Sept 1995		1995	Tanker	Overseas Alaska	Incident	Propulsion failure
24 Dec 1995		1995	Tanker	Overseas Boston	Incident	Propulsion failure
9 June 1996		1996	Tanker	Overseas Boston	Incident	Propulsion failure
8 July 1997		1997	Tanker	Overseas Boston	Incident	Propulsion failure
10 Nov 2005		2005	Tanker	Overseas Puget Sound	Incident	Propulsion failure
1 Feb 2001		2001	Tanker	Overseas Washington	Incident	Propulsion failure
12 Dec 2001		2001	Tanker	Overseas Washington	Incident	Propulsion failure
28 April 02		2002	Tanker	Pacific Sound	Incident	Propulsion failure
25 Dec 1995		1995	Tanker	Paul Buck	Incident	Propulsion failure
15 April 02		2002	Tanker	Polar Endeavor	Incident	Propulsion failure
7 Sept 2002		2002	Tanker	Polar Endeavor	Incident	Propulsion failure
7 May 2002		2002	Tanker	Polar Trader	Incident	Propulsion failure

Event Date	Event Time	Event Year	Vessel Type	Vessel Name	Event Type	Event Type Description
16 Dec 1995		1995	Tanker	Prince William Sound	Incident	Propulsion failure
18 Dec 2002		2002	Tanker	Prince William Sound	Incident	Propulsion failure
31 July 1999		1999	Tanker	SeaRiver Baytown	Incident	Propulsion failure
7 Oct 2003		2003	Tanker	SeaRiver Baytown	Incident	Propulsion failure
20 Mar 2003		2003	Tanker	SeaRiver Hinchinbrook	Incident	Propulsion failure
16 Aug 1996		1996	Tanker	Stavenger Oak	Incident	Propulsion failure
17 Mar 2001		2001	Tanker	Alfios	Incident	Steering failure
22 Oct 1996		1996	Tanker	Arcadia	Incident	Steering failure
3 Nov 1995		1995	Tanker	Berge Eagle (LPG)	Incident	Steering failure
14 June 1995		1995	Tanker	Carla Hills	Incident	Steering failure
1 Dec 2000		2000	Tanker	Kanata Hills	Incident	Steering failure
13 Oct 1999		1999	Tanker	New Endeavor	Incident	Steering failure
15 June 2000		2000	Tanker	Overseas New York	Incident	Steering failure
25 July 2001		2001	Tanker	Overseas Washington	Incident	Steering failure
20 Mar 2000		2000	Tanker	Chevron Mississippi	Incident	Steering failure
18 July 2000		2000	Tanker	Samuel L. Cobb	Incident	Steering failure
2 Nov 1997		1997	Tanker	SeaRiver Baton Rouge	Incident	Steering failure
28 Feb 2003		2003	Tanker	Denali	Incident	Nav equipment failure
11 Jan 2002		2002	Tanker	Overseas Chicago	Incident	Nav equipment failure
16 May 2004		2004	Tanker	Polar California	Incident	Nav equipment failure
23 May 2004		2004	Tanker	Polar California	Incident	Nav equipment failure
25 Feb 2005		2005	Tanker	Polar California	Incident	Nav equipment failure
28 Feb 2004		2004	Tanker	Polar California	Incident	Nav equipment failure
21 Mar 2004		2004	Tanker	Polar Discovery	Incident	Nav equipment failure
28 Apr 2004		2004	Tanker	Polar Discovery	Incident	Nav equipment failure
01 Mar 2004		2004	Tanker	Sea Reliance	Incident	Nav equipment failure
17 April 04		2004	Tanker	Tonsina	Incident	Nav equipment failure
24 Aug 2002		2002	ATB	ATB-550/Sea Reliance	Incident	Propulsion failure
28 July 2001		2001	ITB	ITB Baltimore	Incident	Propulsion failure
18 June 2000		2000	ITB	ITB Groton	Incident	Propulsion failure
27 May 2001		2001	ITB	ITB Groton	Incident	Steering failure
24 Aug 2002		2002	ATB	Sea Reliance	Incident	Steering failure
26 Sep 2002		2002	ITB	ITB MOBIL	Incident	Nav equipment failure
08 Nov 2004		2004	ATB	Ocean Reliance	Incident	Nav equipment failure

Table A-41 Calibration Incidents for Puget Sound Tankers, ITB's/ATB's, 1995-2005

A total of 4 calibration accidents -- 3 tanker accidents (2 allisions, 1 collision) and 1 ITB/ATB accident (1 grounding)-- were identified during the reporting period 1995-2005. A total of 59 calibration incidents – 31 tanker propulsion failures, 11 tanker steering failures, 10 tanker navigational equipment failures, 3 ITB/ATB propulsion failures, 2 ITB/ATB steering failures, and 2 ITB/ATB navigational equipment failures – were also identified during the reporting period 1995-2005. Influence diagrams for the tanker and ITB/ATB calibration accidents in Table A-40, as well as for two incidents and one unusual event, are shown in Appendix A-3. Notably, all tanker and ITB/ATB accidents occurred during the winter months and several involved human response to events occasioned by severe weather.

Substantial information was available for two calibration events—the collision between the 612' single hull inbound tanker *Allegiance* and the escort tug *Sea King* on 19 January 2002 and the grounding of the *ITB New York* after she dragged anchor at March Point on 5 December 1999. Coast Guard 2692 and MISLE records, as well as Washington State Department of Ecology and VTS Puget Sound incident records, were available for these events, as were court documents from resulting litigation, articles from local newspapers, and reports from *Lloyd's Casualty Reporting*.

As can be seen in the Appendix A-3 influence diagram, the *Allegiance – Sea King* collision event was characterized by communication, perception and medical history problems during the inbound night transit to Tesoro. In subsequent litigation, the *Allegiance* was found not to have provided adequate lookout and the *Sea King* tug was found to have lost situational awareness. No pilot error was noted during the event. As a result of the collision, the tug *Sea King* sustained significant structural damage and two crew members were injured; the vessel was dewatered, the tug captain surrendered his license on medical grounds, and significant economic losses were sustained.

The *ITB New York* grounding illustrates how situations such as a dragging anchor can compound quickly for a light single hull ITB at anchor in winds of 40-55 knots. Timely assistance was rendered by three nearby assist tugs that ultimately pulled the vessel afloat. The vessel was in communication with the VTS, who provided assistance positioning and repositioning the vessel. Vessel damage was negligible in this event, or no personnel casualties were noted.

In both of these accidents, situational awareness played a significant role in determining the course and outcome of the event. In one case, lack of situational awareness led to an adverse outcome with personnel injuries, substantial economic losses and vessel structural damage; in the other case, situational awareness enhanced by additional resources on assist vessels and the VTS resulted in mitigated economic, personnel and structural consequences.

The allision of the double hull Bahamian Teekay Shipping tanker *Leyte Spirit* at the Philips Petroleum dock in Ferndale on the morning of 14 December 2001 shows a pattern similar to the *ITB New York* grounding: assist tug and pilot resources were available to the vessel, which was attempting to leave the Ferndale dock with winds gusting from 40-50 knots. The allision occurred when the pilot tried to get the vessel off the dock. In the first attempt to leave the dock, a line from the *Leyte Spirit* to the tug *Sea King* parted, and the vessel allided with the dock. In the second attempt, the *Leyte Spirit* was able to get away from the berth with no further damage to the vessel or the dock. Sufficient information was available about the allision, as the event was captured in Coast Guard 2692 and MISLE reports, as well as Washington State Department of Ecology and Puget Sound Pilot incident reports. In this event, as with the *ITB New York* grounding, the mitigated outcome occasioned by severe weather was influenced by the human and mechanical response resources available (pilots, assist tugs).

Unfortunately, there was less information available for the remaining calibration events. As can be seen in Appendix A-3, there was little information in the Coast Guard MISLE and Puget Sound Pilot Commission records to provide description of the events associated with the allision of the single hull tanker *Overseas Arctic* when she was docking at U.S. Oil in Tacoma on 24 January 1998. Similarly, the influence diagram for the tanker *Overseas Boston* pollution event on 13 January 2002 at the Tosco pier in Ferndale shows that the lack of available information extends to pollution events, although, in general, records are more complete for pollution events than for some allisions, propulsion failures, steering failures or navigational equipment failures.

The influence diagram for the inbound double hull tanker *Gulf Scandic*'s propulsion failure on the night of 12 November 2004 shows that even when event records include data from the Coast Guard 2692 and MISLE files, as well as from the Washington State Department of Ecology, there may be little available information with which to undertake an error analysis. More information was available for the unusual event that occurred on 11 February 2002, to the double bottom tanker *Blue Ridge,* which was underway from Port Angeles and heaving up anchor when the propeller became fouled, resulting in substantial propeller and tanker damage.

In short, the influence diagram analysis echoes the descriptive statistic analysis presented in Figures A-11 – A-15, which showed substantial missing and incomplete information with respect to human and organizational error analyses, even when multiple sources were used to corroborate and analyze the event. This is a recurring problem in maritime accident and incident analyses and suggests the need for greater attention to standardized data capture, collection, sharing and analysis across organizations with interest in improved maritime safety.

Summary of Significant Event Results, 1995-2005

A summary of significant total event frequencies in the Puget Sound VTRA Accident-Incident database is given in Table A-42, which shows that there are significant differences in the normalized total events by vessel type. For normalized total events, 1995-2005, cargo and tanker ships had a statistically higher frequency of events than did tug-barges and Washington State Ferries (WSF). Normalizing the data by transits altered the results of the events by vessel type analysis so as to reflect the surrogate exposure risk suggested by the vessel type's number of transits.

Analysis of events by year showed that 1995 and 1997-2002 had a higher event frequency than other years. However, after normalization by transit data, slightly different test results were observed: years 1998-2002 had a statistically higher number of total events than did other years. Different test results between raw data and normalization data also can be found in events by season. Tests on raw data by season showed that summer and winter had a statistically higher number of total events than did autumn and spring. However, when the data were normalized by transits, autumn and spring had statistically higher numbers of total events than did winter and summer, in part because of the increase in transits during the summer and winter seasons.

Analysis of events by location showed that South Puget Sound had the highest number of events, compared to other locations. One of the important reasons may be that more transits occurred in South Puget Sound than other locations because of the numerous ferry runs. Furthermore, inbound vessels had a statistically higher number of events than did outbound vessels. More transits for inbound vessels in Puget Sound can account for this result. Also, vessels classed by ABS had the highest number of events, compared to those classed by other class societies since many more vessels sailing in Puget Sound belong to ABS.

Analysis of events by vessel flag showed that U.S. flagged vessels had a higher total event frequencies than did those from foreign flags, and among foreign flag vessels, vessels from Panama had a statistically higher event frequency than those from any other foreign flags.

Analysis of events by error type showed that events were significantly caused by mechanical failures (MF) rather than by human and organizational error (HOE), although the analysis was impacted by the lack of data for error analysis. The significant statistical results are summarized in Table A-42. In all cases except incidents caused by mechanical failures, the data were characterized by insufficient information for error analyses.

Table A-42 Summary of Significant Puget Sound Maritime Events, 1995-2005

Test	Results	Test Used	Statistics	Direction
Events by Vessel Type*	**Cargo and WSF ships had higher event frequencies than other vessel types**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 34.2814, Pr > Chi-square <0.0001 Tukey's HSD: F value= 19.24, Pr>F <0.0001	**A: Cargo = WSF B: WSF Fishing C: Fishing Tug-barge D: Tanker A>B>C>D**
Events by Vessel Type (normalized)*	**Cargo and tanker ships had higher normalized event frequencies than tug/barge and WSF ships**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 32.9020, Pr > Chi-square <0.0001 Tukey's HSD: F value= 19.17, Pr>F <0.0001	**Cargo=Tanker> Tug-barge=WSF**
Accident-Incident Pyramids by Vessel Type	**Fishing had the highest accident-incident ratio among five vessel types**	Kruskal-Wallis Pair Wilcoxon	Chi-square statistic 38.9369, DF = 4, Pr > Chi-square <0.0001	**Fishing > Tug-barge > Cargo >Tanker = WSF**
Events by Year	**Years 1997-2002 had higher events than other years.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 60.1687, Pr > Chi-square <0.0001 Tukey's HSD: F-value=11.27, Pr > F<0.0001	**A:2001 2002 1999 2000 1997 1998 1995 B:2002 1999 2000 1997 1998 1995 1996 C: 1999 2000 1997 1998 1995 1996 2004 D: 2000 1997 1995 1996 2004 2003 E:2005** A>B>C>D>E
Events by Year (normalized)	**Years 1999-2002 had higher normalized events than other years.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 59.0563, Pr > Chi-square <0.0001 Tukey's HSD: F-value=13.40, Pr >F <0.0001	**A:2001 2002 2000 1999 1998 B:2002 2000 1999 1998 1997 2004 C:2000 1999 1998 1997 2004 1996 D:1999 1998 1997 2004 1996 2003 E:2005** A>B>C>D>E

Test	Results	Test Used	Statistics	Direction
Events by Location*	**South Puget Sound had a higher number of events than other locations**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 80.7694, Pr>Chi-square<0.0001 Tukey's HSD: F-value= 81.20, Pr >F <0.0001	**A: South Puget Sound B: North Puget Sound, West Strait of Juan de Fuca, East Strait of Juan de Fuca C: West Strait of Juan de Fuca, East Strait of Juan de Fuca, Guemes Channel, San Juan Islands, Saddlebag, Cherry Point, Rosario Strait, Haro Strait A>B>C**
Events by Season*	**Summer and Winter had higher event frequencies than Autumn and Spring did**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 29.3489, Pr>Chi-square <0.0001 Tukey's HSD: F-value=56.31, Pr >F <0.0001	**Summer=Winter>Autumn =Spring***
Events by Season (Normalized)*	**Autumn and Spring had higher normalized event frequencies than Winter and Summer did**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 13.2963, P>Chi-square =0.0040 Tukey's HSD: F-value=6.71, Pr >F =0.0012	**Autumn=Spring> Winter =Summer***
Events by Flag (U.S. Flag vs. Non U.S. Flag)	**Vessels from U.S. flag had higher frequency than those from Non-U.S. flags**	Wilcoxon	Statistic 184.0000, Normal Approximation z= 3.7768, Pr> z=0.0002	**U.S.>Non U.S.**
Events by Non U.S.-Flag*	**Vessels from Panama had higher event frequency than those from other foreign flags**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 21.0342, P>Chi-square =0.0026 Tukey's HSD: F-value= 32.65, Pr >F <0.0001	**Panama> Bahamas*= Canada* =Cyprus* =Liberia* = Russia* =Singapore***
Events by Class Society*	**Vessels classed by ABS had statistically higher number of total events than those from other class societies.**	Krussal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 30.4518, P>Chi-square <0.0001 Tukey's HSD: F-value=34.16, Pr >F <0.0001	**ABS>NV*=NK*=LR***
Events by Direction (Inbound/Outbound)*	**Inbound vessels had significantly higher event frequencies than outbound vessels**	Wilcoxon	Statistic 172.500, Normal Approximate z= 3.0474, Pr> z=0.0023	**Inbound*>Outbound***
Events by Error Type (HOE vs. Mechanical)*				
	Events caused by MF had higher number of frequency than those caused by HOE	Wilcoxon	Statistic 68.0000, Normal Approximation z= -3.8965, Pr> z<0.0001	**MF>HOE**
Events by Error Type for different vessel types*	**Tankers had more events by MF than by HOE**	Wilcoxon	Statistic 77.5000, Normal Approximation z= -3.2350, Pr> z=0.0012	**MF>HOE**
	Tug/barges had more events by MF than by HOE	Wilcoxon	Statistic 95.5000, Normal Approximation z= -2.1130, Pr> z=0.0345	**MF>HOE**
	Cargo ships had more events by MF than by HOE	Wilcoxon	Statistic 70.000, Normal Approximation z= -3.7164, Pr> z=0.0002	**MF>HOE**
	WSF had more events by MF than by HOE	Wilcoxon	Statistic 66.0000, Normal Approximation z= -3.9863, Pr> z<0.0001	**MF>HOE**
	Fishing had more events by MF than by HOE	Wilcoxon	**Statistic 95.5000, Normal Approximation z=-1.9914, Pr> z=0.0464**	**MF>HOE**

* = small sample size Bold results are statistically significant

Accidents in Puget Sound, 1995-2005

A summary of significant accident results from the Puget Sound VTRA Accident-Incident database is given in Table A-43, which shows that the number of accidents gradually increased in Puget Sound between 1996 and 2002; in 2002, accidents began to decline. Explanations for why this decline might be related to reporting and organizational changes, rather than trends in accident frequency.

Accident frequencies between 1995 and 2005 were assessed using the Kruskal-Wallis and Tukey's HSD tests which found that 1995 and 1997-2004 showed significant differences in terms of the numbers of accidents which occurred. These differences were significant at the 95% confidence interval. Normalized accident frequencies showed similar patterns, with the years 1997-2002 and 2004 significantly different than the remainder of the years; these results were significant at the 95% confidence interval.

Analysis of accidents by season showed that summer and winter had a higher number of accidents than spring and autumn. However, after data normalization, no statistical difference was found among the four seasons since more transits occurred during summer and winter seasons. This trend was different than the observed event frequency in Puget Sound, 1995-2005, which saw more normalized events in spring and autumn.

Analysis of accidents by vessel type showed that cargo ships and fishing vessels had the highest accident frequencies among the five vessel types; when the results were normalized, only cargo vessels had the highest accident frequency among the five vessel types. Analysis of accidents by location showed that South Puget Sound had a higher number of accidents than other locations in Puget Sound, most likely because more transits occurred in South Puget Sound than other areas.

Analysis of accidents by vessel flag showed that there were a statistically higher number of accidents occurring to U.S. flag vessels, compared to foreign flag vessels. Among the foreign flag vessels, those from Panama, Canada and Russia had a higher accident frequency than any other foreign flag vessels. Accident data by vessel owner and class society was tested, which showed that Foss, Crowley, U.S. Navy, U.S. Coast Guard, and Olympic Tug and

Barge vessels had the highest accident frequencies and vessels classed by ABS had a statistically higher number of accidents than did those of other class societies. Neither owner nor class data were normalized by vessel transits, as that data were not available. Previous analyses showed significant differences between results with raw and normalized data; those patterns may have also been observed in the vessel owner and class analysis.

Finally, accidents caused by pollution had a statistically higher frequency than those caused by Allision, Grounding, Fire, Collision, Sinking, Flooding, Capsize, Breakaway, and Salvage. Analysis of accidents by error type showed that accidents caused by human error had a statistically higher number than those caused by mechanical failure.

Table A-43 Summary of Significant Statistical Test Results on Puget Sound Accident Frequency, 1995-2005

Test	Results	Test Used	Statistics	Direction
Accidents by Vessel type*	**There were statistical differences in accident frequency among five vessel types**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 39.0843, Pr > Chi-square <0.0001 Tukey's HSD: F Value =26.82, Pr>F <0.0001	**A: Cargo Fishing B: Fishing Tug-Barge C: WSF Tanker* A>B>C**
Accidents by Vessel Type (normalized)*	**Cargo ships had the highest normalized accident frequency**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 27.3205, Pr > Chi-square <0.0001 Tukey's HSD: F Value =26.53, Pr>F <0.0001	**A: Cargo B: Tanker* Tug-Barge C: Tug-Barge WSF A>B>C**
Accidents by Year	**Year 2005 had significantly lower accidents than other years.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 51.6289, Pr > Chi-square <0.0001 Tukey's HSD: F-value=8.88, Pr >F <0.0001	**A:2002 1999 2001 2000 1995 1997 1998 2004 2003 B:2000 1995 1997 1998 2004 2003 1996 C: 2005** A>B>C
Accidents by Year (normalized)	**Years 1996 and 2005 have lower number of normalized accidents than other years.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 51.1032, Pr > Chi-square =0.0017 Tukey's HSD: F-value=9.94, Pr >F <0.0001	**A:2002 2001 2000 1999 1998 2004 1997 B: 2001 2000 1999 1998 2004 1997 2003 C: 1998 2004 1997 2003 1996 D: 1996 2005** A>B>C>D
Accidents by Location*	**South Puget Sound had higher number of accident than other locations**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 79.5272, Pr > Chi-square <0.0001 Tukey's HSD: F-value =79.24, Pr >F <0.0001	**A: South Puget Sound B: North Puget Sound, West Strait of Juan de Fuca, Saddlebag, Cherry Point, East Strait of Juan de Fuca, Guemes Channel C: West Strait of Juan de Fuca, Saddlebag, Cherry Point, East Strait of Juan de Fuca, Guemes Channel, San Juan Islands, Haro Strait A>B>C**
Accidents by Season*	**Summer and Winter had higher accident frequency than Autumn and Spring did**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 29.4899, P>Chi-square <0.0001 Tukey's HSD: F-value=69.62, Pr >F <0.0001	**Summer=Winter > Autumn = Spring***

Test	Results	Test Used	Statistics	Direction
Accidents by Season (normalized)*	No statistical differences for normalized accident frequency exist among four seasons	Kruskal-Wallis	Kruskal-Wallis: Chi-square statistic 1.0841, P>Chi-square =0.7809 Tukey's HSD: F-value=0.78, Pr >F =0.5154	N/A
Accidents by Flag (U.S. Flag vs. Non U.S. Flag)	**Vessels with U.S. flag had higher accident frequency than those from Non-U.S foreign flag.**	Wilcoxon	Statistic 179.5000, Normal Approximation z= 3.4871, Pr> z=0.0005	**U.S.>Non U.S.**
Accidents by Non U.S.-Flag*	**Vessels from Panama/Canada/Russia have higher accident frequency than those from other foreign flags**	Kruskal-Wallis Wilcoxon	Kruskal-Wallis: Chi-square statistic 21.5897, P>Chi-square =0.0014	**Panama= Canada= Russia> Bahamas =Cyprus =Singapore**
Accidents by Owner*	**Vessels from different owners had statistical differences in accident frequency**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 20.9822, P>Chi-square =0.0010 Tukey's HSD: F-value=4.60, Pr >F=0.0016	**A: Foss Crowley US Navy USCG Olympic Tug & Barge** **B: Olympic Tug & Barge Clipper A>B**
Accidents by Class Society*	**Vessels classed by ABS had statistically higher accident frequencies than those from other class societies.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 26.6617, P>Chi-square <0.0001 Tukey's HSD: F-value= 54.05, Pr >F <0.0001	**ABS>NV=NK=LR**
Accidents by Accident type*	**Accidents caused by pollution had statistically higher number of frequency than accidents caused by other types.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 69.4233, P>Chi-square <0.0001 Tukey's HSD: F-value= 78.22, Pr >F <0.0001	**A: Pollution** **B: Allision, Grounding Fire, Collision C: Grounding Fire, Collision, Sinking, Flooding, Capsize, Breakaway** **A>B>C**
Accidents by Error Type	**Accidents caused by HOE had statistically higher number of frequency than accidents caused by MF**	**Wilcoxon**	**Statistic 164.0000, Normal Approximation z= 2.4722, Pr> z=0.0134**	**HOE>MF**

*** = small sample size** **Bold results are statistically significant**

Incidents in Puget Sound, 1995-2005

Analysis of incidents in Puget Sound between 1995 and 2005 showed that the number of incidents gradually increased in Puget Sound between 1996 and 2001; in 2002, incidents began to decline. Explanations for why this decline might be related to reporting and organizational changes, rather than trends in incident frequency, have already been presented.

