Oil Spill Response Vessel Capabilities in the State of Washington: Outer Coast Addendum

Prepared for
State of Washington Department of Ecology
Bellevue, Washington
Contract No. C0500277 and Amendments 1, 2 and 3

File No. 05051
February 2006

THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community

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[not available for signature]

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Corrigendum to June 2005 Report

After the release of the original report, an erroneous data point was discovered in the spill data used for the historical analysis in Section 1. A 42,000-gallon crude oil spill was mistakenly reported as having taken place in Lake Washington in March, 2003. In reality, this spill had taken place in a similarly named body of water in Canada. The data were re-analyzed after correcting the database, and new analytical graphics were prepared. Although the general conclusions of Section 1 of the original report remain largely unchanged, the detailed analysis has been corrected. A new Section 1 for the original report is included with this Addendum.

Additional Acknowledgements

The Glosten Associates wishes to thank the following people for their direct assistance in preparing this addendum:

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Lash Larew / Rainier Heli-Lift

Executive Summary and Introduction

The Glosten Associates, Inc. was asked to expand its June 2005 study "Oil Spill Response Vessel Capabilities in the State of Washington: Use of Commercial Fishing Vessels to Augment Oil Spill Response Capabilities." In particular, Glosten was asked to review the applicability of commercial fishing vessels to response activities for spills occurring offshore or nearshore in the Outer Coast region of the State.

This supplemental report concludes that:

- There is a distribution of almost 400 fishing vessels of opportunity possessing features of interest to an oil spill response operation along the coast. This represents a significant resource base from which to draw.
- Properly organized, the fleet appears to be sufficiently large to support the needs of an offshore on-water recovery operation consisting of the known dedicated regional oil spill recovery resources published in the Northwest Area Contingency Plan. The fleet also has the potential to support additional resources that may be cascaded in from other regions. However, open ocean weather will severely limit the availability and effectiveness of both vessels of opportunity and dedicated resources, particularly in winter months.
- Defensive strategies for the Outer Coast (outlined in the Geographic Response Plans, or "GRPs") focus primarily on exclusionary booming of tributaries. With no safe approaches from the seaward side, most of these strategies must be carried out using ground transportation, helicopters and small skiffs. As a result, it appears that the vessel-of-opportunity fleet adds nothing in the way of preparedness for carrying out most of these defensive strategies.
- The study reinforced the importance of helicopters in carrying out defensive strategies. The adequacy of the helicopter fleet in Washington State to support defensive strategies has not been assessed, because it lies outside of the scope of this study. However, the study did investigate aviation weather constraints that can reduce helicopter availability, and concludes that visibility and ceiling will reduce the number of available flying hours by an overall average of

10%. There are notable trends in flying weather availability as a function of season and time of day. The effect of wind velocity on helicopter operations (particularly those involving slung loads) may have a larger effect, but was outside of the scope of this report. A census of the local helicopter fleet and an investigation of wind limitations on their use are worthy of future investigation.

- Inland defensive strategies for the major inlets, Grays Harbor and Willapa Bay, can benefit from the vessel-of-opportunity fleets homeported there. The Grays Harbor fleet, in particular, appears to have adequate numbers to supply local defensive strategy demands. The Willapa Bay fleet would be marginally able to supply local defensive strategy demands.

In summary, a properly organized fishing fleet can add to regional preparedness on the Outer Coast, but it is not a panacea. A large spill of persistent oil off the coast will likely affect large portions of the coastline. Offshore skimming and nearshore protection on the Outer Coast remain problematical and are only marginally improved by the existence of a large fleet of vessels of opportunity. Other development and planning efforts should proceed, including improved shoreline cleanup and restoration techniques, dispersant usage and in situ burning.

SECTION 1

Refinement of Fishing Vessel Census for the Western Straits and Outer Coast

The ports of the Outer Coast are home to almost 400 commercial fishing vessels having features that could be valuable in supporting oil spill cleanup operations. Mobilization of any of these vessels within 24 hours is feasible, weather permitting, from any of these ports to any other point along the coast.

1.1 Fleet Distribution

In the original June 2005 report, the census of fishing vessels of interest as spill response vessels was estimated at 1100 statewide. This number included both distant water and local fishery vessels homeported in Washington State. In addressing issues associated with Outer Coast spills, this addendum attempts to better quantify the distribution of the fishing fleet in the coastal region, as a resource distinct from that of Puget Sound.

The majority of ocean-capable fishing vessels were found to be distributed among the following port areas:

- Neah Bay
- LaPush
- Grays Harbor
- Willapa Bay
- Lower Columbia River

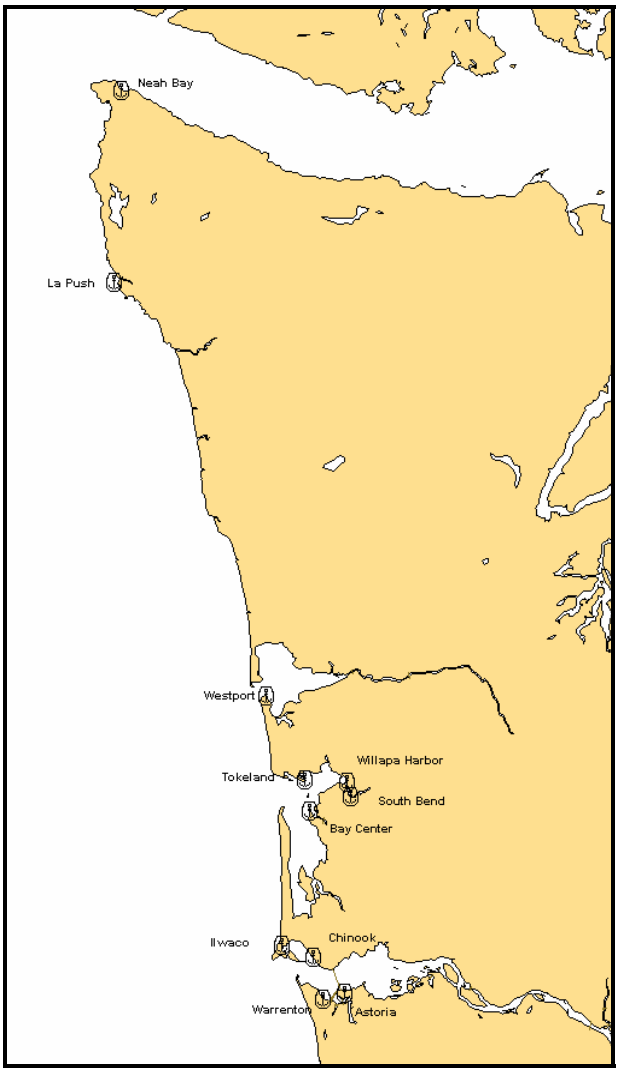


Figure 1-1: Outer Coast Commercial Fishing Fleet Homeports

1.2 Fleet Characteristics and Census (Vessels of Interest Only)

Almost 400 vessels of interest in the Outer Coast Region

All of the major marinas serving these areas were visited, and port officials were interviewed during the month of October 2005. These visits resulted in the fleet census summarized in the table below. The categories listed are the same three general categories first proposed in the June 2005 study.

Table 1-1: Commercial Fishing Fleet Census, Fall 2005

Region	Homeport	Fleet Population		
		Motherships	FRVs*	Skiffs
Lower Columbia River	Ilwaco	25	12	2
	Chinook	8	2	0
	Astoria (East)	12	2	1
	Warrenton	8	2	2
Willapa	South Bend	3	17	0
	Willapa Harbor	7	2	0
	Tokeland	0	13	0
	Bay Center	2	14	0
Grays Harbor	Westport	83	85	0
LaPush		16	3	0
Neah Bay		21	43	0
Totals	**385**	**185**	**195**	**5**

*FRVs include crewboat or fishing party boat configuration as well as fishing vessels less than 50' in length

These numbers compare well with the statewide distribution reported originally, and now identify the previously unreported homeports at LaPush and Willapa Bay. Only those vessels exhibiting characteristics useful to an oil spill were counted; these include vessels from all fisheries, as well as some fishing party charter boats.