Incident frequencies between 1995 and 2005 were assessed using the Kruskal-Wallis and Tukey's HSD tests, which found that years from 1996 to 2002 showed significant differences in terms of the numbers of incidents which occurred, compared to the other years. These differences were significant at the 95% confidence interval. Normalized incident frequencies showed similar patterns, as years 1996 to 2002 still had a higher number of normalized incidents than other years.

Analysis of raw numbers of incidents by season showed that vessels had a higher number of incidents in summer and winter than in spring and autumn. However, tests on normalized incident data showed that spring and autumn had a higher number of incidents than summer and winter, consistent with trends in the normalized accident data reported in the previous section.

Analysis of raw numbers of incidents by vessel type showed that WSF had the highest number of incidents, then cargo ships, and then tankers, tug-barges and fishing vessels. Normalization of the data showed different results: tankers had higher incident frequencies than other vessel types, then cargo vessels, then tug-barges and WSF. This is another example of data with different results using the raw and normalized data.

Analysis of incidents by location showed that South Puget Sound had the highest incident frequency, compared to other locations, similar to the results seen in the total event and accident analysis. Vessels had higher incident frequencies during the day than the night, and U.S. flag vessels had a higher number of incidents than those from foreign flags. Among the foreign flag vessels, vessels from Panama had the highest number of incidents, compared to those from other foreign countries. Clipper, Crowley, Foss, U.S. Navy and Olympic Tug &

Barge vessels had higher numbers of incidents compared to other vessel owners, and vessels classed by ABS had a statistically higher incident frequency than those belonging to other class societies. Neither the owner nor ABS data were normalized by vessel transits, as that data were not available. Previous analysis showed significant differences between results with raw and normalized data; those differences might have been observed in the owner and ABS normalized data analysis, had that data been available. Analysis of incidents by direction showed that inbound vessels had a higher incident frequency than outbound vessels.

Incidents caused by equipment failure were statistically more frequent than those caused by loss of propulsion, loss of steering, near miss, structural failure, and loss of power. Analysis of incidents by error type showed that incidents caused by MF occurred more frequently than those caused by HOE. The same result was observed for all vessels types.

The summary of significant statistical test results for incidents is shown in Table A-44.

Table A-44 Summary of Significantly Statistical Test Results for Puget Sound Incidents, 1995-2005

Test	Results	Test Used	Statistics	Direction
Incidents by Vessel Type*	**WSF had the highest normalized incident frequency**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 40.7493, Pr > Chi-square <0.0001 Tukey's HSD: F Value= 39.92, Pr>F <0.0001	**WSF> Cargo> Tanker= Tug-Barge = Fishing**
Incidents by Vessel Type (normalized) *	**Tankers had the highest normalized incident frequency**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 24.1537, Pr > Chi-square <0.0001 Tukey's HSD: F Value= 20.99, Pr>F <0.0001	**Tanker>Cargo>Tug-Barge=WSF**
Incidents by Year *	**Years 1996-2002 had higher incidents than other years.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 56.7266, Pr> Chi-square < 0.0001, Tukey's HSD: F-value=8.61, Pr >F <0.0001	**A:2001 2000 1998 1996 1997 1999 2002 B: 2000 1998 1996 1997 1999 2002 1995 C:1997 1999 2002 1995 2004 D: 1995 2004 2003 2005** A>B>C>D
Incidents by Year (normalized)*	**Years 2001, 2000, 1998, 2002, 1997, 1996, and 1999 had higher normalized incidents than other years.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 51.1060, Pr> Chi-square < 0.0001 Tukey's HSD: F-value=8.97, Pr >F <0.0001	**A: 2001 2000 1998 2002 1997 1996 1999 B: 1998 2002 1997 1996 1999 2004 C: 1999 2004 C:1999 2004 2003 D: 2004 2003 2005** A>B>C>D
Incidents by Location	**South Puget Sound had higher number of incidents than other locations**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 79.2347, Pr > Chi-square <0.0001 Tukey's HSD: F-value= 44.79, Pr >F <0.0001	**A: South Puget Sound B: North Puget Sound, West Strait of Juan de Fuca, East Strait of Juan de Fuca C: West Strait of Juan de Fuca, East Strait of Juan de Fuca, San Juan Islands, Guemes Channel D: East Strait of Juan de Fuca, San Juan Islands, Guemes Channel, Saddlebag, Cherry Point, Rosario Strait, Haro Strait A>B>C>D**
Incidents by Season*	**Summer and Winter had higher incident frequency than Autumn and Spring did**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 27.5853, P>Chi-square < 0.0001 Tukey's HSD: F-value=21.83, Pr >F <0.0001	**Summer=Winter > Spring= Autumn**
Incidents by Season (Normalized)*	**Spring and Autumn had higher normalized incident frequency than Winter and Summer did**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 14.9298, P>Chi-square =0.0019 Tukey's HSD: F-value=8.07, Pr >F =0.0004	**Spring=Autumn> Winter =Summer**

Test	Results	Test Used	Statistics	Direction
Incidents by Time of Day*	**Incidents occurred more often during day than night**	Wilcoxon	Statistic 156.500, Normal Approximation z= 1.9739, Pr> z=0.0484	**Day>Night**
Incidents by Flag (U.S. Flag vs. Non U.S. Flag)	**Vessels from U.S. flag had higher incidents frequency than those from Non-U.S. flag**	Wilcoxon	Statistic 187.0000, Normal Approximation z= 3.9795, Pr> z<0.0001	**U.S.>Non U.S.**
Incidents by Non U.S.-Flag*	**Vessels from Panama had higher incident frequency than those from other foreign flags**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 23.0145, P>Chi-square =0.0011 Tukey's HSD: F-value =17.20, Pr >F <0.0001	**Panama> Bahamas= Canada =Cyprus =Liberia = Russia =Singapore**
Incidents by Owner*	**Vessels from different owners had statistical different incident frequency**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 11.6234, P>Chi-square =0.0440 Tukey's HSD: F value 2.56, Pr>F 0.0445	**A: Clipper, Crowley, Foss, US Navy, Olympic Tug & Barge** **B: Crowley, Foss, U.S. Navy, Olympic Tug & Barge, USCG A>B**
Incidents by Class Society*	**Vessels classed by ABS had statistically higher incident frequency than those from other class societies.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 28.0562, P>Chi-square <0.0001 Tukey's HSD: F-value= 20.21, Pr >F <0.0001	**ABS>NV=NK=LR**
Incidents by Direction (Inbound/Outbound)*	**Inbound vessels had significant higher incidents frequency than outbound vessels**	Wilcoxon	Statistic 170.500, Normal Approximation z= 2.9421, Pr> z=0.0033	**Inbound>Outbound**
Incidents by Incident type	**Incidents caused by equipment failure had statistically higher frequency than incidents caused by other types.**	Kruskal-Wallis Tukey's HSD	Kruskal-Wallis: Chi-square statistic 58.1122, P>Chi-square <0.0001 Tukey's HSD: F-value= 81.11, Pr >F <0.0001	**A: Equipment failure B: Loss of Propulsion, C: Loss of steering, Structural Failure, Near miss, Loss of Power, Loss of Anchor** **A>B>C**
Incidents by Error Type	Incidents caused by MF has statistically higher frequency than incidents caused by HOE	**Wilcoxon**	**Statistic 66.0000, Normal Approximation z= -3.9863, Pr> z<0.0001**	**MF>HOE**

References

Grabowski, M.R., Merrick, J.R., Harrald, J.R, Mazzuchi, T.A. & van Dorp, J.R. (2000). Risk Modeling in Distributed, Large-Scale Systems. *IEEE Transactions on Systems, Man & Cybernetics—Part A: Systems and Humans*. 30:6, November, 651-660.

Harrald, J.R., Mazzuchi, T.A., Spahn, J., Van Dorp, J.R., Merrick, J., Shrestha, S. & Grabowski, M.R. (1998). Using System Simulation to Model the Impact of Human Error in a Maritime System. *Safety Science*. 30, 235–247.

Merrick, J.R.W., van Dorp, J.R., Mazzuchi, T., Harrald, J.R., Spahn, J.E. & Grabowski, M.R. The Prince William Sound Risk Assessment. *Interfaces*. 32:6, November-December 1992, 25-40.

National Research Council. (1983). *Ship Collisions with Bridges: The Nature of the Accidents, their Prevention and Mitigation*. Washington, D.C.: National Academy Press.

National Research Council (1990). *Crew Size and Maritime Safety*. Washington, D.C.: National Academies Press. http://www.trb.org/news/blurb_detail.asp?id=2654, retrieved 29 June 2007.

National Research Council. (1994). *Minding the Helm: Marine Navigation and Piloting*. Washington, D.C.: National Academies Press. http://www.trb.org/news/blurb_detail.asp?id=2651, retrieved 29 June 2007.

National Research Council. (1999). *Applying Advanced Information Systems to Ports and Waterways Management*. Washington, D.C.: National Academies Press. http://www.trb.org/news/blurb_detail.asp?id=2641, retrieved 29 June 2007.

National Research Council. (2003). *Special Report 273: Shipboard Automatic Identification System Displays: Meeting the Needs of Mariners*. Washington, D.C.: National Academies Press. http://www.trb.org/news/blurb_detail.asp?id=1425, retrieved 29 June 2007.

National Transportation Safety Board. (1994). *Safety Study: A Review of Flightcrew-Involved Major Accidents of U.S. Air Carriers, 1978 – 1990*. NTSB Report No. NTSB/SS-94/01. Washington, D.C.: National Transportation Safety Board, January.

Pacific States/British Columbia Oil Spill Task Force. (1995). *Recommendations to Prevent Oil Spills Caused by Human Error: 1995 Report to the Pacific States/BC Oil Spill Task Force*. Victoria, British Columbia: Pacific States/BC Oil Spill Task Force. http://www.oilspilltaskforce.org/docs/project_reports/HumanFactorRec.pdf, retrieved 28 June 2007.

Pacific States/British Columiba Oil Spill Task Force. (1997). *Spill and Incident Data Collection Project Report*. Victoria, British Columbia: Pacific States/British Columbia Oil Spill Task Force. July. http://www.oilspilltaskforce.org/docs/notes_reports/DataProjectReport.pdf, retrieved 29 June 2007.

Pacific States/British Columbia Oil Spill Task Force. (2007). *Data Dictionary*. Victoria, British Columbia: Pacific States/British Columbia Oil Spill Task Force. July. http://www.oilspilltaskforce.org/docs/datadictionary.pdf, retrieved 29 June 2007.

Rasmussen, J. (1983). Skills, Rules and Knowledge: Signals, Signs and Symbols and Other Distinctions in Human Performance Models. *IEEE Transactions on Systems, Man & Cybernetics*. 13, 257-266.

Rasmussen, J. (1986). *Information Processing and Human-Machine Interaction*. Amsterdam: North Holland Publishing.

Reason, J. (1997). *Managing the Human and Organizational Response to Accidents*. Brookfield, VT: Ashgate Publishing.

Shappell, S.A. & Weigemann, D.A. (1997). A Human Error Approach to Accident Investigation: The Taxonomy of Unsafe Operations. *International Journal of Aviation Psychology*. 7, 269-292.

Shappell, S.A. & Weigemann, D.A. (2001). Human Factors Analysis and Classification System. *Flight Safety Digest*. February, 15-25.

Steward, M.J. (2007). *Mitigating the Risk of Accidents and Incidents in Energy Transportation: Empirical Analysis of Risk and Escort Operations in Puget Sound*. Master's Thesis. May 2007: Rensselaer Polytechnic Institute, 2007.

Transportation Research Board. (2008). Prospectus for Maritime Safety Reporting Database. Washington, D.C. National Academies/National Research Council. Transportation Research Board, Task Force on Marine Safety and Human Factors, June 2008.

U.S. Coast Guard (1999). Regulatory Assessment: Use of Tugs to Protect Against Oil Spills in the Puget Sound Area. Report No. 9522-002.

U.S. Department of Homeland Security, United States Coast Guard. (2005). Study to Investigate Marine Casualty Data. Prospectus prepared for U.S. General Accounting Office, House Subcommittee on the U.S. Coast Guard, 18 May 2005. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h889ih.txt.pdf, retrieved 18 May 2005.

Van Dorp, J.R., Merrick, J.R.W., Harrald, J.R., Mazzuchi, T.A., & Grabowski, M.R. A Risk Management Procedure for the Washington State Ferries. *Risk Analysis*. 21:1, 2001, 127-142.

Appendix A-1
Puget Sound Tanker Events, Accidents and Incident Analysis
1995-2005

Puget Sound Tanker Events, Accidents and Incidents, 1995-2005

In this section, an analysis of tanker events between 1995 and 2005, as recorded in the Puget Sound VTRA Accident-Incident database, is undertaken. Tankers include crude oil tankers, product tankers, LPG tankers, LNG tankers, combined chemical and oil tankers, chemical tankers, and Military Sealift Command tankers. 171 tanker events are in the database: 35 are accidents (20.47%), 111 are incidents (64.9%), and the remaining 25 records are unusual events. The tanker accident-incident pyramids for years 1995-2005 are shown in Figure A-16. Note that there are small sample sizes for all tanker accidents and unusual events.

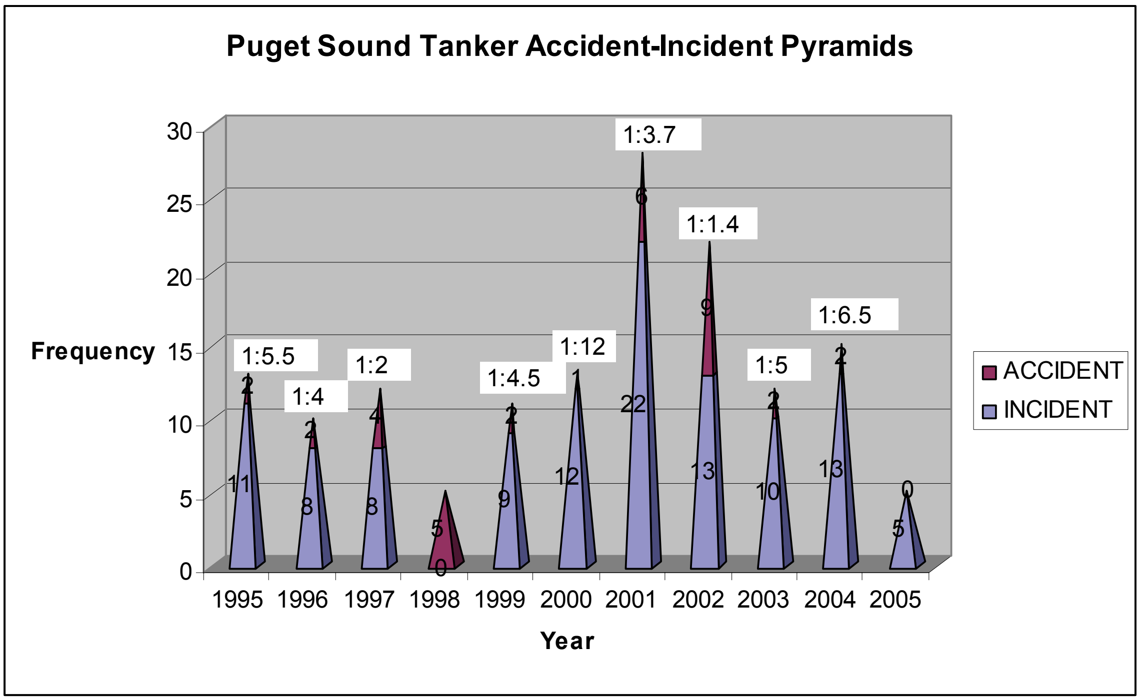


Figure A-16 Tanker Accident-Incident Ratios, 1995-2005

Tanker Events by Year, 1995-2005

Total tanker transit data (1996-2005) and tanker events, accidents, incidents, and unusual events (1995-2005) are given in Table A-45 and Figure A-17 below. The normalized data are also shown in Table A-46.

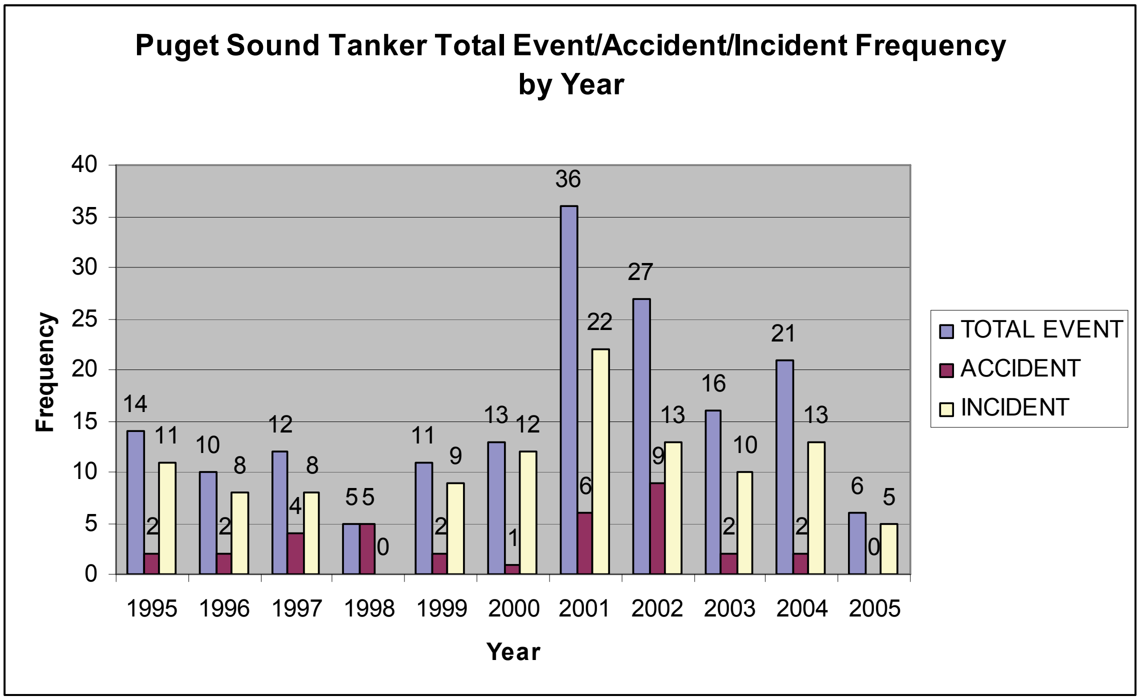


Figure A-17 Tanker Total Events, Accidents, and Incidents by Year, 1995-2005

Table A-45 Tanker Normalized Total Events, Accidents, and Incidents, 1995-2005 * = small sample size

Year (1)	Transit (2)		Total events (3)		Normalized events (4)=(3)/(2)	Accidents (5)		Normalized Accidents (6)=(5)/(2)	Incidents (7)		Normalized Incidents (8)=(7)/(2)	Unusual events (9)	
	N	%	N	%		N	%		N	%		N	%
1995	N/A	N/A	14*	8.2	N/A	2*	5.7	N/A	11 *	9.9	N/A	1 *	0.04
1996	2001	9.5	10 *	5.8	0.004998	2 *	5.7	0.001	8 *	7.2	0.003998	0	0
1997	2289	10.9	12 *	7.0	0.005242	4 *	11.4	0.001747	8 *	7.2	0.003495	0	0
1998	2107	10.0	5 *	2.9	0.002373	5 *	14.3	0.002373	0	0	0	0	0
1999	2095	9.9	11*	6.4	0.005251	2 *	5.7	0.000955	9 *	8.1	0.004296	0	0
2000	2557	12.1	13*	7.6	0.005084	1 *	2.9	0.000391	12*	10.8	0.004693	0	0
2001	2145	10.2	36 *	21.1	0.016783	6 *	17.1	0.002797	22*	19.8	0.010256	8 *	32
2002	1848	8.8	27 *	15.8	0.01461	9 *	25.7	0.00487	13 *	11.7	0.007035	5 *	20
2003	1889	9.0	16*	9.4	0.00847	2*	5.7	0.001059	10*	9	0.005294	4 *	16
2004	2031	9.6	21 *	12.3	0.01034	2 *	5.7	0.000985	13 *	11.7	0.006401	6 *	24
2005	2103	10.0	6 *	3.5	0.002853	0	0	0	5 *	4.5	0.002378	1 *	4
Total	**21065**	**100**	**171**	**100**	**N/A**	**35**	**100**	**N/A**	**111**	**100**	**N/A**	**25***	**100**

From Figure A-17, it can be seen that years 2001 and 2002 had the greatest number of tanker events in Puget Sound. Kruskal-Wallis and Tukey's HSD tests showed that there were statistical differences between normalized events and incidents from 1996-2005, with years 2002 and 2003 having the events and incidents (Table A-46). However, Wilcoxon tests on the data found that no statistical differences before and after year 2000 (Table A-47).

Table A-46: Kruskal-Wallis and Tukey's HSD Tests on Total Events, Accidents, and Incidents Frequencies by Year, 1995-2005

Variable		DF	Test Statistics	Direction
Raw Data	**Total Events**	10	Kruskal-Wallis: Chi-square statistic 24.1119, Pr > Chi-square =0.0073 Tukey's HSD: F-value=3.62, Pr >F =0.0003	A:2001 2002 2004 2003 1995 B: 2002 2004 2003 1995 2000 1997 1999 1996 2005 1998 **A>B**
	Accidents*	10	Kruskal-Wallis: Chi-square statistic 12.4000, Pr > Chi-square =0.2592 Tukey's HSD: F-value=1.27, Pr >F =0.2549	N/A
	Incidents	10	Kruskal-Wallis: Chi-square statistic 23.1115, Pr > Chi-square =0.0103 Tukey's HSD: F-value=2.22, DF = 10, Pr >F =0.0207	A: 2001 2004 2002 2000 1995 2003 1999 1996 1997 2005 B: 2004 2002 2000 1995 2003 1999 1996 1997 2005 1998 **A>B**
Normalized Data	**Total Events**	9	Kruskal-Wallis: Chi-square statistic 23.9004, Pr > Chi-square =0.0045 Tukey's HSD: F-value=3.69, Pr >F =0.0005	A: 2002 2003 2005 1996 2004 B: 2003 2005 1996 2004 1998 2001 1997 2000 1999 **A>B**
	Accidents*	9	Kruskal-Wallis: Chi-square statistic 9.2947, Pr > Chi-square=0.4105 Tukey's HSD: F-value=1.02, Pr >F 0.4263	N/A
	Incidents	9	Kruskal-Wallis: Chi-square statistic 22.5624, Pr > Chi-square =0.0073 Tukey's HSD: F-value=2.50, DF = 9, Pr >F =0.0120	A: 2002 2003 1996 2005 2001 2004 1998 1997 2000 B: 2003 1996 2005 2001 2004 1998 1997 2000 1999 **A>B**

*** = small sample size** **Bold results are statistically significant**

Table A-47 Wilcoxon Test Result for Tanker Raw and Normalized Events, Accidents, and Incidents before and after Year 2000

Variable		N*	Test statistic	Normal approximate Z	Two-sided Pr> $\|Z\|$	Direction
Raw Data	**Total events**	5/6*	20.0000	-1.8257	0.0679	N/A
	Accidents*	5/6*	32.0000	0.3830	0.7017	N/A
	Incidents	5/6*	20.0000	-1.8341	0.0666	N/A
Normalized Data	**Total events**	5*	19.0000	-1.7756	0.0758	N/A
	Accidents*	5*	25.0000	-0.5222	0.6015	N/A
	Incidents	5*	19.000	-1.7756	0.0758	N/A

*** = small sample size** **Bold results are statistically significant**

Tanker Events by Location

Total tanker events, accidents, incidents, and unusual events, and percent for different geographic areas, are given in Figure A-18 and Table A-48.

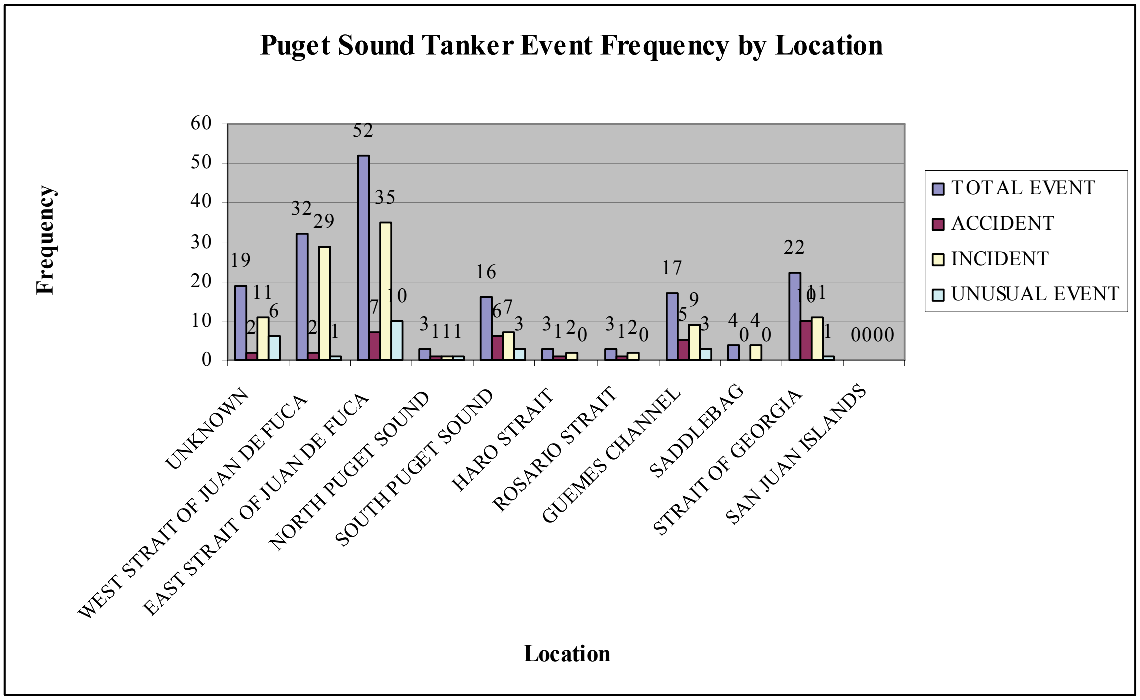


Figure A-18 Puget Sound Tanker Events, Accidents and /Incidents by Location, 1995-2005

Table A-48 Tanker Events, Accidents, and Incidents, by Location, 1995-2005

Zone	Total Tanker Events		Tanker Accidents		Tanker Incident		Tanker Unusual Event	
	N*	%	N*	%	N*	%	N	%
West Strait of Juan de Fuca	32	18.7	2*	5.71	29*	26.13	1*	4
East Strait of Juan de Fuca	52	30.4	7*	20	35	31.53	10*	40
North Puget Sound	3*	1.75	1*	2.86	1*	0.9	1*	4
South Puget Sound	16*	9.36	6*	17.14	7*	6.31	3*	12
Haro Strait/Boundary Pass	3*	1.75	1*	2.86	2*	1.80	0*	0
Rosario Strait	3*	1.75	1*	2.86	2*	1.80	0*	0
Guemes Channel	17*	9.94	5*	14.28	9*	8.11	3*	12
Saddlebags	4*	2.34	0*	0	4*	3.60	0*	0
Strait of Georgia/Cherry Point	22*	12.87	10*	28.57	11*	9.91	1*	4
San Juan Islands	0*	0	0*	0	0*	0	0*	0
Unknown	19*	11.1	2*	5.71	11*	9.91	6*	24
Total	**171**	**100**	**35**	**100**	**111**	**100**	**25***	**100**

N: Number of total events, accidents, incidents, and unusual events;%: Percent of event frequency for every geographic area.
*** = small sample size** **Bold results are statistically significant**

Table A-48 and Figure A-18 show that the areas West and East Strait of Juan de Fuca are areas that had the most of events for tankers in Puget Sound from year 1995-2005. This is a significantly different result than for other vessel types, which showed most events occurring in South Puget Sound. The East and West Straits of Juan de Fuca are areas of particular interest, as vessels in the East Straits are often engaged in northward transits to refineries. A Wilcoxon test of the tanker events, accidents, and incidents in the East and West Straits of Juan de Fuca, however, found no difference in numbers of events for these two areas (Table A-49).

Further analysis using the Kruskal-Wallis and Tukey's HSD tests showed that there were statistical differences in total events, accidents, and incident frequencies among the 10 geographic areas (Table A-50). Table A-50 shows that tankers have a similar geographic distribution for events and incidents, as both have the highest frequencies in the East and West Straits of Juan de Fuca. Note, however, that tanker accident locations differ, and occur most frequently in the Cherry Point, East Strait of Juan de Fuca, and South Puget Sound areas. All data are limited by small sample sizes.

Table A-49: Wilcoxon Tests on Tanker Events, Accidents, and Incidents Frequencies between East and West Strait of Juan de Fuca, 1995-2005

Variable	N	Test statistic	Normal approximate Z	Two-sided Pr> $\|Z\|$	Direction
Tanker Events	11	114.0000	-0.8279	0.4078	N/A
Accidents	11	109.0000	-1.4102	0.1585	N /A
Incidents	11	122.0000	-0.3002	0.7640	N/A

Table A-50: Kruskal-Wallis and Tukey's HSD Tests on Tanker Events, Accidents, and Incidents Frequencies by Location, 1995-2005 * = small sample size

Variable	DF	Test Statistics	Direction
Total Events	9	Kruskal-Wallis: Chi-square statistic 47.5930, Pr > Chi-square <0.0001 Tukey's HSD: F-value=7.36, Pr >F <0.0001	A: East Strait of Juan de Fuca, West Strait of Juan de Fuca B: West Strait of Juan de Fuca, Cherry point, Guemes Channel, South Puget Sound, Saddlebag C: Cherry point, Guemes Channel, South Puget Sound, Saddlebag, North Puget Sound, Rosario Strait, Haro Strait, San Juan Islands **A>B>C**
Accidents*	9	Kruskal-Wallis: Chi-square statistic 22.4411, Pr > Chi-square =0.0076 Tukey's HSD: F-value=2.65, Pr >F =0.0086	A: Cherry Point, East Strait of Juan de Fuca, South Puget Sound, Guemes Channel, West Strait of Juan de Fuca, Rosario Strait, North Puget Sound, Haro Strait B: East Strait of Juan de Fuca, South Puget Sound, Guemes Channel, West Strait of Juan de Fuca, Rosario Strait, North Puget Sound, Haro Strait, Saddlebag, San Juan Islands **A>B**
Incidents	9	Kruskal-Wallis: Chi-square statistic 46.0565, Pr > Chi-square <0.0001 Tukey's HSD: F-value=8.31, Pr >F <0.0001	A: East Strait of Juan de Fuca, West Strait of Juan de Fuca B: West Strait of Juan de Fuca, Cherry point C: Cherry point, Guemes Channel, South Puget Sound, Saddlebag, Haro Strait, Rosario Strait, North Puget Sound, San Juan Islands **A>B>C**

*** = small sample size**

Events in the East and West Straits of Juan de Fuca before and after the year 2000 were also tested to determine whether events had different frequencies before and after 2000, when the Cherry Point dock was built. A Wilcoxon test showed that no difference was found in events in the West Strait and East Strait (Table A-51). Note that these results are also limited by small sample sizes.

Table A-51 Wilcoxon Tests on Tanker Events, Accidents, and Incidents Frequencies in East and West Strait of Juan de Fuca before and after 2000, 1995-2005

Variable		N*	Test statistic	Normal approximate Z	Two-sided Pr> $\|Z\|$	Direction
West Strait of Juan de Fuca	Tanker Events	11*	28.0000	-0.3685	0.7125	N/A
	Accidents*	11*	30.5000	0.1361	0.8918	N/A
	Incidents	11*	28.5000	-0.2796	0.7798	N/A
East Strait of Juan de Fuca	Tanker Events	11*	20.0000	-1.8599	0.0629	N/A
	Accidents*	11*	32.5000	0.5118	0.6088	N/A
	Incidents	11*	20.5000	-1.7545	0.0793	N/A

*** = small sample size** **Bold results are statistically significant**

Tanker Events by Season

Figures A-19 and A-20 show raw and normalized total events, accidents, and incidents by season, from which it can be seen that the 2002 and 2003 seasons had higher raw and normalized total events than those in other years.

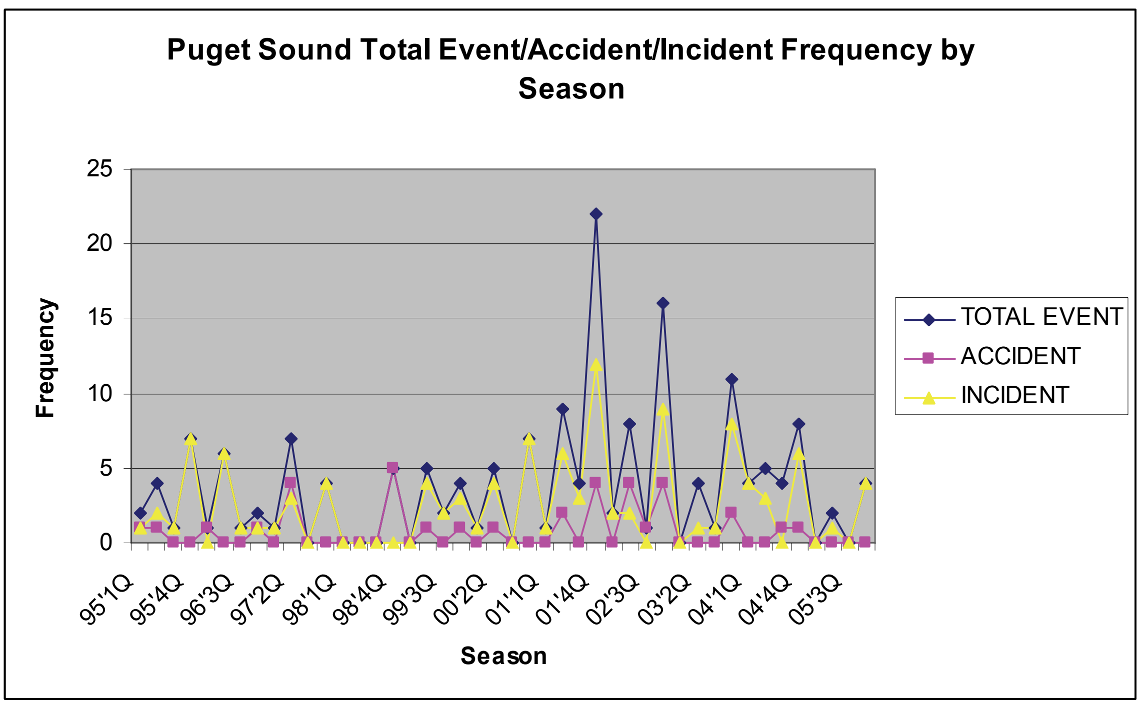


Figure A-19 Raw Puget Sound Tanker Events, Accidents and Incidents, 1995-2005

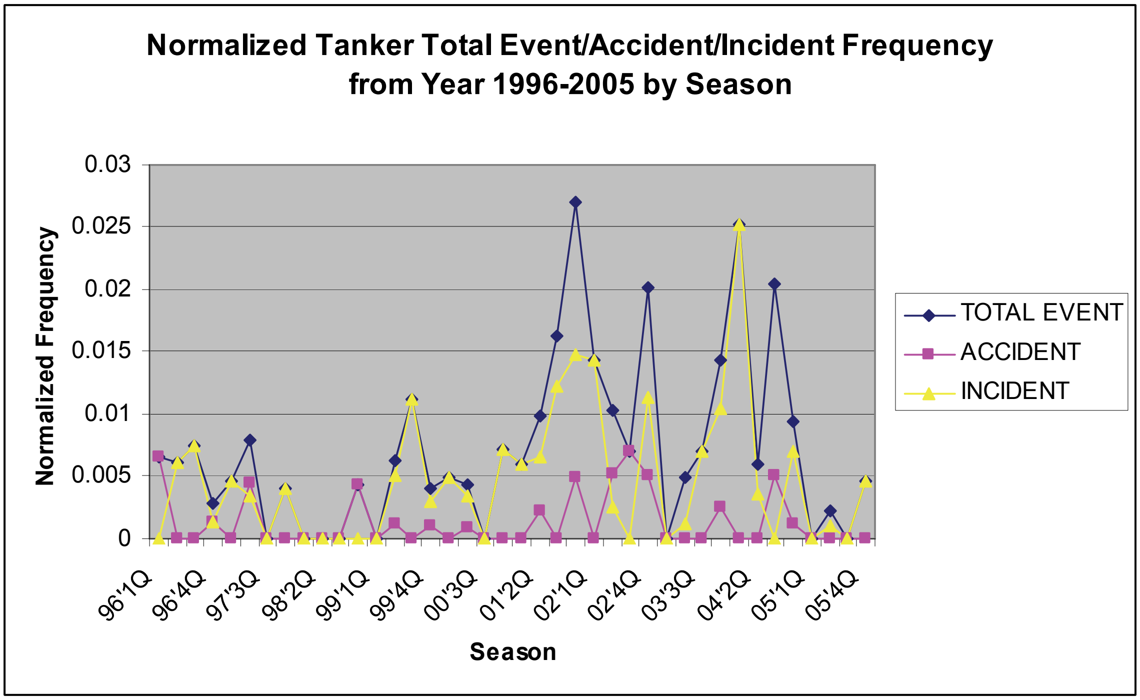


Figure A-20 Normalized Puget Sound Tanker Events, Accidents and Incidents, 1996-2005

Analysis using Kruskal-Wallis and Tukey's HSD tests showed that although tankers had different total event and incident frequencies among the four seasons in the raw data analysis, no statistical difference for normalized tanker events, accidents, or incidents existed among the four seasons (Table A-52). Note that the data are limited by small sample sizes.

Table A-52 Kruskal-Wallis and Tukey's HSD tests of Raw and Normalized Event, Accident, and Incident Frequencies for Tanker by Season * =small sample size

Variable		DF	Test statistic	Direction
Raw Data	**Total Events**	3	Kruskal-Wallis: Chi-square statistic 24.8965, D Pr> Chi-square <0.0001 Tukey's HSD: F-value=10.79, Pr >F =0.0001	**A: Winter Summer** **B: Summer Autumn** **C: Autumn Spring** **A>B>C**
	Accidents*	3	Kruskal-Wallis: Chi-square statistic 9.6246, Pr> Chi-square =0.0220 Tukey's HSD: F-value=3.84, Pr >F =0.0166	**A: Winter Summer** **B: Summer Spring Autumn** **A>B**
	Incidents	3	Kruskal-Wallis: Chi-square statistic 18.9876, Pr> Chi-square =0.0003 Tukey's HSD: F-value=11.62, Pr >F <0.0001	**A: Winter** **B: Summer Spring Autumn** **A>B**
Normalized Data	**Total Events**	3	Kruskal-Wallis: Chi-square statistic 1.3870, P> Chi-square =0.7086 Tukey's HSD: F-value=0.83, Pr >F =0.4859	N/A
	Accidents*	3	Kruskal-Wallis: Chi-square statistic 6.1219, P> Chi-square =0.1058 Tukey's HSD: F-value=0.71, Pr >F =0.5544	N/A
	Incidents	3	Kruskal-Wallis: Chi-square statistic 2.8621, P> Chi-square =0.4134 Tukey's HSD: F-value=0.78, Pr >F=0.5146	N/A

A seasonality index was constructed to assess the likelihood of tanker events, accidents and incidents in Puget Sound by season between 1995 and 2005. This analysis showed that events in summer and winter seasons occurred more often than events in the spring and autumn seasons, similar to the observations for all vessels reported in earlier sections. For normalized events, the winter season had more than other seasons (Table A-53). This contrasts with the results for all vessels in VTRA Accident-Incident database, which showed that events occurred more often in summer and winter than in the spring and autumn; for normalized events, spring and winter had slightly more events than summer and winter (Table A-20). This suggests that normalized tanker accidents had different seasonality patterns than all other vessels taken together for the period 1995-2005. Table A-53 also shows that normalized tanker events, accidents, and incidents happened more frequently in winter, compared to other three seasons between 1995-2005. However, spring and autumn had more incidents than did the summer and winter seasons for all vessel types between 1995 and 2005 (Table A-20). Therefore, normalized tanker events showed different seasonality patterns compared to all vessels taken together, 1996-2005. For raw data, tanker total events, accidents, and incidents show the same seasonality patterns as all vessels taken together in the period of 1995-2005.

Table A-53 Raw and Normalized Seasonal Index for Tanker Total Events, Accidents, and Incidents, 1995-2005

Season	Raw Seasonal Index		
	Total Events	Accidents	Incidents
Spring	0.28	0.23	0.36
Summer	1.29	1.49	1.15
Autumn	0.33	0.23	0.29
Winter	2.11	2.06	2.20
	Normalized Seasonal Index		
Spring	0.81	0.49	1.10
Summer	0.82	1.06	0.82
Autumn	0.98	0.91	0.88
Winter	1.39	1.54	1.38

Tanker Events by Time of Day

Tanker events by time of day in the Puget Sound VTRA database were assessed by day and night, as shown in the Table A-54. The large amount of missing data in Table A-54 suggests this analysis needs to be revalidated with a more complete data set.

Table A-54: Puget Sound Tanker Event Type by Time of Day, 1995-2005

Time	Total Events		Accidents		Incidents	
	N	%	N	%	N	%
Day	52	30.4	13*	37.1	36	32.4
Night	26*	15.2	6*	17.1	16*	14.4
Null	93	54.4	16*	45.8	59	53.2

*** = small sample size**

A Wilcoxon analysis of the data in Table A-54 shows that tankers had no different accident frequencies during the day and the night in Puget Sound between years 1995-2005. However, total events and incidents occurred more often during the day than the night for tanker ships (Table A-55). Note that those results are limited by small sample size and by the large amount of missing data.

Table A-55 Wilcoxon Tests of Tanker Events, Accidents, and Incidents, by Time of Day, 1995-2005

Variable	N	Test statistic	Normal approximation Z	Two-sided Pr> $\lvert Z \rvert$	Direction
Total Events	11	158.0000	2.1181	**0.0342**	**Day>Night**
Accidents*	11	147.5000	1.4788	0.1392	N/A
Incidents	11	161.5000	2.3555	**0.0185**	**Day>Night**

*** = small sample size** **Bold results are statistically significant**

Tanker Events by Vessel Flag

Although most vessels in Puget Sound are U.S. flag vessels, some are foreign-flag vessels. The distribution of total events, accidents, and incidents between U.S. vessels and foreign flag vessels is shown in Table A-56. Note all of that the data is limited by small sample sizes.