1.3 Estimated Response Times for Vessel of Opportunity Fleet

Less than 24-hour mobilization time for vessel-of-opportunity fleet (weather permitting)

In order to establish an expected response time for any of these vessels, courses were plotted from each home port to a hypothetical spill location off of Cape Flattery, the northernmost point within the Outer Coast region of interest. The table below predicts running times from each of the port locations to that site.

Table 1-2: Running Times to Cape Flattery

Region	Homeport	Distance (NM)	Speed (kts)	Response Time (hours)
Lower Columbia River	Ilwaco	144	10	14.4
	Chinook	145	10	14.5
	Astoria (East)	152	10	15.2
	Warrenton	149	10	14.9
Willapa	South Bend	134	10	13.4
	Willapa Harbor	132	10	13.2
	Tokeland	126	10	12.6
	Bay Center	130	10	13.0
Grays Harbor	Westport	107	10	10.7
LaPush		33	10	3.3
Neah Bay		9	10	0.9

Allowing time for crewing, fueling and general preparations for getting underway, it is reasonable to expect that if properly organized, vessels from any of these fleets can reach a spill site anywhere on the Outer Coast within 24 hours, weather permitting.

SECTION 2

Weather-Related Operational Statistics

Unlike the protected waters of Puget Sound, weather on the Outer Coast can severely limit on-water work associated with the control of an oil spill, particularly in the winter months. The concept of weather "availability" should be considered in planning efforts. Weather will affect both on-water recovery ("offensive") efforts and protection ("defensive") strategies. Visibility will similarly affect air support operations, but to a much lesser degree, and with different seasonality than marine weather.

Weather was recognized as a potential limiting factor in spill response on the Outer Coast. An analysis of historical data was undertaken in an attempt to quantify this impact. Data collection points for marine weather and aviation weather are plotted in Figure 2-1 below.

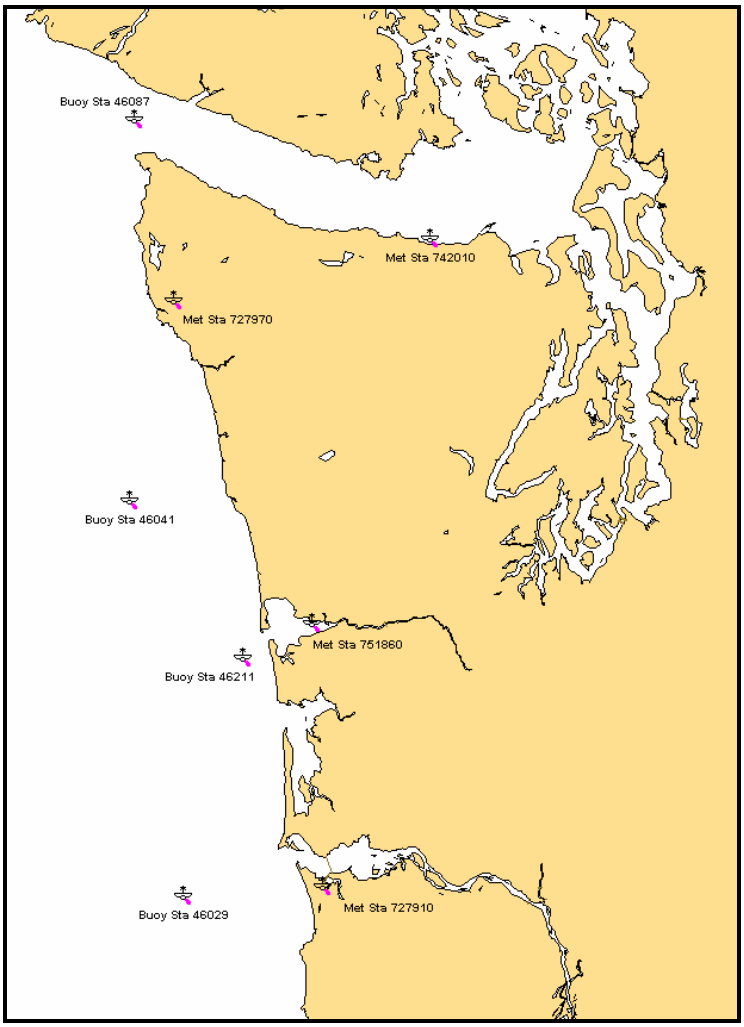


Figure 2-1: Meteorological Monitoring Stations

2.1 Marine Weather: Statistics and Effect on Response Activities

7- to 8-foot seas represent a key limit to on-water operations

For a spill on the Outer Coast, on-water containment and recovery operations will be conducted in open ocean conditions. Unlike in the protected waters of Puget Sound, vessels engaged in recovery operations here will be subjected to sea conditions. As part of the fleet census effort, fishermen were interviewed whenever possible. In particular, they were queried as to what represented limiting weather conditions for them to operate. For most of the Outer Coast fleet, there seemed to be consensus that any sea state in excess of about 7- to 8-foot significant wave height would hamper their ability to perform useful work, and may, in some cases, pose a survival threat in crossing bars at entrance channels. Operators of some of the larger steel fishing vessels, though, opined that 8- to 12-foot seas were more representative of their operating limits. Planning for offshore recovery work must take these statistics into account.

48 hours established as a minimum duration for good weather

Weather statistics have been prepared for areas in the vicinity of Neah Bay, Grays Harbor, Willapa Bay and Lower Columbia River (Ilwaco and Astoria). For each of these sites, plots are presented to demonstrate the probability, by month, that the significant wave height does not exceed 3 feet, 7 feet and 10 feet as a function of duration. A 48-hour weather duration was selected to represent the minimum time required for any vessel of opportunity to proceed to a cleanup site and perform useful work. The plots thus show the probability of finding favorable weather windows of various durations in a given month. The complete statistical report is included in Appendix B.

Potential reduction in vessel availability due to weather: 20% to 90%

The tables that follow summarize the resulting weather availability, or the number of days in any given month when benign weather (seas less than 7 feet) can be expected to persist for at least 48 hours. They predict that in a year, more than half of the days will allow vessels to get underway and have at least 48 hours in which to be able to do useful work offshore. As one would expect, there is high seasonal variability in the statistics, ranging from more than 80% (4 days out of 5) in the summer to slightly more than 10% (1 day out of 10) in the winter.

Table 2-1: Grays Harbor: Probability of 48-hour Weather Window by Month

Period	Weather Operability (%)
January	13.3
February	16.6
March	20.0
April	26.4
May	50.7
June	62.7
July	80.4
August	76.7
September	50.1
October	29.1
November	10.4
December	8.8
Annual	**39.2**

Table 2-2: Lower Columbia River: Probability of 48-hour Weather Window by Month

Period	Weather Operability (%)
January	12.8
February	19.1
March	17.6
April	30.4
May	41.9
June	43.4
July	68.0
August	74.3
September	62.0
October	33.9
November	15.2
December	17.6
Annual	**34.5**

Table 2-3: Neah Bay: Probability of 48-hour Weather Window by Month

Period	Weather Operability (%)
January	32.4
February	26.1
March	28.5
April	41.0
May	71.0
June	65.5
July	63.4
August	83.6
September	39.5
October	27.4
November	19.5
December	11.2
Annual	**46.7**

2.2 Aviation Weather: Statistics and Effect on Response Activities

2.2.1 General Discussion of Air Support in Response Operations

Helicopters are a necessity in Outer Coast response

An investigation of oil spill response on the Outer Coast would be incomplete without an examination of aviation operations. Unlike the relatively protected waters of the Strait of Juan de Fuca and the greater Puget Sound, the rocks and the high energy surf along the Outer Coast virtually prohibit nearshore clean-up activities by small boats. This scenario favors the outcome that any spilled oil approaching the beach will eventually wash ashore. Few coastal roads provide direct access to the ocean beaches, and many of the beaches, particularly those in the north, are heavily cobbled. These conditions make the helicopter not only the logistical support vehicle of choice, but also of necessity.