Table A-56 U.S. and Non-U.S. Flag Tanker Events, Accidents, and Incidents, 1995-2005

Year	Total events		Accidents		Incidents	
	US	Non-US	US	Non-US	US	Non-US
1995	11*	3*	1*	1*	9*	2*
1996	7*	3*	1*	1*	6*	2*
1997	11*	1*	3*	1*	8*	0
1998	4*	1*	4*	1*	0	0
1999	7*	4*	2*	0	5*	4*
2000	10*	2*	0	1*	10*	1*
2001	25*	8*	2*	4*	18*	4*
2002	16*	8*	5*	4*	10*	3*
2003	12*	0	2*	0	10*	0
2004	13*	3*	1*	1*	10*	2*
2005	6*	0	0	0	5*	0
Total	122	33	21	14*	91	18*
Percent	71.3	19.3	60	40	82.0	16.2

*** = small sample size**

Table A-56 shows that accidents occurred to U.S. and non-U.S. flag tankers at almost the same rate, while incidents occurred to U.S. flag tankers more than the non-U.S. flag tankers. A Wilcoxon test showed that U.S. flag tankers had a higher number of total events and incidents than those non U.S. flag tankers. However, no difference in accident frequency occurred between U.S. and Non U.S. flag tankers (Table A-57). Note that the data are limited by small sample sizes.

Table A-57 Wilcoxon Tests on Tanker Events, Accidents, and Incident Frequencies by Vessel Flag, 1995-2005

Variable	N	Test statistic	Normal approximation Z	Two-sided Pr> $\lvert Z \rvert$	Direction
Tanker Events	11	178.5000	3.4243	**0.0006**	**U.S.>Non U.S.**
Accidents*	11	144.0000	1.2004	0.2300	N/A
Incidents	11	178.0000	3.4167	**0.0006**	**U.S.>Non U.S.**

*** = small sample size**

Total tanker events, accidents, and incidents by different foreign flags were assessed, as seen in Table A-58. No statistically significant results were found in this analysis, which was limited by small sample size.

Table A-58 Tanker Total Event/Accident/Incident by Vessel Flag, 1995-2005

Vessel Flag	Tanker Events		Accidents		Incidents		Unusual Events	
	N	%	N	%	N	%	N	%
U.S.	122	71.3	21*	60	91	82.0	10*	40
Bahamas	2*	1.2	1*	2.9	1*	0.9	0	0
Greece	3*	1.8	1*	2.9	2*	1.8	0	0
Isle of Man	4*	2.4	2*	5.7	2*	1.8	0	0
Liberia	8*	4.8	5*	14.3	3*	2.7	0	0
Marshall Islands	2*	1.2	0		2*	1.8	0	0
Panama	5*	2.9	3*	8.6	2*	1.8	0	0
Norway	3*	1.8	0		3*	2.7	0	0
Singapore	2*	1.2	1*	2.9	0		1*	4
Other	20*	11.7	1*	2.9	5*	4.5	14*	56
Total	171	100	35	100	111	100	25	100

*** = small sample size**

Tanker Events by Vessel Owner

The total events, accidents, and incidents frequencies for vessels from different owners are showed in the Table A-59.

Table A-59 Tanker Events, Accidents, Incidents, Unusual Events by Vessel Owner, 1995-2005

Vessel Owner	Tanker Events		Accidents		Incidents		Unusual Events	
	N	%	N	%	N	%	N	%
SeaRiver Maritime	19*	11.1	2*	5.7	16*	14.4	1*	4
Polar Tankers	11*	6.4	2*	5.7	9*	8.1	0	0
Overseas Shipholding	25*	14.6	5*	14.3	19*	17.1	1*	4
Nordic American Tanker Shipping	4*	2.3	2*	5.7	2*	1.8	0	0
Marine Transport Corp	5*	2.9	0	0	2*	1.8	3*	12
Lightship Tankers	4*	2.3	1*	2.9	3*	2.7	0	0
Keystone Shipping	19*	11.1	2*	5.7	16*	14.4	1*	4
Chevron USA / Chevron Shipping	9*	5.3	1*	2.9	8*	7.2	0	0
ARCO	5*	2.9	2*	5.7	3*	2.7	0	0
SHIPCO 670 / Alaska Tanker Company (ATC)	13*	7.6	3*	8.6	9*	8.1	1*	4
Other	57	33.3	15*	42.9	24*	21.6	18*	72
Total	171	100	35	100	111	100	25	100

*** = small sample size**

Table A-59 shows that Overseas Shipholding, Keystone Shipping and SeaRiver Maritime are the owners of tanker vessels that had the most event frequencies in Puget Sound between 1995 and 2005. A Kruskal-Wallis analysis, however, shows that tankers from these three owners had no statistical difference in total event, accident, and incident frequencies (Table A-60). These data were all characterized by small sample sizes.

Table A-60 Kruskal-Wallis Tests of Tanker Events, Accidents, and Incident Frequencies by Vessel Owner, 1995-2005

Variable	DF	Test Statistics	Direction
Total Events	2	Kruskal-Wallis: Chi-square statistic 1.2356, P> Chi-square =0.5722	N/A
Accidents	2	Kruskal-Wallis: Chi-square statistic 0.3101, P> Chi-square =0.8501	N/A
Incidents	2	Kruskal-Wallis: Chi-square statistic 1.3920, P> Chi-square =0.4847	N/A

Tanker Events by Direction

Tankers sailing in Puget Sound can be classified as inbound vessels and outbound vessels. Total tanker events, accidents, and incidents for both inbound tankers and outbound tankers are shown in Table A-61. The statistical tests on the tanker events, accidents, or incidents by direction are not available because of small sample size.

Table A-61 Puget Sound Tanker Events by Direction, 1995-2005

Direction	Total Events		Accidents		Incidents	
	N	%	N	%	N	%
Inbound	23*	13.5	1*	2.9	21*	18.9
Outbound	4*	2.3	0	0	4*	3.6
Null	144	84.2	34*	97.1	86	77.5

*** = small sample size**

Tanker Events by Hull Type

There are four hull types for tankers in the database: single hull, double hull, double sides, and double bottoms, as seen in Figure A-21 and Table A-62. Missing information was classified as "unknown". A Wilcoxon test of the Table A-62 data shows that double hull vessels had significantly higher numbers of total events, accidents, and incidents than single hull tankers (Table A-63). Note that this data, too, is limited by small sample sizes.

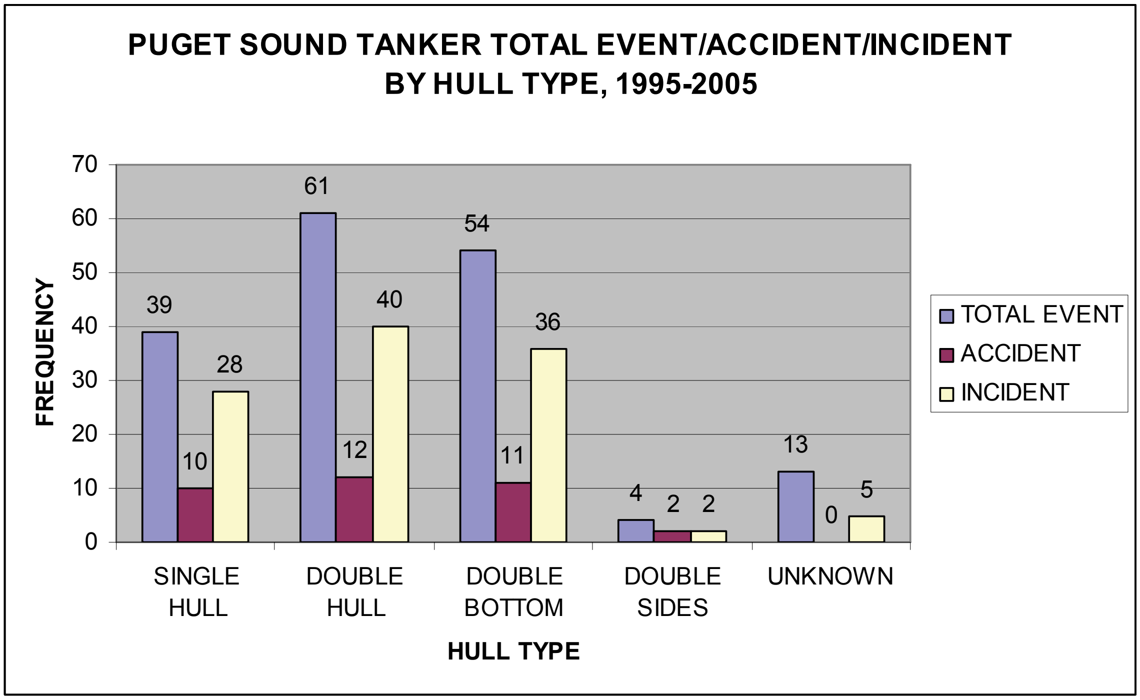


Figure A-21 Tanker Accidents, Incidents and Unusual Events by Hull Types, 1995-2005

Table A-62 Tanker Accident/Incident/Unusual Event Frequency by Hull Type, 1995-2005

Event	Single Hull	Double Hull	Double Sides	Double Bottom	Unknown
Accidents	10*	12*	2*	11*	0
Incidents	28*	40	2*	36*	5*
Unusual Events	1*	9*	0	7*	8*
Total	39*	61	4*	54	13*

*** = small sample size**

Table A-63 Wilcoxon Tests of Tanker Events, Accidents, and Incidents by Hull Type, 1995-2005

Variable	N	Test statistic	Normal approximate Z	Two-sided Pr> $\|Z\|$	Direction
Tanker Events	11	91.0000	-2.3390	**0.0193**	**Double Hull* >Single Hull***
Accidents	11	94.5000	-2.2226	**0.0262**	**Double Hull* >Single Hull***
Incidents	11	93.0000	-2.2206	**0.0264**	**Double Hull* >Single Hull***

*** = small sample size**

Tanker Events by Vessel Size

Tankers were classified by deadweight tonnage to determine if events were associated with differing vessel sizes. Vessel sizes were classified as three categories: below 40,000; 40,000~80,000; and above 80,000 DWT (Table A-64).

Table A-64 Tanker Events by Vessel Size, 1995-2005

Vessel Size	Tanker Events		Accidents		Incidents	
	N	%	N	%	N	%
Below 40,000 DWT	71	41.5	20*	55.6	45	40.54
40,000-80,000 DWT	71	41.5	12*	33.3	50	45.05
80,000 DWT above	20*	11.7	3*	8.3	14*	12.61

*** = small sample size**

A Kruskal-Wallis analysis of the Table A-64 data showed statistical differences between total events, accidents, and incidents for tankers of different sizes (Table A-65). Tankers less than 80,000 gross tons had significantly higher numbers of events, accidents and incidents than did larger tankers, those that were above 80000 gross tons. Note also that these results are limited by small sample sizes.

Table A-65 Kruskal-Wallis and Tukey's HSD tests of Tanker Events, Accidents, and Incidents by Vessel Size, 1995-2005

Variable	DF	Test statistic	Directions
Tanker Events	2	Kruskal-Wallis: Chi-square statistic 13.2427, P> Chi-square =0.0013 Tukey's HSD: F-value=6.28, Pr >F =0.0053	(Below 40000)= (40000-80000)> (80000 above)*
Accidents	2	Kruskal-Wallis: Chi-square statistic 8.3235, P> Chi-square =0.0156 Tukey's HSD: F-value=4.66, Pr >F =0.0173	A: (Below 40000), (40000-80000) B: (40000-80000), (80000 above) **A>B***
Incidents	2	Kruskal-Wallis: Chi-square statistic 10.4913, P> Chi-square =0.0053 Tukey's HSD: F-value=5.73, Pr >F=0.0078	A: (40000-80000), (Below 40000) B: (80000 above) **A>B***

* = **small sample size**

Tanker Events under Escort/No Escort

Escorts tugs can reduce the risk of accident occurrence for tankers. They can intercede in the event of power or steering failure, and can provide a power assist for tankers under power. However, a disadvantage of escort tugs is that additional vessels are introduced into the already congested waterway, increasing the potential for casualties between the escort tugs and other vessels. The analysis of tanker accidents and incidents under escort and not under escort can help in understanding the efficacy and quality of the escort system in the Puget Sound Marine transportation system. However, since transit data for vessels under escort and vessels not under no escort is not available, tests could only be run to determine whether there were significant differences of raw event frequencies in those two conditions, as seen in Table A-66. Since previous normalization analyses in this database have shown significant differences between raw data and normalized data trends, caution is advised with the escort vs. no escort analyses.

Table A-66 Tanker Events by Vessel under Escort/No Escort, 1995-2005

Escort or No Escort	Tanker Events		Accidents		Incidents	
	N	%	N	%	N	%
Escort	117	68.4	22*	62.9	82	73.9
No Escort	46	26.9	13*	37.1	28*	25.2
Null	8	4.7	2*	5.7	1*	0.9
Total	171	100	35*	100	111	100

*** = small sample size**

A Wilcoxon test of the Table A-66 data shows that tankers under escort had a higher number of total events and incidents than those with no escort. However, no difference of accident frequency was found for tankers under these two conditions (Table A-67). Therefore, the results may be different with normalized data, compared to the results with raw data. Note, however, that the accident statistics and the no-escort incident data are limited by small sample sizes.

Table A-67 Wilcoxon Tests of Tanker Events, Accidents, and Incidents by Vessels under Escort/no Escort, 1995-2005

Variable	N	Test statistic	Normal approximation Z	Two-sided Pr> $\|Z\|$	Direction
Tanker Events	11	169.5000	2.8316	**0.0046**	**Escort> No Escort**
Accidents	11	143.5000	1.1590	0.2465	N/A
Incidents	11	167.5000	2.7099	**0.0067**	**Escort> No Escort***

*** = small sample size** **Bold results are statistically significant**

Tanker Events by Classification Society

Tanker events were characterized by the vessel's classification society, using information from Lloyd's List; the results from this analysis are shown in Table A-68.

Class Society	Tanker Events		Accidents		Incidents		Unusual Events	
	N	%	N	%	N	%	N	%
ABS	80	46.8	9*	25.7	59	53.2	12*	48
Lloyd's Register (LR)	6*	3.5	4*	11.4	2*	1.8	0	0
Nippon Kaiji Kyokai (NK)	5*	2.9	3*	8.6	1*	0.9	1*	4
Norske Veritas Classification A/S (NV)	3*	1.8	0	0	3*	2.7	0	0
Russian Maritime Register of Shipping (RS)	1*	0.6	0	0	1*	0.9	0	0
Null	76	44.4	19*	54.3	45	40.5	12*	48
Total	**171**	**100**	**35**	**100**	**111**	**100**	**25**	**100**

Table A-68 Tanker Events by Classification Society, 1995-2005

N: Number of records from the class society; %: Percent of records from the class society.

*** = Small sample size**

Table A-68 shows that ABS-classed vessels had the highest number of total events, accidents, incidents, and unusual events, compared to other class societies. However, statistical tests by class society are not available because of small sample sizes.

Tanker Accidents and Incidents by Event Type

In the Puget Sound VTRA Accident-Incident database, there were five types of tanker accidents: allisions, collisions, fire/explosion, groundings, and pollution. Tanker incidents were comprised of equipment failures, loss of power, loss of propulsion, loss of steering, near miss, and structural failure/damage. The statistical data are shown in Table A-69.

Table A-69 Puget Sound Tanker Accidents and Incidents by Type, 1995-2005

Accident Type	Allision	Collision	Fire/ explosion	Grounding		Pollution	
Frequency	4*	1*	2*	1*		27*	
Incident Type	**Equipment failure**	**Loss of power**	**Loss of propulsion**	**Loss of anchor**	**Loss of steering**	**Near miss**	**Structural failure /damage**
Frequency	55	1*	22*	3*	8*	4*	18*

*** = Small sample size**

Table A-69 shows that pollution was the major accident type and equipment failure was a major incident type for tankers in Puget Sound, 1995-2005. This pattern is consistent with that of all vessel types, as reported in the main body of this report. Kruskal-Wallis and Tukey's HSD analyses of the data also showed results similar to those for all vessels: that pollution is significantly the largest accident type, and equipment failures are the largest incident type (Table A-70). These results are all characterized by small sample sizes.

Table A-70 Kruskal-Wallis and Tukey's HSD tests of Tanker Accident and Incident types in Puget Sound, 1995-2005

Variable	DF	Test Statistics	Direction
Accident Type	4	Kruskal-Wallis: Chi-square statistic 29.4903, P>Chi-square <0.0001 Tukey's HSD: F-value= 16.56, Pr >F <0.0001	**Pollution* >Allision*, Fire*, Collision*, Grounding***
Incident Type	6	Kruskal-Wallis: Chi-square statistic 39.8337, P>Chi-square <0.0001 Tukey's HSD: F-value= 9.09, Pr >F <0.0001	**Equipment failure>Loss of Propulsion*, Structural Failure*, Loss of steering*, Near miss*, Loss of Anchor, Loss of Power***

*** = small sample size** **Bold results are statistically significant**

Tanker Events by Error Types

The frequency of tanker total events, accidents, and incidents caused by human and organizational error (HOE) and mechanical failure (MF) is shown in Table A-71.

Table A-71 Tanker Event Frequencies by Error Types, 1995-2005

Error	Total Event		Accident		Incident	
	N	%	N	%	N	%
HOE	41	24.0	15*	42.9	8*	7.2
MF	113	66.1	13*	37.1	100	90.1
Weather	5*	2.9	2*	5.7	3	2.7
Insufficient Information	12*	7.0	5*	14.3	0	0
Total	171	100	35*	100	111	100

*** = small sample size**

Earlier, Table A-37 showed Wilcoxon test results with tankers having significantly more events and incidents caused by mechanical failure than by human and organizational error; there was no statistically significant difference in tanker accidents caused by human error, compared to mechanical failure (Table A-72). With the exception of the event error types (which showed no significant error type results), these results are consistent with those shown for all vessels (Table A-37). However, these data are limited by small sample sizes.

Table A-72 Wilcoxon Tests of Tanker Events, Accidents, and Incidents by Error Type, 1995-2005

Variable	N	Test statistic	Normal approximation Z	Two-sided Pr> $\|Z\|$	Direction
Tanker Events	11	77.5000	-3.2350	**0.0012**	**MF>HOE***
Accidents	11	127.5000	0.0698	**0.9443**	N/A
Incidents	11	75.0000	-3.4405	**0.0006**	**MF>HOE***

*** = small sample size**

Summary of Puget Sound Tanker Events, Accidents and Incidents, 1995-2005

Analysis of tanker events, accidents, and incidents showed that 2001 had the highest number of events and incidents, compared to other years. However, no statistical difference was found for accident frequencies from years 1995-2005. Tests on normalized data showed that 2002 had the highest number of accidents, compared to other years. When tanker events by season were analyzed, winter had the highest number of total events, accidents, and incidents, compared to other seasons. No statistically significant difference was found among the normalized data by season.

Analysis of tanker events by location showed that East and West Strait of Juan de Fuca had the highest number of total events and incidents, compared to other locations, and Cherry Point was found to have the highest number of accidents among locations. When analysis of data in the East and West Straits of Juan de Fuca was undertaken, for events before and after year 2000, Wilcoxon test results showed no statistically significant difference. These tanker results are significantly different than the results reported for all vessels, which showed South Puget Sound as the location with the highest number of events, accidents and incidents.

Analysis of tanker events by time of day showed that tankers had a statistically higher number of total events and incidents during the day than the night. In addition, U.S. flag, double hull, and Under Escort vessels had higher numbers of total events and incidents, compared to Non-U.S. flag, single hull, and No Escort vessels.

Analysis of tanker events by vessel size showed that small tankers (vessels below 40,000 DWT) had higher numbers of total events, accidents, and incidents, compared to vessels of other sizes.

For tankers, pollution was the major accident type and equipment failures were the major incident type, consistent with the results earlier reported for all vessel types. Analysis of tanker events by accident types showed that tanker pollution accidents occurred statistically more often than tanker accidents of other types. Similarly, analysis showed that tanker equipment failure incidents occurred significantly more often than tanker incidents of other types.

Analysis of tanker events by error type showed that tankers had higher number of total events and incidents caused by mechanical failure, rather than human error. These results were consistent with events by error type for all vessels in the Puget Sound VTRA Accident-Incident database.The significant test results of tanker vessels events data in Puget Sound are shown in Table A-72. Note that many of these data suffer from small sample sizes.