Helicopter operations will likely originate each day from a general aviation airport and operate throughout the work day from remote, unimproved landing zones or heli-bases. Helicopter operators use their own fuel trucks to refuel their ships at these landing zones. The principal airports likely to be involved in a coastal response are:

- Astoria Regional
- Forks
- Hoquiam / Bowerman
- Port Angeles / Fairchild International
- Quillayute Prairie

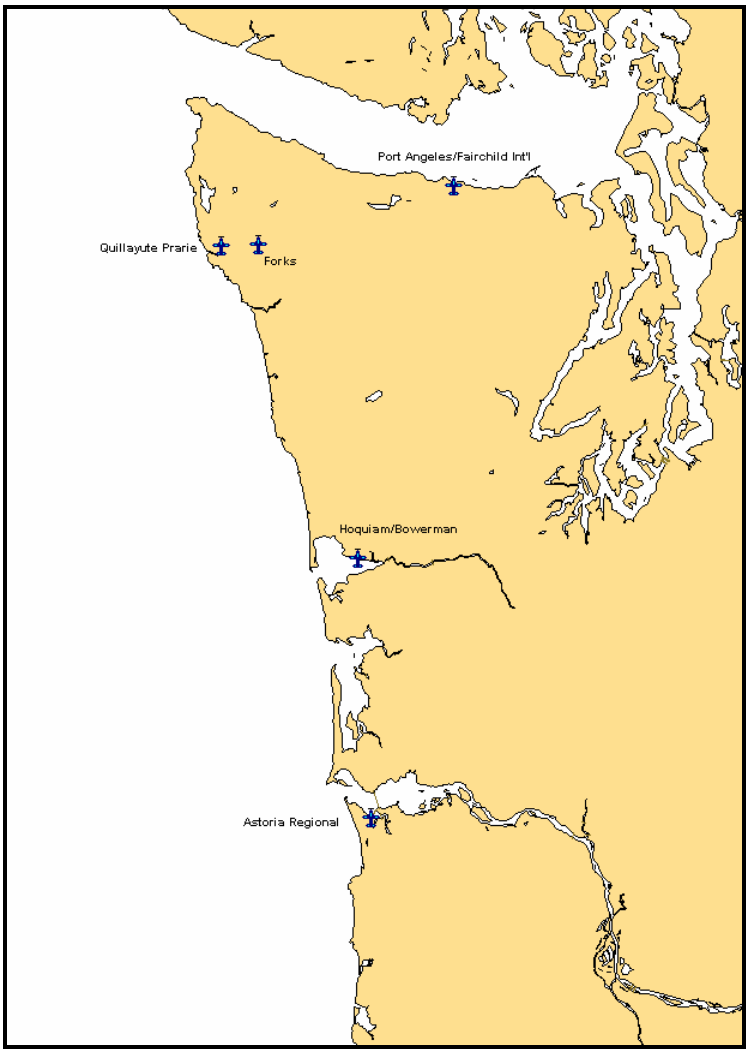


Figure 2-2: Outer Coast Airport Facilities

VFR conditions necessary

During a coastal oil spill response, commercial helicopters will operate under visual flight rules (VFR), enabling them to fly over land with a minimum 1/2-mile visibility and a 500' cloud ceiling. Flights over water require 2 miles of visibility and a proportionally higher cloud ceiling. During periods of good visibility, multiple helicopters can operate in the same air space with pilots communicating their route, position and intentions on a common frequency. As the visibility declines, the risk of mid-air collision increases.

Managing traffic and airspace

The low visibility collision risk is managed by reducing the number of aircraft flying. For example, during the *Tenyo Maru* response (1991), the most recent major oil spill on the Outer Coast, a 9-ship helicopter operation that served a 20-mile area of coast from the same landing zone, was reduced to 2 ships flying during periods of low visibility. The subsequent reduction in response productivity during those periods was substantial.