Test		Results	Test Used	Statistics	Direction
By Year	**Tanker Events**	**There are statistical differences in tanker events by year for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 24.1119, DF = 10, Pr > Chi-square =0.0073 F-value=3.62, DF = 10, Pr >F <0.0003	**A:2001 2002 2004 2003 1995** **B: 2002 2004 2003 1995 2000 1997 1999 1996 2005 1998** **A>B**
	Incidents	**There are statistical differences in tanker incidents by year for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 23.1115, DF = 10, Pr > Chi-square =0.0103 F-value=2.22, DF = 10, Pr >F =0.0207	**A: 2001 2004 2002 2000 1995 2003 1999 1996 1997 2005** **B: 2004 2002 2000 1995 2003 1999 1996 1997 2005 1998** **A>B**
By Year (normalized)	**Tanker Events**	**There are statistical differences in normalized tanker events for years 1996-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 23.9004, DF = 9, Pr > Chi-square =0.0045 F-value=3.69, DF = 9, Pr >F =0.0005	**A: 2002 2003 2005 1996 2004** **B: 2003 2005 1996 2004 1998 2001 1997 2000 1999** **A>B**
	Incidents	**There are statistical differences in normalized tanker incidents for year 1996-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 22.5624, DF = 9, Pr > Chi-square =0.0073 F-value=2.50, DF = 9, Pr >F =0.0120	**A: 2002 2003 1996 2005 2001 2004 1998 1997 2000** **B: 2003 1996 2005 2001 2004 1998 1997 2000 1999** **A>B**
By Location	**Tanker Events**	**There are statistical differences in tanker events by location for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 47.5930, DF = 9, Pr > Chi-square <0.0001 F-value=7.36, DF = 9, Pr >F <0.0001	**A: East Strait of Juan de Fuca, West Strait of Juan de Fuca B: West Strait of Juan de Fuca, Cherry point, Guemes Channel, South Puget Sound, Saddlebag C: Cherry point, Guemes Channel, South Puget Sound, Saddlebag, North Puget Sound, Rosario Strait, Haro Strait, San Juan Islands** A>B>C

Test		Results	Test Used	Statistics	Direction
	Accidents	**There are statistical differences in tanker accidents by location for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 22.4411, DF = 9, Pr > Chi-square =0.0076 F-value=2.65, DF = 9, Pr >F =0.0086	**A: Cherry Point, East Strait of Juan de Fuca, South Puget Sound, Guemes Channel, West Strait of Juan de Fuca, Rosario Strait, North Puget Sound, Haro Strait B: East Strait of Juan de Fuca, South Puget Sound, Guemes Channel, West Strait of Juan de Fuca, Rosario Strait, North Puget Sound, Haro Strait, Saddlebag, San Juan Islands** A>B
	Incidents	**There are statistical differences in tanker incidents by location among the 10 geographic areas for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 46.0565, DF = 9, Pr > Chi-square <0.0001 F-value=8.31, DF = 9, Pr >F <0.0001	**A: East Strait of Juan de Fuca, West Strait of Juan de Fuca B: West Strait of Juan de Fuca, Cherry point C: Cherry point, Guemes Channel, South Puget Sound, Saddlebag, Haro Strait, Rosario Strait, North Puget Sound, San Juan Islands** A>B>C
By Season	**Tanker Event**	**There are statistical differences in tanker events by season for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 24.8965, DF =3, Pr<0.0001 F-value=10.79, DF = 3, Pr >F =0.0001	**A: Winter Summer** **B: Summer Autumn** **C: Autumn Spring** **A>B>C**
	Accidents	**There are statistical differences in tanker accidents by season for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 9.6246, DF =3, Pr=0.0220 F-value=3.84, DF = 3, Pr >F =0.0166	**A: Winter Summer** **B: Summer Spring Autumn** **A>B**
	Incidents	**There are statistical differences in tanker incidents by season for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 18.9876, DF =3, Pr=0.0003 F-value=11.62, DF = 3, Pr >F <0.0001	**A: Winter** **B: Summer Spring Autumn** **A>B**
By Time of Day	**Tanker Events**	**Tanker events occurred more often during the day than the night for years 1995-2005**	Wilcoxon	Statistic 158.0000, Normal Approximation z= 2.1181, Pr> z=0.0342	**Day>Night**
	Incidents	**Tanker incidents occurred more often during the day than the night for years 1995-2005.**	Wilcoxon	Statistic 161.5000, Normal Approximation z= 2.3555, Pr> z=0.0185	**Day>Night**

Test		Results	Test Used	Statistics	Direction
By Flag (U.S. Flag vs. Non U.S. Flag)	**Tanker Events**	**U.S. flag tankers have higher event frequencies than tankers that are not U.S. flag for years 1995-2005.**	Wilcoxon	Statistic 178.5000, Normal Approximation z= 3.4243, Pr> z=0.0006	**US.>Non U.S.**
	Incidents	**U.S. flag tankers have higher incident frequencies than tankers that are not U.S. flag for years 1995-2005.**	Wilcoxon	Statistic 178.0000, Normal Approximation z= 3.4167, Pr> z=0.0006	**U.S.>Non U.S.**
By Vessel Size	**Tanker Events**	**Tankers > 80000 DWT and above had lower number of total event frequencies than tanker < 80000 DWT for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 13.2427, DF =2, P=0.0013 F-value=6.28, DF = 2, Pr >F =0.0053	**(Below 40000)= (40000-80000)> (80000 above)**
	Accidents	**Tankers with different deadweight tonnages had different accident frequencies for years 1995-2005**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 8.3235, DF =2, P=0.0156 F-value=4.66, DF =2, Pr >F =0.0173	**A: (Below 40000), (40000-80000)** **B: (40000-80000), (80000 above)** **A>B**
	Incidents	**Tankers with different deadweight tonnages had different incident frequencies for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 10.4913, DF =2, P=0.0053 F-value=5.73, DF =2, Pr >F=0.0078	**A: (40000-80000), (Below 40000)** **B: (80000 above)**
By Hull Type	**Tanker Events**	**Tankers with double hull has higher number of events frequency than tankers with single hull**	Wilcoxon	Statistic 91.0000, Normal Approximation z= -2.3390, Pr> z=0.0193	**Double Hull*>Single Hull***
	Accidents	**Tankers with double hull has higher number of accidents frequency than tankers with single hull**	Wilcoxon	Statistic 94.5000, Normal Approximation z= -2.2226, Pr> z=0.0262	**Double Hull*>Single Hull***
	Incidents	**Tankers with double hull has higher number of incidents frequency than tankers with single hull**	Wilcoxon	Statistic 93.0000, Normal Approximation z= -2.2206, Pr> z=0.0264	**Double Hull*>Single Hull***
By Escort vs. No Escort	**Tanker Events**	**Tankers under escort had higher number event frequencies than did tankers with no escort for years 1995-2005.**	Wilcoxon	Statistic 169.5000, Normal Approximation z= 2.8316, Pr> z=0.0046	**Escort> No Escort**
	Incidents	**Tankers under escort had higher incident frequencies than did tankers without escort for years 1995-2005.**	Wilcoxon	Statistic 167.5000, Normal Approximation z= 2.7099, Pr> z=0.0067	**Escort> No Escort**

Test		Results	Test Used	Statistics	Direction
By Accident/Incident Type	**Accidents**	**Tanker accidents caused by pollution had statistically higher frequencies than did other tanker accident types for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 29.4903, P>Chi-square <0.0001 F-value= 16.56, Pr >F <0.0001	**Pollution>Allision, Fire, Collision, Grounding**
	Incidents	**Tanker incidents caused by equipment failures had statistically higher frequencies than did other tanker incident types for years 1995-2005.**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 39.8337, P>Chi-square <0.0001 F-value= 9.09, Pr >F <0.0001	**Equipment failure>Loss of Propulsion, Structural Failure, Loss of steering, Near miss, Loss of Anchor, Loss of Power**
By Error Type (HOE vs. Mechanical)	**Tanker Events**	**Tankers had significantly more events caused by MF than by HOE for years 1995-2005.**	Wilcoxon	Statistic 77.5000, Normal Approximation z= -3.2350, Pr> z=0.0012	**MF>HOE**
	Incidents	**Tankers had significantly more incidents caused by MF than by HOE for years 1995-2005.**	Wilcoxon	Statistic 75.0000, Normal Approximation z= -3.4405, Pr> z=0.0006	**MF>HOE**

Table A-73: Summary of Significant Puget Sound Tanker Results for Events, Accidents and Incident Frequencies, 1995-2005

Appendix A-2
Puget Sound Tug-Barge Events, Accidents and Incident Analysis 1995-2005

Puget Sound Tug-Barge Events, Accidents, and Incidents, 1995-2005

In this section, an analysis of events occurring to tug-barges in the Puget Sound VTRA Accident-Incident database is analyzed. There were 421 events related to tug-barges in the accident-incident database; 325 (77.2%) were accidents, 87 (20.7%) were incidents, and 9 (2.1%) were unusual events (Table A-74). This compares to a smaller number of tanker events and accidents, and a higher number of tanker incidents, as seen in Table A-74. Statistical tests on tanker and tug-barge event data showed that tug-barges had a statistically higher number of total events and accidents than tankers when the raw data were analyzed; however, statistical tests on normalized data showed that tankers had a statistically higher number of total events and incidents than tug-barges; there were no statistically significant differences between tanker and tug-barge normalized accident frequencies over the period 1995-2005. Note that tanker accidents and unusual events, as well as tug-barge unusual events, are characterized by small sample sizes (Table A-75).

Table A-74 Puget Sound Tug-Barge Accidents, Incidents, and Unusual Events, 1995-2005

Event	Tug/barge	Percentage	Tankers	Percentage
Accidents	325	77.2%	35*	20.5%
Incidents	87	20.7%	111	64.9%
Unusual Events	9*	2.1%	25*	14.6%
Total	421	100%	171	100%

***=Small sample size**

Table A-75Wilcoxon Tests of Puget Sound Tug-Barge and Tanker Accidents and Incidents, 1995-2005

Variable		N	Test statistic	Normal approximation Z	Two-sided Pr> $|Z|$	Directions
Raw Data	**Total Events**	11	76.5000	-3.2842	0.0010	**Tug-Barge >Tanker***
	Accidents	11	67.0000	-3.9304	<0.0001	**Tug-Barge >Tanker***
	Incidents	11	149.5000	1.5146	0.1299	**N/A**
Normalized Data	**Total Events**	10	154.0000	3.7041	0.0002	**Tanker >Tug-Barge***
	Accidents	10	111.0000	0.4536	0.6501	**N/A**
	Incidents	10	145.0000	3.0237	0.0025	**Tanker >Tug-Barge***

* = **small sample size**

The accident:incident pyramids for tug-barges for each year between 1995-2005 are shown in Figure A-22. In contrast to the tanker accident-incident pyramids, which showed the greatest number of events in year 2001, year 2000 was the year with the greatest number of tug-barge events. Statistical tests on accident-incident ratios of both tankers and tug-barges show that tug-barges had a statistically higher accident-incident ratio than did tankers (Table A-76). Note, however, that these data suffer from small sample sizes.

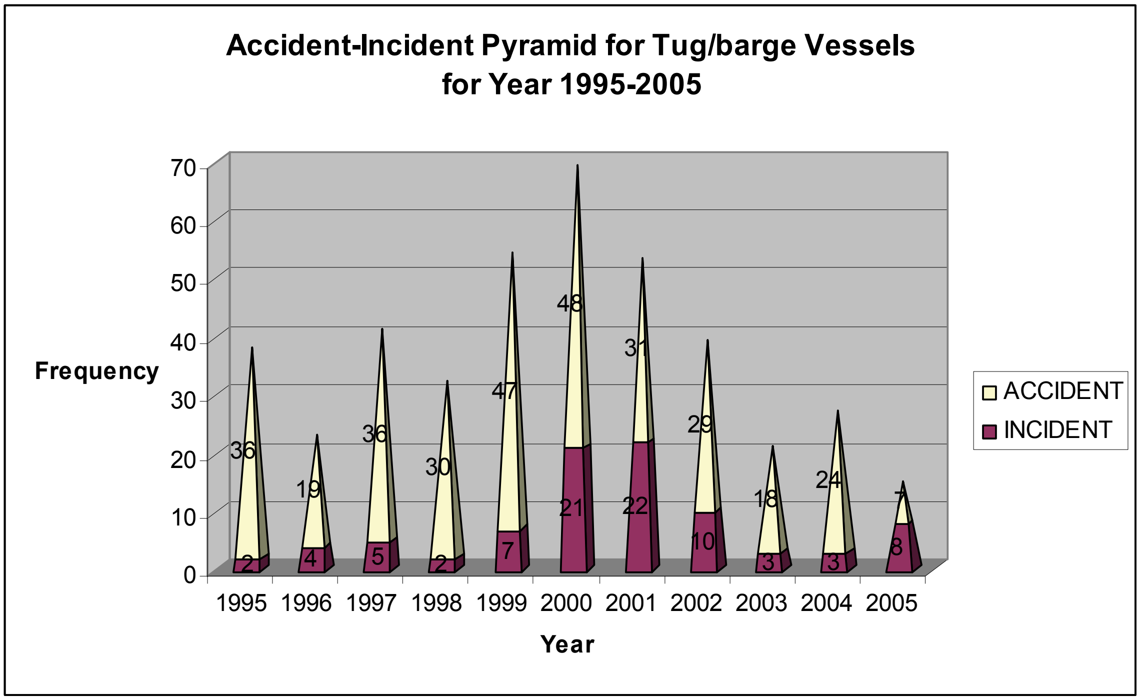


Figure A-22 Tug-Barge Accident-Incident Pyramids from year 1995-2005

Table A-76 Wilcoxon Tests on Accidents-Incidents Ratio for Both Tankers and Tug-Barges, 1995-2005

Variable	N	Test statistic	Normal approximation Z	Two-sided Pr> $\|Z\|$	Direction
Ratio	11	77.0000	-3.2504	0.0012	**Tug-Barge >Tanker ***

*** = small sample size**

Tug-Barge Events by Location

Table A-77 and Figure A-23 show that total tug-barge events, accidents, incidents, and unusual events for different geographic locations for the years 1995-2005 occurred more often in South Puget Sound. In contrast to tanker events, which primarily occurred in the East and West Strait of Juan de Fuca, most tug-barge event occurred in South Puget Sound, as did tug-barge accidents, incidents, and unusual events. Note that the data in Table A-77 are limited by small sample sizes.

Table A-77 Tug-barge Total Events, Accidents, Incidents and Unusual Events by Location, 1995-2005

Zone	Total Tug-barge Events		Tug-barge Accidents		Tug-barge Incidents		Tug-barge Unusual Events	
	N	%	N	%	N	%	N	%
West Strait of Juan de Fuca	21*	5.0	8 *	2.5	13 *	14.9	0	0
East Strait of Juan de Fuca	23 *	5.5	13 *	4	10 *	11.5	0	0
North Puget Sound	39	9.3	28 *	8.6	11 *	12.6	0	0
South Puget Sound	254	60.3	226	69.5	25 *	28.7	3 *	33.3
Haro Strait/Boundary Pass	1 *	0.2	1 *	0.3	0	0	0	0
Rosario Strait	11 *	2.6	5 *	1.5	6 *	6.9	0	0
Guemes Channel	21 *	5.0	14 *	4.3	6 *	6.9	1 *	11.1
Saddlebag	17 *	4.0	14 *	4.3	3 *	3.4	0	0
Strait of Georgia/Cherry Point	20 *	4.8	8 *	2.5	11 *	12.6	1 *	11.1
San Juan Islands	4 *	1.0	3 *	0.9	1 *	1.1	0	0
Unknown	10 *	2.4	5 *	1.5	1 *	1.1	4 *	44.4
Total	**421**	**100**	**325**	**100**	**87**	**100**	**9 ***	**100**

N: Number of total events, accidents, incidents, unusual events;
%: Percent of event frequency for every zone. *** = small sample size**

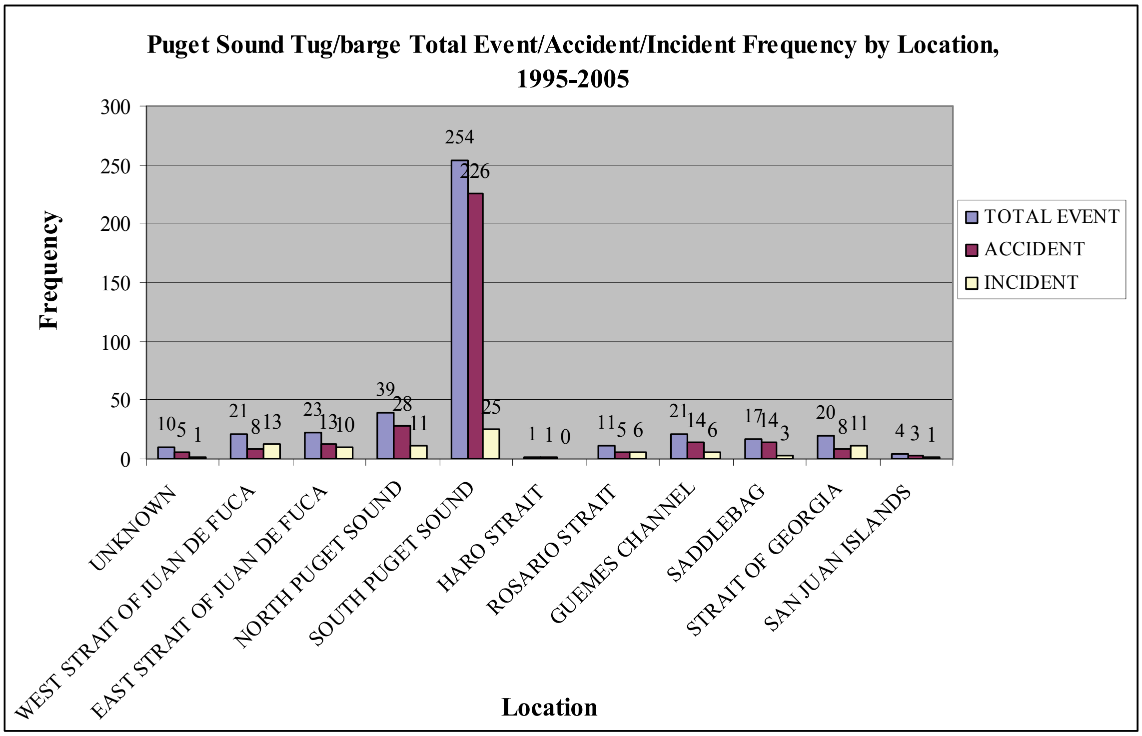


Figure A-23 Tug-Barge Accidents, Incidents and Unusual Events by Location

Analysis of Kruskal-Wallis and Tukey's HSD tests showed that there are statistical differences between total tug-barge events, accidents, incidents among the 10 zones, with South Puget Sound having more total tug-barge events and accidents frequencies than other remaining zones (Table A-78). Note that the distribution of significant locations for incidents is higher than those of events and accidents: in addition to South Puget Sound, incidents also occurred most frequently in the West Strait of Juan de Fuca, North Puget

Sound, Cherry Point, the East Strait of Juan de Fuca, Rosario Straits, and Guemes Channel. Normalization of the data by location was not possible since transit data corresponding to every zone was not available. Note, in addition, that the data is limited by small sample sizes.

Table A-78 Kruskal-Wallis and Tukey's HSD Tests on Tug-Barge Events, Accidents, and Incidents Frequencies by Location, 1995-2005

Variable	DF	Test Statistics	Direction
Total Events	9	Kruskal-Wallis: Chi-square statistic 56.0251, Pr > Chi-square <0.0001 Tukey's HSD: F-value=42.47, Pr >F <0.0001	**A: South Puget Sound B: North Puget Sound, East Strait of Juan de Fuca, West Strait of Juan de Fuca, Guemes Channel, Cherry Point, Saddlebag, Rosario Strait, San Juan Islands, Haro Strait A>B ***
Accidents	9	Kruskal-Wallis: Chi-square statistic 51.3300, Pr > Chi-square <0.0001 Tukey's HSD: F-value=55.14, Pr >F <0.0001	**A: South Puget Sound B: North Puget Sound, Guemes Channel, Saddlebag, East Strait of Juan de Fuca, West Strait of Juan de Fuca, Cherry Point, Rosario Strait, San Juan Islands, Haro Strait A>B ***
Incidents	9	Kruskal-Wallis: Chi-square statistic 21.6864, Pr > Chi-square =0.0099 Tukey's HSD: F-value=3.03, Pr >F =0.0030	**A: South Puget Sound, West Strait of Juan de Fuca, North Puget Sound, Cherry Point, East Strait of Juan de Fuca, Rosario Strait, Guemes Channel B: West Strait of Juan de Fuca, North Puget Sound, Cherry Point, East Strait of Juan de Fuca, Rosario Strait, Guemes Channel, Saddlebag, San Juan Islands, Haro Strait A>B ***

*** = small sample size**

Tug-Barge Events by Year

Tug-barge accidents, incidents, and unusual event frequencies from year 1995-2005 are shown in Figure A-24.

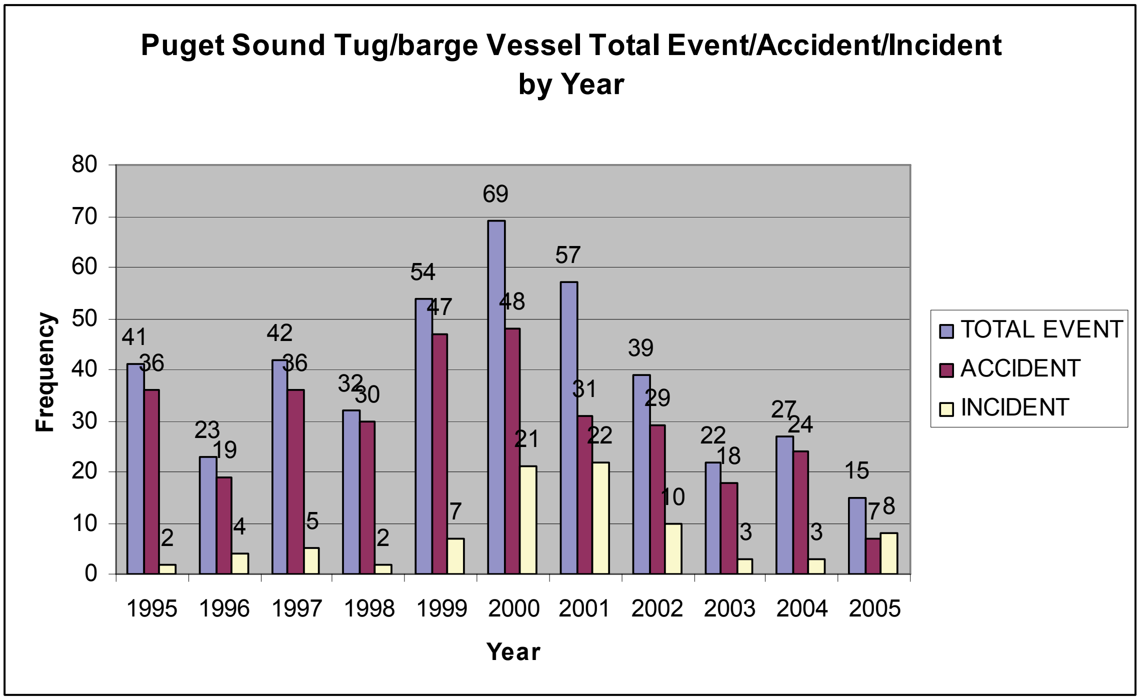


Figure A-24 Tug-Barge Accidents, Incidents and Unusual Events by Year, 1995-2005

Kruskal-Wallis and Tukey's HSD tests show that year 2000 had the highest number of events and accidents, while year 2001 had the highest number of incidents from 1995-2005. Tests on the normalized data showed that year 2001 had the highest number of normalized events and accidents, while year 2002 had the highest number of normalized incidents. These results are in contrast to the tanker results in the previous section, which showed that years 2001 and 2002 had significantly higher number of raw and normalized events, accidents, and incidents. Note that the results in Tables A-79 and A-80 are both limited by small sample sizes for accidents and incidents.

Table A-79 Puget Sound Tug-barge Normalized Events, Accidents and Incident Frequencies by Year, 1995 -2005 * = small sample size

Year (1)	Transit (2)		Total Event (3)		Normalized Event (4)=(3)/(2)	Accident (5)		Normalized Accident (6)=(5)/(2)	Incident (7)		Normalized Incident (8)=(7)/(2)	Unusual Event (9)	
	N	%	N	%		N	%		N	%		N	%
1995	N/A	N/A	41	9.74	N/A	36 *	11.708	N/A	2 *	2.30	N/A	3*	33.3
1996	24477	9.4	23	5.46	0.00094	19*	5.85	0.000776	4 *	4.60	0.000163	0*	0
1997	30969	11.9	42	9.98	0.001356	36*	11.08	0.001162	5*	5.75	0.000161	1*	11.1
1998	25769	9.9	32*	7.60	0.001242	30*	9.23	0.001164	2*	2.30	0.0000776	0*	0
1999	27016	10.4	54	12.83	0.001999	47	14.46	0.00174	7*	8.05	0.000259	0*	0
2000	27553	10.6	69	16.39	0.002504	48	14.77	0.001742	21*	24.14	0.000762	0*	0
2001	24941	9.6	57	13.54	0.002285	31*	9.54	0.001243	22*	25.29	0.000882	4*	44.4
2002	24776	9.5	39	9.26	0.001574	29*	8.92	0.00117	10*	11.49	0.000404	0*	0
2003	26342	10.1	22*	5.23	0.000835	18*	5.54	0.00683	3*	3.45	0.000114	1*	11.1
2004	24456	9.4	27*	6.41	0.001104	24*	7.38	0.000981	3*	3.45	0.000123	0*	0
2005	24139	9.3	15*	3.56	0.000621	7*	2.15	0.00029	8*	9.20	0.000331	0*	0
Total	260438	100	421	100	N/A	325	100	N/A	87	100	N/A	9*	100

Table A-80 Kruskal-Wallis and Tukey's HSD Test Statistics of Raw and Normalized Tug-Barge Total Events, Accidents, and Incidents, 1995-2005

Variable		Test Statistics	Direction
Raw Data	Total Events	Kruskal-Wallis: Chi-square statistic 45.2864, DF = 10, Pr > Chi-square <0.0001 Tukey's HSD: F-value=6.72, DF = 10, Pr >F <0.0001	**A:2000 2001 1999 1997 1995 B: 2001 1999 1997 1995 2002 1998 C: 1999 1997 1995 2002 1998 2004 D: 1997 1995 2002 1998 2004 1996 2003 2005 A>B>C>D**
	Accidents	Kruskal-Wallis: Chi-square statistic 39.4093, DF = 10, Pr > Chi-square <0.0001 Tukey's HSD: F-value=5.12, DF = 10, Pr >F <0.0001	**A: 2000 1999 1997 1995 2001 1998 2002 2004 B: 1997 1995 2001 1998 2002 2004 1996 2003 C: 2001 1998 2002 2004 1996 2003 2005 A>B>C ***
	Incidents	Kruskal-Wallis: Chi-square statistic 49.9608, DF = 10, Pr > Chi-square <0.0001 Tukey's HSD: F-value=8.33, DF = 10, Pr >F <0.0001	**A: 2001 2000 B: 2000 2002 C: 2002 2005 1999 1997 1996 2004 2003 1998 1995***
Normalized Data	Total Events	Kruskal-Wallis: Chi-square statistic 36.2490, DF = 9, Pr > Chi-square <0.0001 Tukey's HSD: F-value=5.81, DF = 9, Pr >F <0.0001	**A: 2001 2002 2000 1996 B: 2002 2000 1996 1998 2003 1999 C: 2000 1996 1998 2003 1999 2005 2004 1997 A>B>C**
	Accidents	Kruskal-Wallis: Chi-square statistic 25.6630, DF = 9, Pr > Chi-square =0.0023 Tukey's HSD: F-value=3.36, DF = 9, Pr >F =0.0011	**A: 2001 2000 1996 1998 2002 2003 1999 B: 2000 1996 1998 2002 2003 1999 2005 2004 1997 A>B**
	Incidents	Kruskal-Wallis: Chi-square statistic 49.3806, DF = 9, Pr > Chi-square <0.0001 Tukey's HSD: F-value=9.74, DF = 9, Pr >F <0.0001	**A: 2002 2001 B: 2003 2000 1998 2005 1997 2004 1996 1999 A>B**

* = small sample size

There was also no difference in tug-barge total events, accidents, or incidents before and after the year 2000, using the Wilcoxon test.

Tug-Barge Events by Season

The raw and normalized total events, accidents, and incidents frequencies for tug-barges by season are shown in Figures A-25 and A-26.

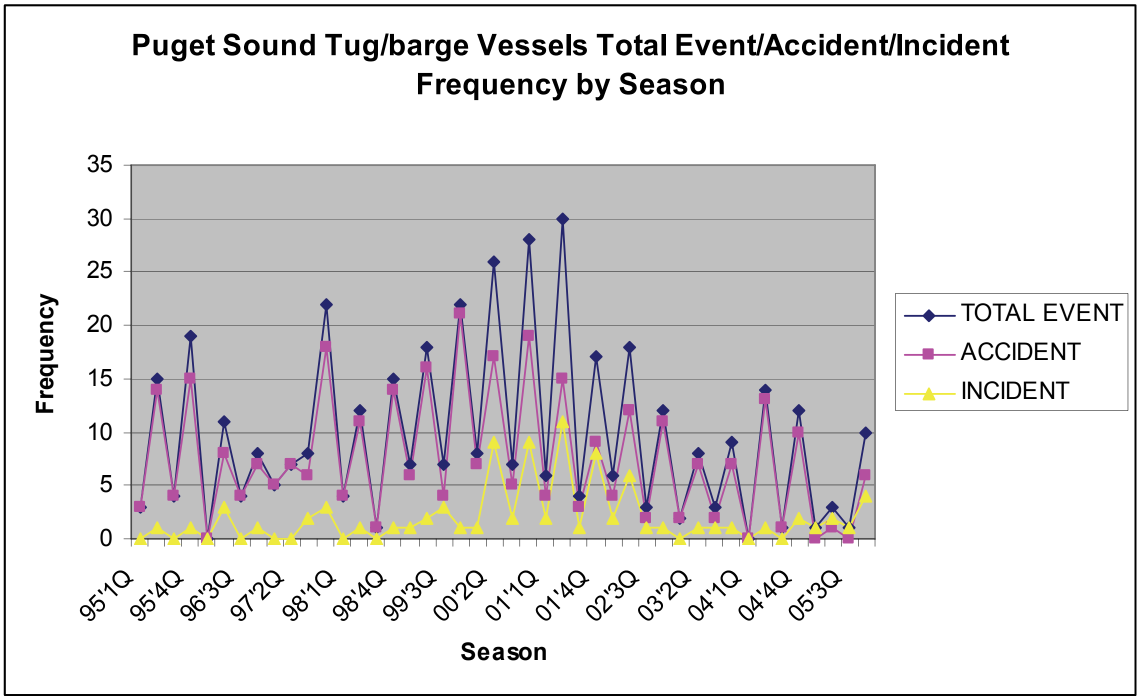


Figure A-25 Raw Tug-Barge Total Events, Accidents, and Incidents by Season, 1995-2005

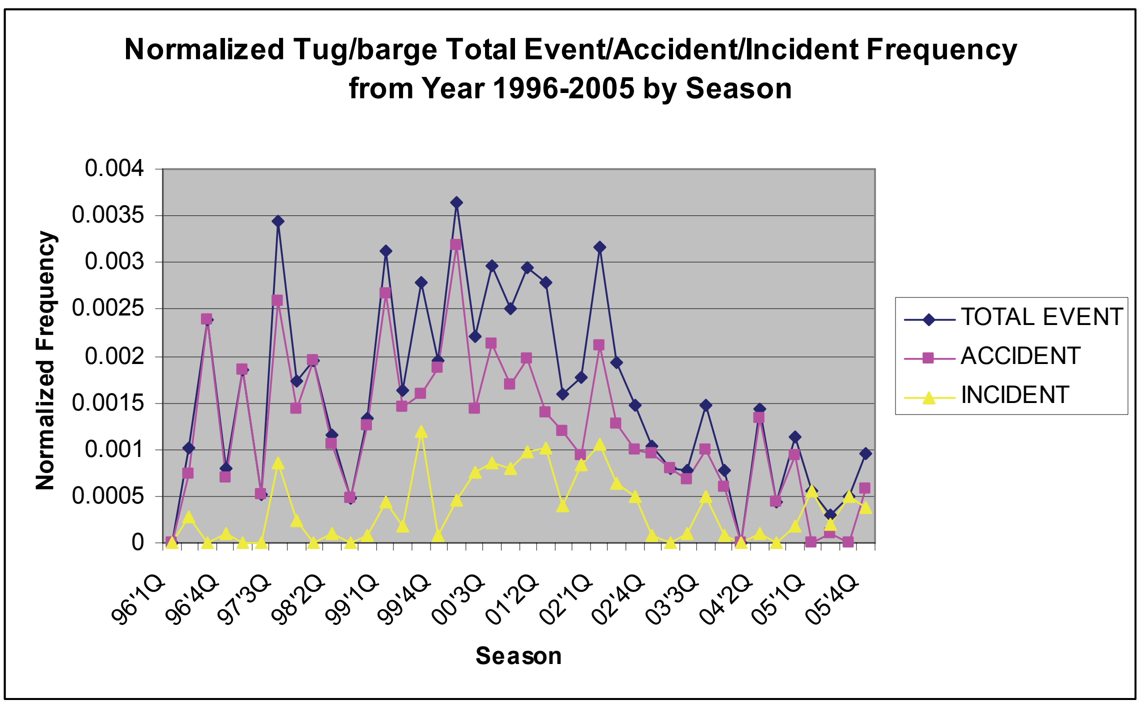


Figure A-26 Normalized Tug-Barge Total Events, Accidents, and Incidents by Season, 1996-2005

Kruskal-Wallis and Tukey's HSD tests on the raw data showed that winter and summer had a higher number of tug-barge total events and accidents than did autumn and spring, with no difference of incident frequency among the four seasons. However, the same tests on the normalized data found no differences in total events, accidents, and incidents among the four seasons for tug-barges (Table A-81). For raw data, winter and summer had the highest number of tug-barge total events and accidents, compared to spring and autumn, the same results as those of tanker ships (Table A-51). However, tug-barges did not have a statistically different number of incidents among the four seasons as tank ships did. Both tug-barges and tank ships did not have statistically different number of normalized total events, accidents, and incidents.

Table A-81 Kruskal-Wallis and Tukey's HSD tests of Raw and Normalized Tug-Barge Events, Accidents and Incidents by Season

Variable		DF	Test statistic	Direction
Raw Data	**Total Events**	3	Kruskal-Wallis: Chi-square statistic 27.8035, DF =3, Pr<0.0001 Tukey's HSD: F-value=16.03, DF = 3, Pr >F <0.0001	**A: Winter Summer** **B: Autumn Spring** **A>B ***
	Accidents	3	Kruskal-Wallis: Chi-square statistic 27.2958, DF =3, Pr<0.0001 Tukey's HSD: F-value=18.59, DF = 3, Pr >F <0.0001	**A: Winter Summer** **B: Spring Autumn** **A>B ***
	Incidents	3	Kruskal-Wallis: Chi-square statistic 10.6972, DF =3, Pr=0.0135 Tukey's HSD: F-value=3.42, DF = 3, Pr >F =0.0263	N/A
Normalized	**Total Events**	3	Chi-square statistic 1.0085, DF =3, P=0.7992 Tukey's HSD: F-value=0.50, DF = 3, Pr >F =0.6816	N/A
	Accidents	3	Chi-square statistic 1.1584, DF =3, P=0.7630 Tukey's HSD: F-value=0.63, DF = 3, Pr >F =0.6017	N/A
	Incidents	3	Chi-square statistic 1.1753, DF =3, P=0.7589 Tukey's HSD: F-value=0.48, DF = 3, Pr >F =0.6965	N/A

*** = small sample size**

A seasonality index was also constructed to assess the likelihood of tug-barge events, accidents and incidents in Puget Sound by season between 1995 and 2005. This analysis showed that events in summer and winter seasons occurred more often than in the spring and autumn seasons due to the longer periods; for normalized events, spring and autumn had more events, accidents, and incidents than other seasons (Table A-82); The normalized tug-barge results differ from raw tug-barge results: using a normalized seasonality index, spring and autumn had the most tug-barge events, accidents, and incidents; these results were contrary to the tanker seasonality index results, both raw and normalized (Table 52), which showed normalized tanker events occurring most frequently in winter, normalized tanker accidents occurring in summer and winter, and normalized tanker incidents occurring most frequently in spring and winter. Note that these data are limited by small sample sizes.

Table A-82 Raw and Normalized Seasonal Index for Tug-Barge Events, Accidents, and Incidents, 1995-2005

Season	Raw Seasonal Index		
	Total Event	Accident	Incident
Spring	0.40 (0.28)	0.43 (0.23)	0.32 (0.36)
Summer	1.54 (1.29)	1.49 (1.49)	1.70 (1.15)
Autumn	0.41 (0.33)	0.39 (0.23)	0.51 (0.29)
Winter	1.65 (2.11)	1.69 (2.06)	1.47 (2.20)
	Normalized Seasonal Index		
Spring	1.14 (0.81)	1.20 (0.49)	0.96 (1.10)
Summer	0.87 (0.82)	0.83 (1.06)	0.93 (0.82)
Autumn	1.11(0.98)	1.06 (0.91)	1.32 (0.88)
Winter	0.88 (1.39)	0.91 (1.54)	0.80 (1.38)

Note: The number in ( ) is the corresponding value of tugs

Tug-Barge Events by Time of Day

Events that occurred in the Puget Sound VTRA area between 1995 and 2005 occurred during the day or night. The data of occurrence times are shown in Table A-83.

Table A-83 Tug-barge Events, Accidents, and Incidents by Time of Day, 1995-2005

Time of Day	Total Event		Accident		Incident	
	N	%	N	%	N	%
Day	200	47.5	158	48.6	39*	44.8
Night	92	21.9	73	22.5	18*	20.7
Null	129	30.6	94	28.9	30*	34.5
Total	421	100	325	100	87	100

N = Number or Frequency; %: Percent of Frequency;

***=Small sample size**

From the table, it can be seen that many of the tug-barge events, accidents, and incidents occurred during the day, probably because there are more vessel transits during the day than night. However, note that almost half of the tug-barge records do not have timing information associated with the event. A Wilcoxon test on the raw data showed no statistical differences in total events, accidents, and incidents between day and night. These results differ from the tanker results in the previous section, which found that tanker events and incidents occurred significantly more often in the day rather than the night. The tanker data was similarly characterized by large amounts of missing timing information.

Table A-84 Wilcoxon Tests on Tug-Barge Events, Accidents, and Incidents by Vessel Time of Day, 1995-2005

Variable	N	Test statistic	Normal approximate Z	Two-sided Pr> $\|Z\|$	Direction
Total Events	11	145.5000	1.2530	0.2102	N/A
Accidents	11	142.5000	1.0575	0.2903	N/A
Incidents	11	134.0000	0.5047	0.6137	N/A

Tug-Barge Events by Vessel Flag

Tug-barge events that occurred in the Puget Sound VTRA area of interest between 1995 and 2005 occurred aboard tug-barges of varying flags, as seen in Figure A-27. More events occurred to U.S. flag tug-barges during the reporting period than to non-U.S. flag tug-barges; these differences were significant at the 95% confidence level using the Wilcoxon test. Similarly, significantly more accidents (349, 82.9%) occurred to U.S. flag tug-barges than to non-U.S. flag tug-barges; these differences were found to be significant at the 95% level, using the Wilcoxon test (Table A-85). A similar pattern was observed in total numbers of incidents over the time period, with 87.4% of the incidents occurring to U.S. tug-barges. These differences were found to be significant at the 95% level using the Wilcoxon test.

These results, with the exception of the accident results, are consistent with the tanker results in the previous section. Tanker accidents showed no significant effect for vessel flag (Table A-56). Note that the foreign flag tanker events, accidents and incidents comprise between 20-40% of each event type; in contrast, the tug-barge events, accidents and incidents are almost completely (85-90%) dominated by U.S. flag tug-barges. This is perhaps because of the very small number of foreign flag tug-barges operating in Puget Sound during the reporting period.

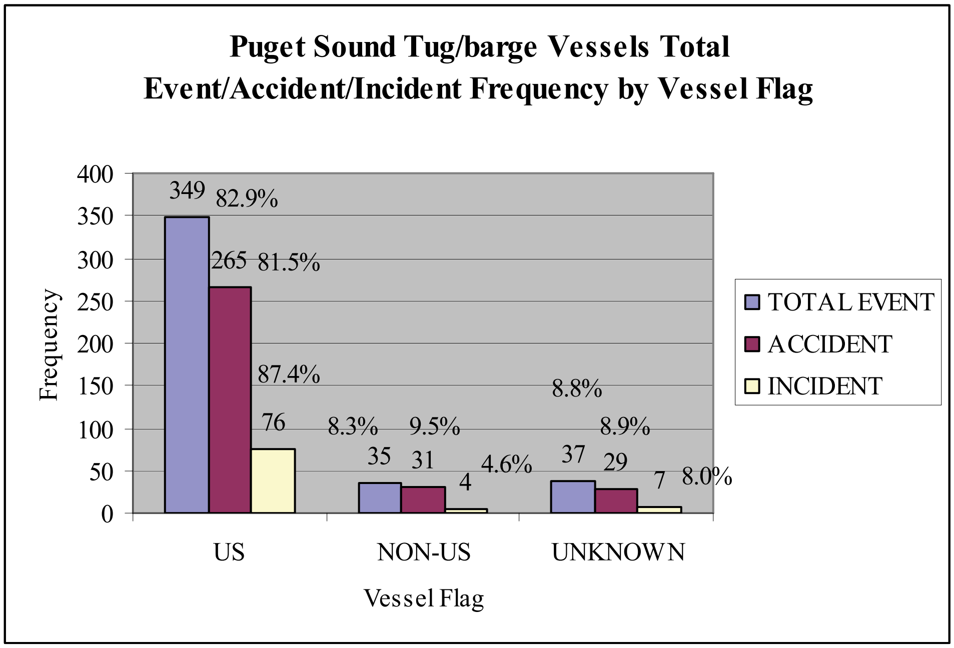


Figure A-27 Tug-Barge Events by Vessel Flag, 1995-2005

Table A-85 Wilcoxon Tests on Tug-Barge Events, Accidents, and Incidents by Vessel Flag, 1995-2005

Variable	N	Test statistic	Normal Approximation Z	Two-sided Pr> $\lvert Z \rvert$	Direction
Total Events	11	187.0000	3.9874	<0.0001	**U.S.>Non U.S. ***
Accidents	11	185.0000	3.8822	0.0001	**U.S.>Non U.S. ***
Incidents	11	185.5000	3.9837	<0.0001	**U.S.>Non U.S. ***

* = **small sample size**

Total tug-barge events, accidents, and incidents for foreign flag tug-barge vessels are shown in Table A-86.

Table A-86 Puget Sound Foreign Flag Tug-barge Events, Accidents, and Incidents by Flag, 1995-2005

Vessel Flag	Total Event		Accident		Incident	
	N	%	N	%	N	%
US	349	82.9	265	81.5	76	87.4
BRAZIL	2*	0.5	2*	0.6	0	0
CANADA	27*	6.4	23*	7.1	4*	4.6
NIGERIA	1*	0.2	1*	0.3	0	0
PANAMA	2*	0.5	2*	0.6	0	0
VANUATU	1*	0.2	1*	0.3	0	0
OTHER	39	9.3	31	9.5	7*	8.0
TOTAL	**421**	**100**	**325**	**100**	**87**	**100**

***=Small sample size**

Table A-86 shows that Canadian tug-barges have the highest frequency of events, accidents and incidents, compared to other foreign flag tug-barges in Puget Sound. However, with the exception of the U.S. flag data, all tug-barge foreign flag data is limited by small sample sizes.

Tug-Barge Events by Vessel Owner

There are significant differences in tug-barge events among different tug-barge owners. However, some vessel owners may no longer exist, or some vessels may have changed their operators.

Table A-87 Tug-barge Events, Accidents, Incidents and Unusual Events by Vessel Owner, 1995-2005

Vessel Owner	Total Event		Accident		Incident		Unusual Event	
	N	%	N	%	N	%	N	%
Foss	68	16.2	54	16.6	10*	11.5	4*	44.4
Sause Brothers Ocean Towing Co. Inc.	6*	1.4	4*	1.2	2*	2.3	0	0
Island Tug & Barge Co.	24*	5.7	19*	5.8	5*	5.7	0	0
Sea Coast Transportation LLC	8*	1.9	4*	1.2	4*	4.6	0	0
Marine Transport Corp.	6*	1.4	2*	0.6	4*	4.6	1*	11.1
Seaspan International Ltd.	12*	2.9	12*	3.7	0	0	0	0
U.S. Shipping Partners LP	7*	1.7	1*	0.3	6*	6.9	1*	11.1
U.S. Navy	15*	3.6	15*	4.6	0	0	0	0
Western Towboat Company	6*	1.4	6*	1.8	0	0	0	0
Olympic Tug & Barge Inc.	30*	7.1	23*	7.1	7*	8.0	0	0
Dunlap Towing Company	7*	1.7	4*	1.2	3*	3.4	0	0
Crowley	54	12.8	44	13.5	10*	11.5	0	0
Other	178	42.3	127	39.1	36*	41.4	3*	33.3
TOTAL	**421**	**100**	**325**	**100**	**87**	**100**	**9***	**100**

***=Small sample size**

Table A-87 shows Foss, Crowley, Olympic Tug & Barge, and Island Tug & Barge Co. are the tug-barge vessel owners with the highest event and accident frequencies. A Kruskal-Wallis test shows that tug-barges from these four owners had no statistical difference in terms of incident frequencies (Table A-88). Normalized results for this analysis may have shown different results than the raw data results shown in Table A-88.