Figure 2-3: Reduced Visibility Helicopter Operations during the *Tenyo Maru* Response

At the peak of the *Exxon Valdez* incident, 123 aircraft were operating in the spill area. Of that number, 80% were helicopters independently chartered by the responsible party, response contractors and government agencies. It took 30 days before a system of aviation command and control was established to "systematize the prior chaos."[1] While an air operations branch exists under the operations section of the incident command system, it is almost never functionally tested during oil spill drills and exercises.

2.2.2 Aviation Weather Statistics

Potential reduction in available flying hours

Raw weather data for aviation proved to be somewhat difficult to acquire. However, the National Climatic Data Center produces statistics that are valuable to this study, with data analysis for flying conditions close to those quoted above for limiting conditions over land. The figures that follow demonstrate that at the principal airports sampled, low visibility will have relatively minor effects on air operations at those points of departure. Definite seasonal and time-of-day trends are evident in the plots. In general, visibility and ceiling constraints will prevent VFR flight operations less than 12% of the time in any given month. However, planners should be aware that visibility is highly variable with location along the Outer Coast, and actual responses could experience greater percentages of limiting conditions.

Limiting wind conditions not studied

The effect of wind on flight operations, particularly those involving externally slung cargoes, was outside the scope of this study, and may be a more significant factor than visibility. It would be a worthwhile future investigation.

[1] Interview with Lash Larew, executive vice-president of Rainier Heli-Lift

----------INTERNATIONAL STATION METEOROLOGICAL CLIMATE SUMMARY----------

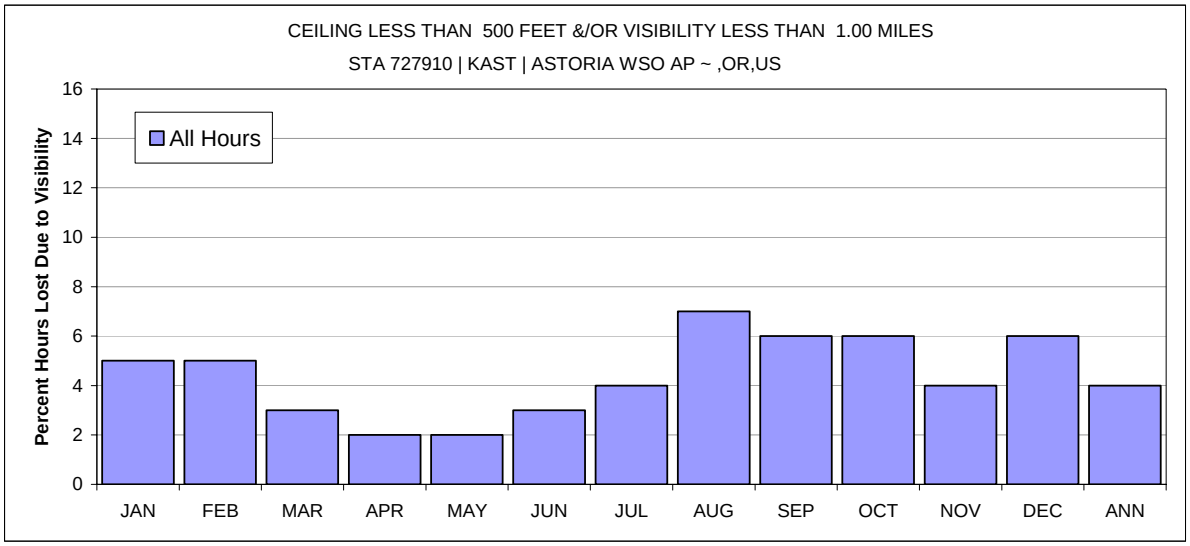
STA 727910 | KAST | ASTORIA WSO AP ~ ,OR,US
:LAT 46 09N :LONG 123 53W :ELEV 8(ft) 2(m) :TYPE NOAA SMOS V2.1 07021992
Table 20 - Percent Hours with FLYING WEATHER

CEILING LESS THAN 500 FEET &/OR VISIBILITY LESS THAN 1.00 MILES

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	#YRS
1:00 LST	6	6	3	3	3	5	7	12	8	9	5	7	6	42
4:00 LST	6	7	6	6	4	6	9	14	12	11	6	8	8	42
7:00 LST	7	7	6	6	5	6	9	15	14	15	7	7	9	42
10:00 LST	5	5	1	1	1 *		1	2	3	4	5	5	3	42
13:00 LST	4	2	1 *	*	*	*	*	*	*		2	4	1	42
16:00 LST	4	2	1	1 *		1 *		1	1	2	1	3	2	42
19:00 LST	4	3	1	1	1	1	2	4	3	3	4	5	3	42
22:00 LST	6	4	2	2	2	4	6	7	6	7	4	7	5	42
All Hours	5	5	3	2	2	3	4	7	6	6	4	6	4	42

* = VALUE > 0 AND < 0.5 PERCENT
# = EXCESSIVE MISSING DATA - VALUE NOT COMPUTED
- = MISSING DATA

----------FEDERAL CLIMATE COMPLEX ASHEVILLE----------



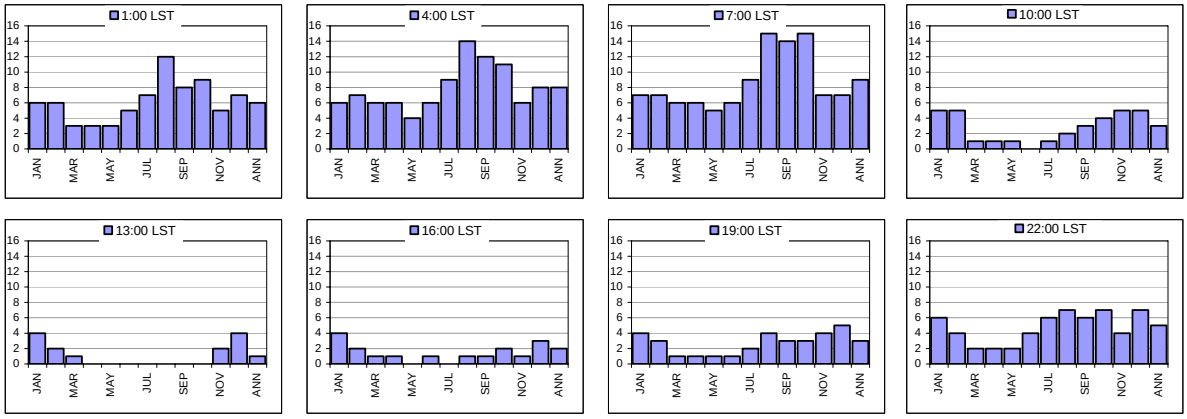


Figure 2-4: Flying Weather from Astoria

----------INTERNATIONAL STATION METEOROLOGICAL CLIMATE SUMMARY----------

STA 727970 | KUIL | QUILLAYUTE WSCMO AP ~ ,WA,US
LAT 47 57N :LONG 124 33W :ELEV 179(ft) 55(m) :TYPE NOAA SMOS V2.1 07021992
Table 20 - Percent Hours with FLYING WEATHER

CEILING LESS THAN 500 FEET &/OR VISIBILITY LESS THAN 1.00 MILES

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	#YRS
1:00 LST	12	9	7	6	8	7	13	19	17	16	10	9	11	25
4:00 LST	11	10	8	8	11	12	17	23	16	17	10	10	13	25
7:00 LST	11	11	9	7	9	12	17	24	16	11	9	11	12	25
10:00 LST	11	10	7	4	3	6	4	6	7	10	8	11	7	25
13:00 LST	11	9	5	3	2	3	2	2	3	6	6	8	5	25
16:00 LST	12	9	5	4	3	3	2	3	5	9	7	8	6	25
19:00 LST	9	9	6	4	4	4	5	6	7	9	8	11	7	25
22:00 LST	10	9	6	5	5	6	9	12	11	15	9	10	9	25
All Hours	11	9	7	5	6	7	9	12	10	12	8	10	9	25