Table A-88 Kruskal-Wallis and Tukey's HSD Tests on Tug-Barge Events, Accidents, and Incidents by Vessel Owner, 1995-2005

Variable	DF	Test Statistics	Direction
Total Events	3	Kruskal-Wallis: Chi-square statistic 10.7222, P> Chi-square =0.0145 Tukey's HSD: F-value=4.69, Pr >F =0.0090	A: Foss; Crowley; Olympic Tug & Barge Inc. B: Crowley; Olympic Tug & Barge; Island Tug & Barge Co **A>B ***
Accidents	3	Kruskal-Wallis: Chi-square statistic 11.0232, P> Chi-square =0.0178 Tukey's HSD: F-value=4.56, Pr >F =0.0098	A: Foss; Crowley; Olympic Tug & Barge B: Crowley; Olympic Tug & Barge; Island Tug & Barge Co **A>B***
Incidents	3	Kruskal-Wallis: Chi-square statistic 1.9896, P> Chi-square =0.5922	N/A

*** = small sample size**

Tug-Barge Events by Classification Society

The information about the class society for tug-barges can be found in Table A-89.

Table A-89 Tug-Barge Events, Accidents, Incidents and Unusual Events by Class Society, 1995-2005

Class Society	Total Event		Accident		Incident		Unusual Event	
	N	%	N	%	N	%	N	%
ABS	113	26.8	80	24.6	30 *	34.5	3 *	33.3
Bureau Veritas (BV)	1 *	0.2	0	0	1 *	1.1	0	0
Lloyd's Register (LR)	4 *	1.0	3 *	0.9	1 *	1.1	0	0
Registro Italiano Navale (RINA) (RI)	1 *	0.2	1 *	0.3	0	0	0	0
Null	302	71.7	241	74.2	55	63.2	6 *	66.6
Total	**421**	**100**	**325**	**100**	**87**	**100**	**9 ***	**100**

*** = small sample size**

From Table A-89, we can find that ABS class tug-barges had the highest number of total events, accidents, incidents, and unusual events than other class societies. Statistical tests on tug-barge event data are not available because of small sample sizes.

Tug-Barge Events by Hull Type

There are four hull types for tug-barges in the database: single hull, double hull, double sides, and double bottoms. Table A-90 shows the numbers of tugs with different hull types. Note in Table A-90 that some records were missing information about hull type and thus were classified as "unknown". A Wilcoxon test of the Table A-90 tug-barge data shows that single hull tug-barges had a higher number of total events, accidents, and incidents than double hull tug-barges (Table A-91). These results contrast with the tanker results, which showed that double-hulled tankers had significantly higher numbers of events, accidents and incidents over the reporting period. This may be because of the dominance of double-hulled tankers in the tanker data records, and the dominance of single hull tug-barges in the tug-barge data records. Transit data was not available to normalize the data. Given the differences that were observed with this data set when the data were normalized, as analysis of the differences in event frequencies by hull type for both raw and normalized data should be undertaken.

Table A-90 Tug-Barge Accidents, Incidents, and Unusual Events by Hull Type, 1995-2005

Event	Single Hull	Double Hull	Unknown
Accidents	274	1*	50
Incidents	71	6*	10*
Unusual Events	6*	1*	2*
Total	**351**	**8***	**62**

*** = small sample size**

Table A-91 Wilcoxon Tests on Tug-Barge Events, Accidents, and Incidents Frequencies by Hull Type 1995-2005

Variable	N	Test statistic	Normal approximation Z	Two-sided Pr> $\|Z\|$	Direction
Total Events	11	187.0000	4.0172	<0.0001	**Single hull > Double hull***
Accidents	11	187.0000	4.1158	<0.0001	**Single hull > Double hull***
Incidents	11	185.0000	3.9220	<0.0001	**Single hull > Double hull***

*** = small sample size**

Tug-Barge Accidents and Incidents by Event Type

In the Puget Sound Accident-Incident database, there are five types of tug-barge accidents: allisions, collisions, fire/explosions, groundings, and pollution. Tug-barge incidents were comprised of equipment failures, loss of power, loss of propulsion, loss of steering, near misses, and structural failure/damage. The statistical data are shown in Tables A-92 and A-93.

Table A-92 Puget Sound Tug-Barge Accident Frequency by Accident Type, 1995-2005

Accident Type	Allision	Breakaway	Capsize	Collision	Fire/explosion
Frequency	90	4*	7*	20*	7*
Accident Type	**Flooding**	**Grounding**	**Pollution**	**Salvage**	**Sinking**
Frequency	5*	22*	164	0	6*

*** = small sample size**

Table A-93 Puget Sound Tug-Barge Incident Frequency by Incident Type, 1995-2005

Incident Type	Equipment Failure	Loss of power	Loss of propulsion	Loss of steering	Near miss	Structural failure/damage
Frequency	55	0	17*	6*	5*	4*

***=Small sample size**

Tables A-92 and A-93 show that pollution was again the major accident type and equipment failure was the major incident type for tug-barges in Puget Sound between 1995-2005, as confirmed by Kruskal-Wallis and Tukey's HSD tests (Table A-94). These results are identical to those shown for all vessels (Tables A-33 and A-34); however, the results are limited by a small sample size.

Table A-94 Kruskal-Wallis and Tukey's HSD tests results on Tug-Barge Accidents and Incidents by Event Type, 1995-2005

Variable	DF	Test Statistics	Direction
Accident Type	8	Kruskal-Wallis: Chi-square statistic 52.8120, P>Chi-square <0.0001 Tukey's HSD: F-value= 29.29, Pr >F <0.0001	**Pollution>Allision>Grounding, Collision, Fire, Capsize, Sinking, Flooding, Breakaway***
Incident Type	4	Kruskal-Wallis: Chi-square statistic 17.8887, P>Chi-square =0.0013 Tukey's HSD: F-value= 7.76, Pr >F <0.0001	**Equipment failure>Loss of Propulsion, Loss of steering, Near miss, Structural Failure ***

*** = small sample size**

Tug-Barge Events by Error Type

The frequency of tug-barge total events, accidents, and incidents caused by human error and mechanical failure are shown in Table A-95.

Table A-95 Tug-Barge Accidents and Incidents by Error Type, 1995-2005

Year	Tug/barge accident	Tug/barge accident by HOE	Tug/barge accident by MF	Tug/barge incident	Tug/barge incident by HOE	Tug/barge incident by MF
1995	36 *	0	0	2 *	0	2 *
1996	19 *	2*	1 *	4 *	0	4 *
1997	36 *	7 *	2*	5 *	0	4 *
1998	30 *	4 *	1*	2 *	0	2 *
1999	47	4*	0*	7 *	0	7 *
2000	48	4*	2*	21*	0	21*
2001	31 *	4*	0	22 *	1 *	21 *
2002	29 *	0	0	10 *	0	9 *
2003	18 *	2*	0	3 *	2 *	1*
2004	24 *	0	2*	3 *	0	3 *
2005	7 *	2*	1*	8 *	0	8 *

Wilcoxon tests show that, for tug-barges, more total events and accidents are caused by human error than are caused by mechanical failures. However, more incidents are caused by mechanical failure, rather than human error (Table A-96). These results are consistent with those shown for all vessels (Table A-36). The tug-barge results are identical to the tanker results, with the exception of accidents, which showed no significant trend in the tanker data (Table A-72). Note, however, that the data are limited by small sample sizes.

Table A-96 Wilcoxon Tests on Tug-Barge Events, Accidents, and Incidents Frequencies by Error Type, 1995-2005

Variable	N	Test statistic	Normal approximation Z	Two-sided Pr> $\lvert Z \rvert$	Direction
Total Events	11	94.5000	-2.1139	0.0345	**MF>HOE***
Accidents	11	157.0000	2.0825	0.0373	**HOE>MF***
Incidents	11	68.5000	-3.9529	<0.0001	**MF>HOE***

Summary of Tug-Barge Events, Accidents and Incidents, 1995-2005

Test results of tug-barge total events, accidents, and incidents by year showed that year 2000 had the highest event and accident frequencies while year 2001 had the highest incident frequencies between 1995-2005. Tests on the normalized data showed that year 2001 had the highest normalized event and accident frequencies while year 2002 had the highest normalized incident frequency.

Test results of tug-barge events by season showed that winter and summer had a statistically higher number of total events and accidents than did spring and autumn. However, no statistical difference in accidents was found among the four seasons. Furthermore, tests on the normalized tug-barge data showed no statistical difference in total events, accidents, and incidents.

Tests on tug-barge total events, accidents, and incidents by location showed that South Puget Sound had a significantly higher number of total events, accidents and incidents, compared to other locations. This result is in contrast to the tanker events, which occurred significantly more frequently in the East and West Straits of Juan de Fuca.

Significant test results showed that U.S. flag tug-barges had significantly more events, accidents, and incidents frequencies than non-U.S. flag tug-barges. Tests on tug-barge data by hull type showed that single hull tug-barges had a statistically higher number of total events, accidents, and incidents than double hull tug/barges.

For tug-barges, as with the tankers, pollution was the major accident type, and equipment failures were the most frequent incident type in Puget Sound between 1995 and 2005. Tests on tug-barge data by error type showed that tug-barges had statistically higher number of total events and accidents caused by human error than those by mechanical failure. However, tug-barges had significantly more incidents caused by mechanical failure than those by human error. These results were consistent with those results for all vessels. The significant test results of tug-barge total events, accidents, incidents are shown in Table A-97. Note, however, that many of these results are limited by small sample sizes.

Table A-97 Summary of Significant Puget Sound Tug-Barge Event, Accident and Incident Results, 1995-2005

Test		Results	Test Used	Statistics	Direction
by Year	**Total Events**	**There are statistics differences of total event from year 1995-2005 for tug/barge vessels**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 45.2864, DF = 10, Pr > Chi-square <0.0001 F-value=6.72, DF = 10, Pr >F <0.0001	**A:2000 2001 1999 1997 1995 B: 2001 1999 1997 1995 2002 1998 C: 1999 1997 1995 2002 1998 2004 D: 1997 1995 2002 1998 2004 1996 2003 2005 A>B>C>D**
	Accidents	**There are statistics differences of accident from year 1995-2005 for tug/barge vessels**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 39.4093, DF = 10, Pr > Chi-square <0.0001 F-value=5.12, DF = 10, Pr >F <0.0001	**A: 2000 1999 1997 1995 2001 1998 2002 2004 B: 1997 1995 2001 1998 2002 2004 1996 2003 C: 2001 1998 2002 2004 1996 2003 2005 A>B>C ***
	Incidents	**There are statistics differences of incident from year 1995-2005 for tug/barge vessels**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 49.9608, DF = 10, Pr > Chi-square <0.0001 F-value=8.33, DF = 10, Pr >F <0.0001	**A: 2001 2000 B: 2000 2002 C: 2002 2005 1999 1997 1996 2004 2003 1998 1995***
By Year (normalized)	**Total Events**	**There are statistics differences of normalized total events from year 1996-2005 for tug/barge vessels**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 36.2490, DF = 9, Pr > Chi-square <0.0001 F-value=5.81, DF = 9, Pr >F <0.0001	**A: 2001 2002 2000 1996 B: 2002 2000 1996 1998 2003 1999 C: 2000 1996 1998 2003 1999 2005 2004 1997 A>B>C**
	Accidents	**There are statistics differences of normalized accidents from year 1996-2005 for tug/barge vessels**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 25.6630, DF = 9, Pr > Chi-square =0.0023 F-value=3.36, DF = 9, Pr >F =0.0011	**A: 2001 2000 1996 1998 2002 2003 1999 B: 2000 1996 1998 2002 2003 1999 2005 2004 1997 A>B**
	Incidents	**There are statistics differences of normalized incidents from year 1996-2005 for tug/barge vessels**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 49.3806, DF = 9, Pr > Chi-square <0.0001 F-value=9.74, DF = 9, Pr >F <0.0001	**A: 2002 2001 B: 2003 2000 1998 2005 1997 2004 1996 1999 A>B**
by Location	**Total Events**	**South Puget Sound had more tug/barge total event frequency than other areas**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 56.0251, DF = 9, Pr > Chi-square <0.0001 F-value=42.47, DF = 9, Pr >F <0.0001	**A: South Puget Sound B: North Puget Sound, East Strait of Juan de Fuca, West Strait of Juan de Fuca, Guemes Channel, Cherry Point, Saddlebag, Rosario Strait, San Juan Islands, Haro Strait A>B ***

Test		Results	Test Used	Statistics	Direction
	Accidents	**South Puget Sound had more tug/barge accident frequency than other areas**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 51.3300, DF = 9, Pr > Chi-square <0.0001 F-value=55.14, DF = 9, Pr >F <0.0001	**A: South Puget Sound B: North Puget Sound, Guemes Channel, Saddlebag, East Strait of Juan de Fuca, West Strait of Juan de Fuca, Cherry Point, Rosario Strait, San Juan Islands, Haro Strait A>B ***
	Incidents	**There are statistics difference of incidents among 10 areas**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 21.6864, DF = 9, Pr > Chi-square =0.0099 F-value=3.03, DF = 9, Pr >F =0.0030	**A: South Puget Sound, West Strait of Juan de Fuca, North Puget Sound, Cherry Point, East Strait of Juan de Fuca, Rosario Strait, Guemes Channel B: West Strait of Juan de Fuca, North Puget Sound, Cherry Point, East Strait of Juan de Fuca, Rosario Strait, Guemes Channel, Saddlebag, San Juan Islands, Haro Strait A>B ***
by Season	**Total Events**	**Tug/barge had more total event frequency in winter and summer seasons than in autumn and spring seasons**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 27.8035, DF =3, Pr<0.0001 F-value=16.03, DF = 3, Pr >F <0.0001	**A: Winter Summer B: Autumn Spring A>B ***
	Accidents	**Tug/barge had more accident frequency in winter and summer seasons than in spring and autumn seasons**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 27.2958, DF =3, Pr<0.0001 F-value=18.59, DF = 3, Pr >F <0.0001	**A: Winter Summer B: Spring Autumn A>B ***
by Flag (U.S. Flag vs. Non U.S. Flag)	**Total Events**	**Vessels from U.S. have higher events frequency than those from Non-U.S.**	Wilcoxon	Statistic 187.0000, Normal Approximate z= 3.9874, Pr> z<0.0001	**U.S.>Non U.S. ***
	Accidents	**Vessels from U.S. have higher accidents frequency than those from Non-U.S.**	Wilcoxon	Statistic 185.0000, Normal Approximate z= 3.8822, Pr> z=0.0001	**U.S.>Non U.S. ***
	Incidents	**Vessels from U.S. have higher incidents frequency than those from Non-U.S.**	Wilcoxon	Statistic 185.5000, Normal Approximate z= 3.9837, Pr> z <0.0001	**U.S.>Non U.S.***

Test		Results	Test Used	Statistics	Direction
by Owner	**Total Events**	**Vessels from different owners had statistics difference of total event frequency**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 10.7222, DF =3, P=0.0145 F-value=4.69, DF = 3, Pr >F =0.0090	**A: Foss; Crowley; Olympic tug/barge Inc. B: Crowley; Olympic tug/barge Inc; Island tug/barge Co A>B ***
	Accidents	**Vessels from different owners had statistics difference of accident frequency**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 11.0232, DF =3, P=0.0178 F-value=4.56, DF = 3, Pr >F =0.0098	**A: Foss; Crowley; Olympic tug/barge Inc. B: Crowley; Olympic tug/barge Inc; Island tug/barge Co A>B ***
By Hull Type	**Total Events**	**Single hull tug/barge had higher number of total event frequency than those had double hull**	Wilcoxon	Statistic 187.0000, Normal Approximate z= 4.0172, Pr> z <0.0001	**Single hull > Double hull ***
	Accidents	Single hull tug/barge had higher number of accident frequency than those had double hull	**Wilcoxon**	**Statistic 187.0000, Normal Approximate z= 4.1158, Pr> z<0.0001**	**Single hull > Double hull ***
	Incidents	**Single hull tug/barge had higher number of incident frequency than those had double hull**	Wilcoxon	Statistic 185.0000, Normal Approximate z= 3.9220, Pr> z< 0.0001	**Single hull > Double hull ***
By Accident /Incident Type	**Accidents**	**Accidents caused by pollution had statistically higher number of frequency than those caused by other types**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 52.8120, P>Chi-square <0.0001 F-value= 29.29, Pr >F <0.0001	**Pollution>Allision>Grounding, Collision, Fire, Capsize, Flooding, Sinking , Breakaway***
	Incidents	**Incidents caused by equipment failure had statistically higher number of frequency than those caused by other types**	Kruskal-Wallis Tukey's HSD	Chi-square statistic 17.8887, P>Chi-square =0.0013 F-value= 7.76, Pr >F <0.0001	**Equipment failure>Loss of Propulsion, Loss of steering, Near miss, Structural Failure ***
by Error Type (HOE vs. Mechanical)	**Total Events**	**Tug/barge vessels had more events caused by HOE than by MF**	Wilcoxon	Statistic 94..5000, Normal Approximate z=-2.1139, Pr> z=0.0345	**MF>HOE ***
	Accidents	**Tug/barge vessels had more accidents caused by HOE than by MF**	Wilcoxon	Statistic 157.0000, Normal Approximate z=2.0825, Pr> z<0.0373	**HOE>MF ***
	Incidents	**Tug/barge vessels had more incidents caused by MF than by HOE**	Wilcoxon	Statistic 68.5000, Normal Approximate z= -3.9529, Pr> z<0.0001	**MF>HOE ***

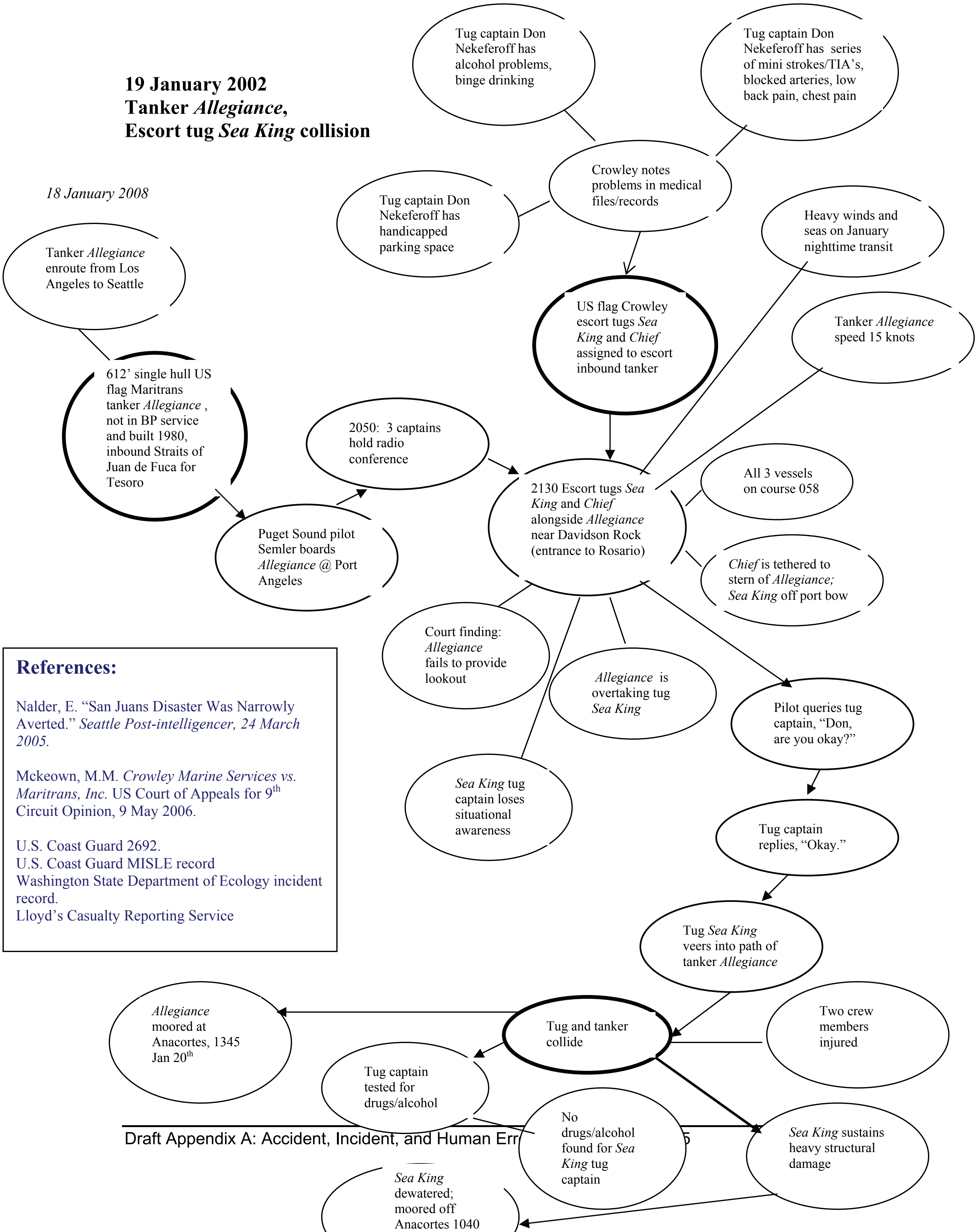
* = small sample size

Appendix A-3

Influence Diagrams for Puget Sound Tanker, ATB/ITB Calibration Accidents, Sample Incidents and Unusual Event, 1995-2005

19 January 2002
Tanker *Allegiance*,
Escort tug *Sea King* collision

18 January 2008



References:

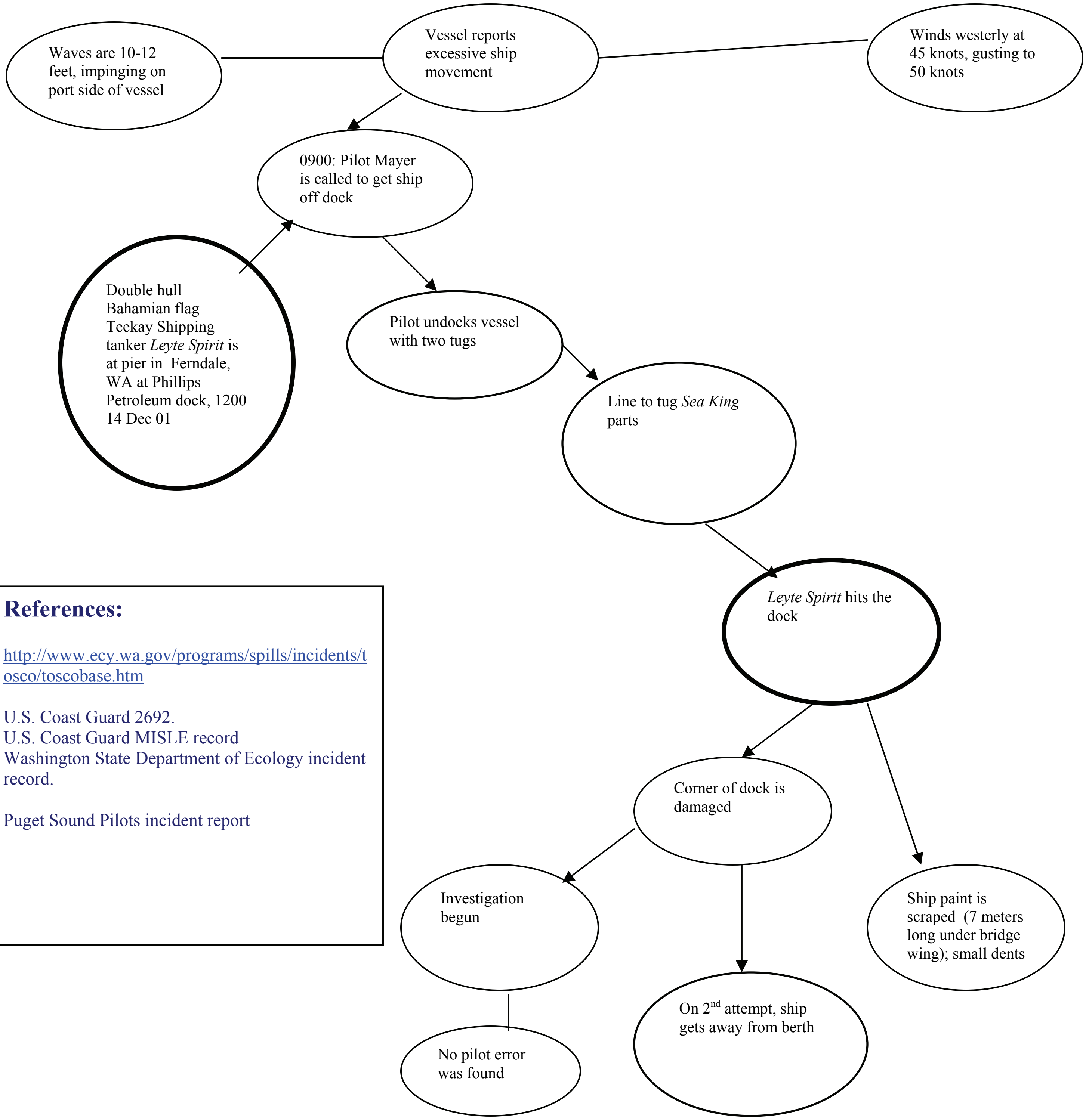
Nalder, E. "San Juans Disaster Was Narrowly Averted." *Seattle Post-intelligencer, 24 March 2005.*

Mckeown, M.M. *Crowley Marine Services vs. Maritrans, Inc.* US Court of Appeals for 9th Circuit Opinion, 9 May 2006.

U.S. Coast Guard 2692.
U.S. Coast Guard MISLE record
Washington State Department of Ecology incident record.
Lloyd's Casualty Reporting Service

14 Dec 2001
Tanker *Leyte Spirit*, allision

18 January 2008



References:

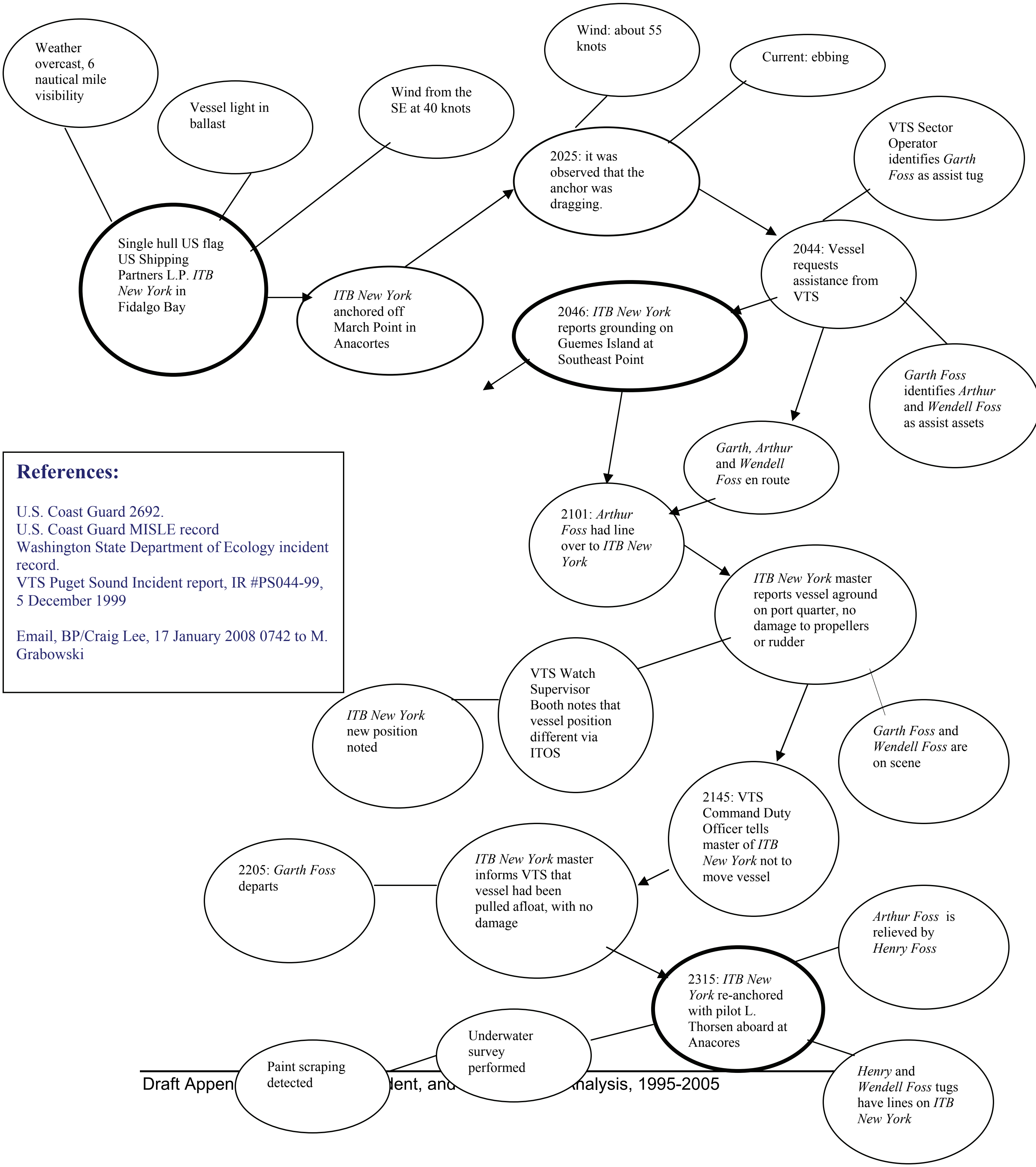
http://www.ecy.wa.gov/programs/spills/incidents/tosco/toscobase.htm

U.S. Coast Guard 2692.
U.S. Coast Guard MISLE record
Washington State Department of Ecology incident record.

Puget Sound Pilots incident report

5 December 1999
***ITB New York*, grounding**

18 January 2008



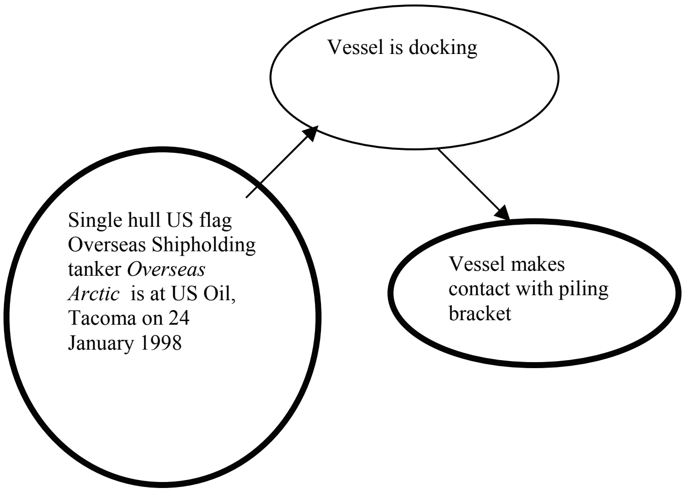
References:

U.S. Coast Guard 2692.
U.S. Coast Guard MISLE record
Washington State Department of Ecology incident record.
VTS Puget Sound Incident report, IR #PS044-99, 5 December 1999

Email, BP/Craig Lee, 17 January 2008 0742 to M. Grabowski

24 January 1998
Tanker *Overseas Arctic*, allision

18 January 2008



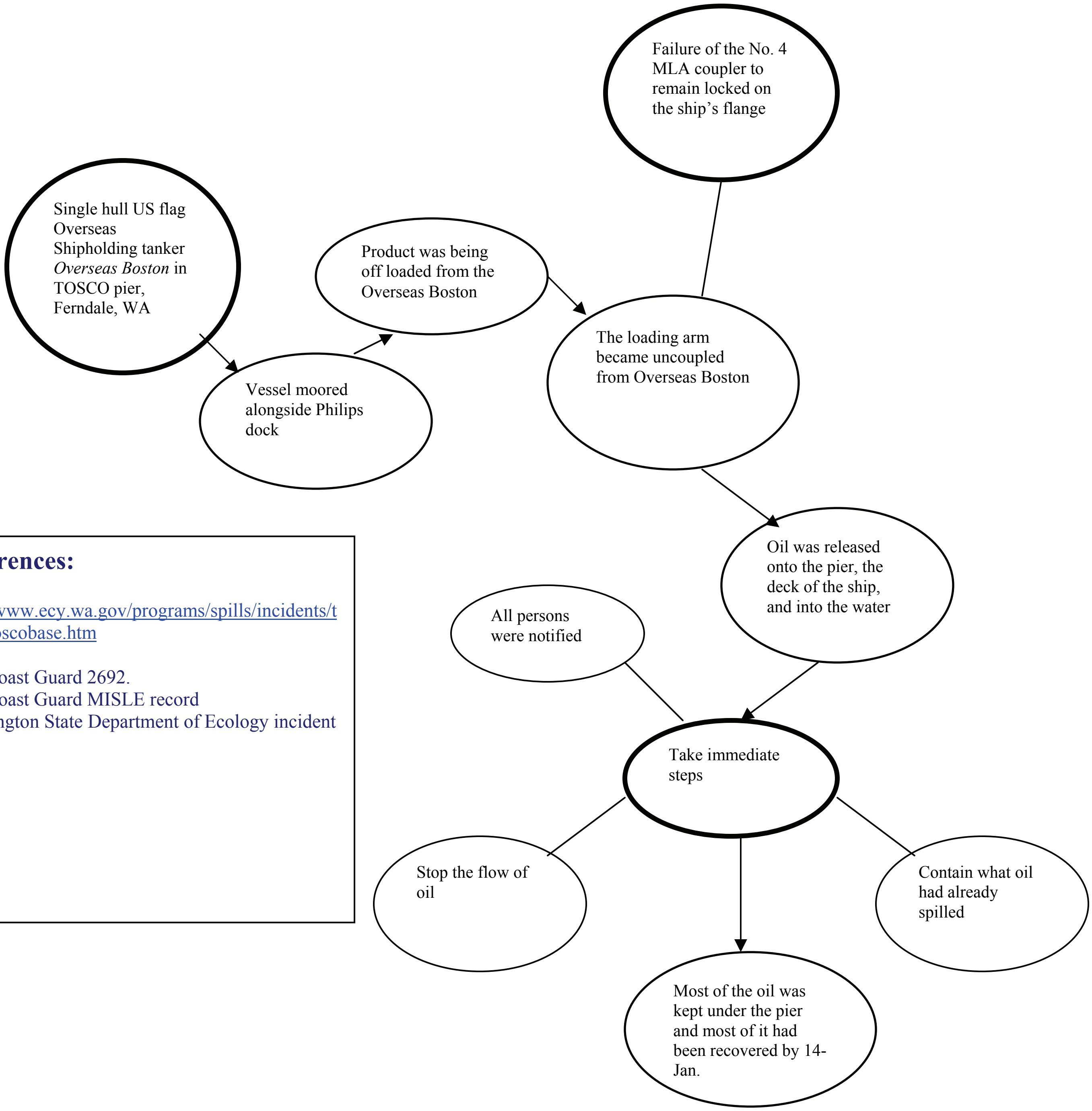
References:

U.S. Coast Guard MISLE record

Puget Sound Pilot Commission record 190906

BP/Steve Alexander phonecon 17 January 2008 1000 to M Grabowski

13 January 2002
Tanker *Overseas Boston*, pollution

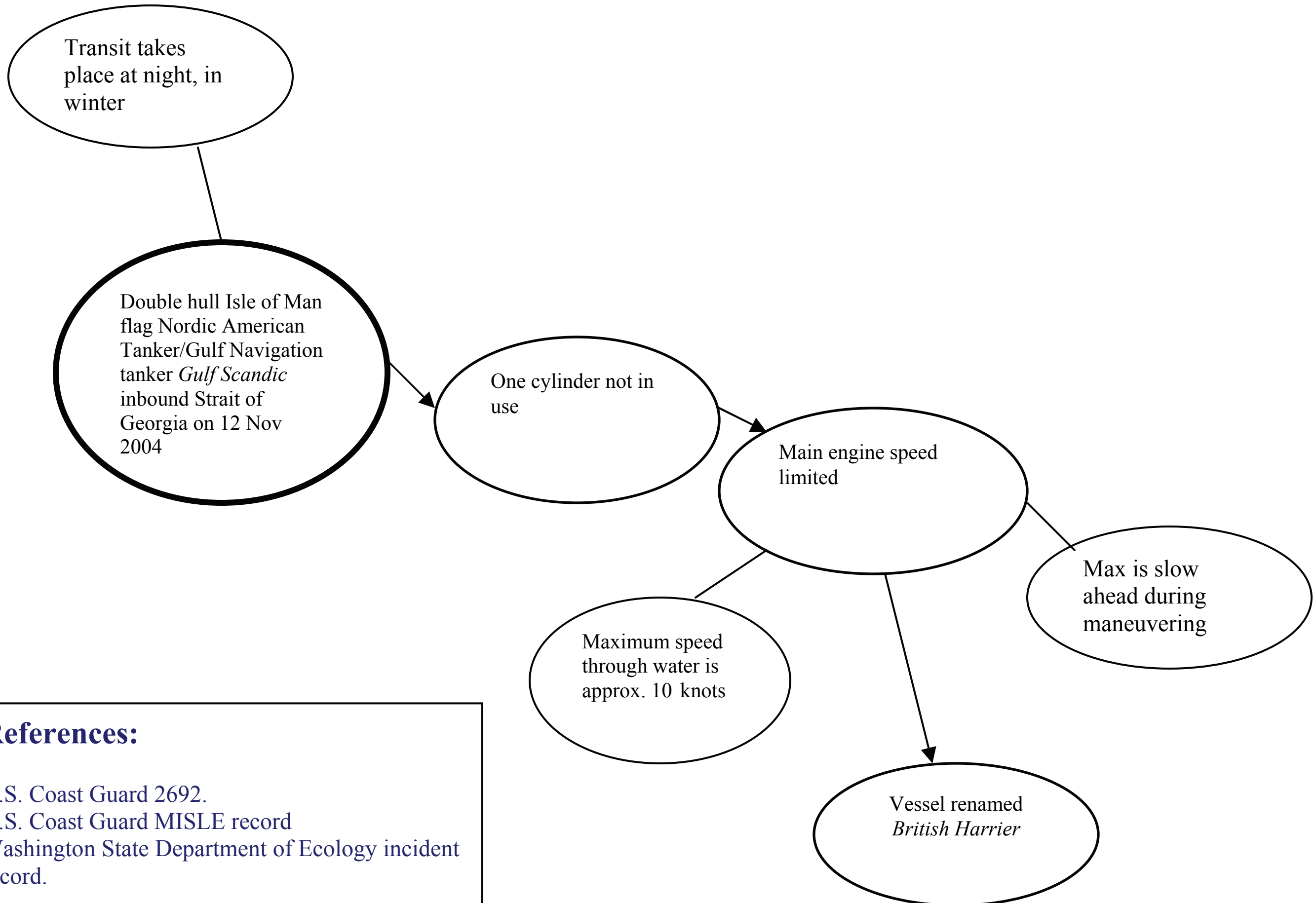


References:

http://www.ecy.wa.gov/programs/spills/incidents/tosco/toscobase.htm

U.S. Coast Guard 2692.
U.S. Coast Guard MISLE record
Washington State Department of Ecology incident record.

12 November 2004
Tanker *Gulf Scandic*, Propulsion Failure *18 January 2008*



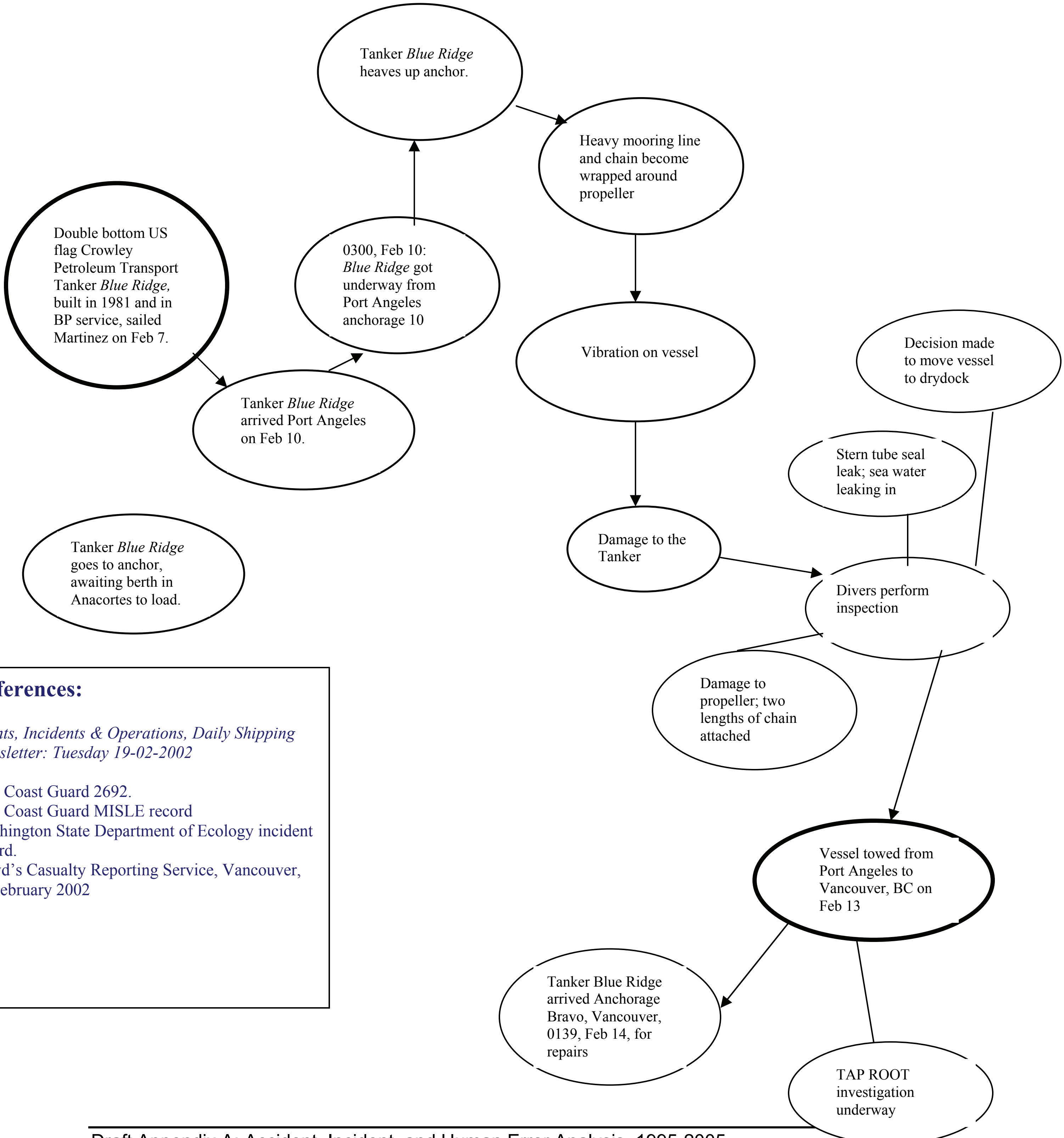
References:

U.S. Coast Guard 2692.
U.S. Coast Guard MISLE record
Washington State Department of Ecology incident record.

BP/Steve Alexander phonecon with M. Grabowski, 17 January 2008 1000EST

11 February 2002
Tanker *Blue Ridge*, Unusual Event
Wire in propeller

18 January 2008



References:

Events, Incidents & Operations, Daily Shipping Newsletter: Tuesday 19-02-2002

U.S. Coast Guard 2692.
U.S. Coast Guard MISLE record
Washington State Department of Ecology incident record.
Lloyd's Casualty Reporting Service, Vancouver, 14 February 2002