* = VALUE > 0 AND < 0.5 PERCENT
# = EXCESSIVE MISSING DATA - VALUE NOT COMPUTED
- = MISSING DATA

----------FEDERAL CLIMATE COMPLEX ASHEVILLE----------

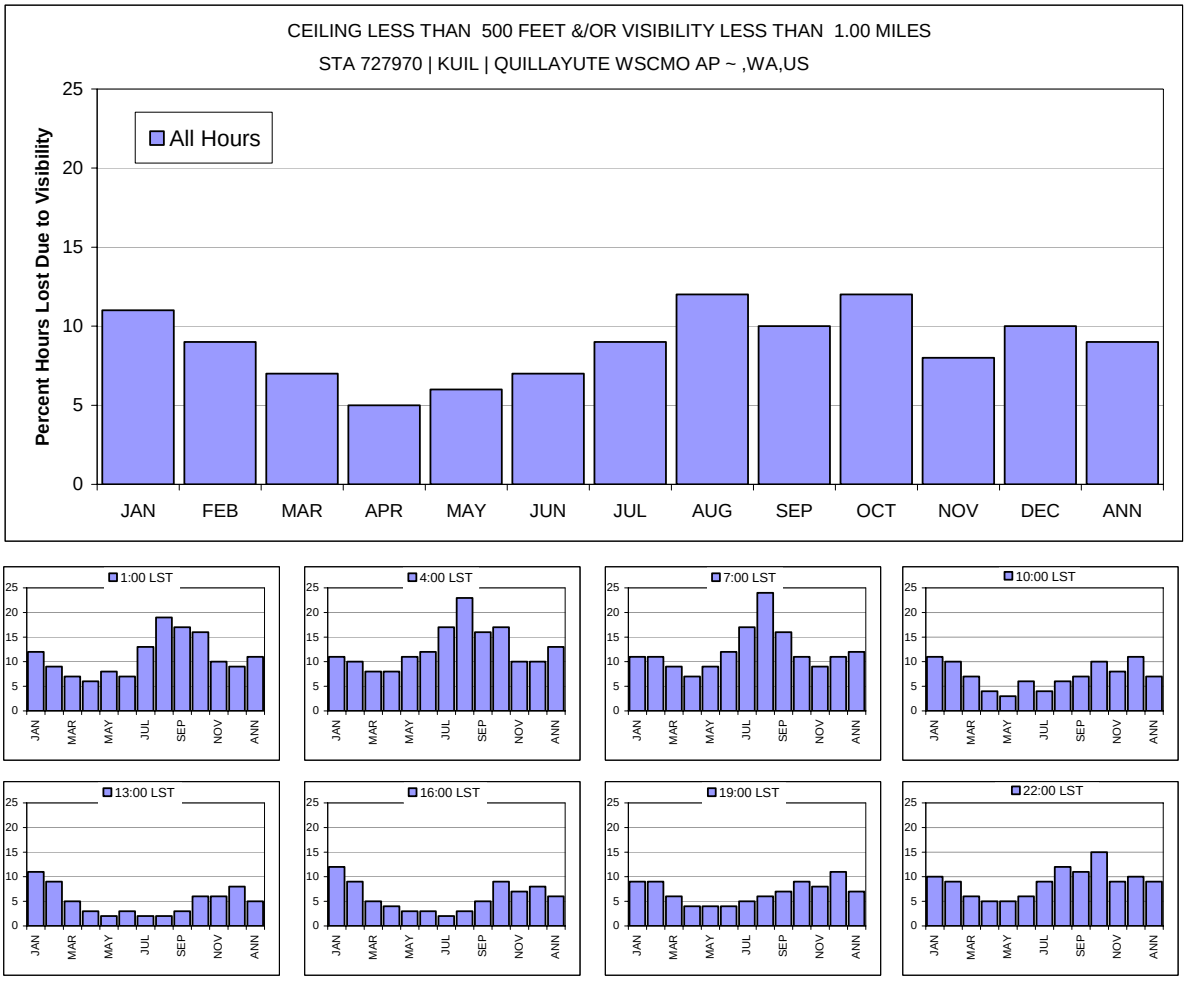


Figure 2-5: Flying Weather from Quillayute

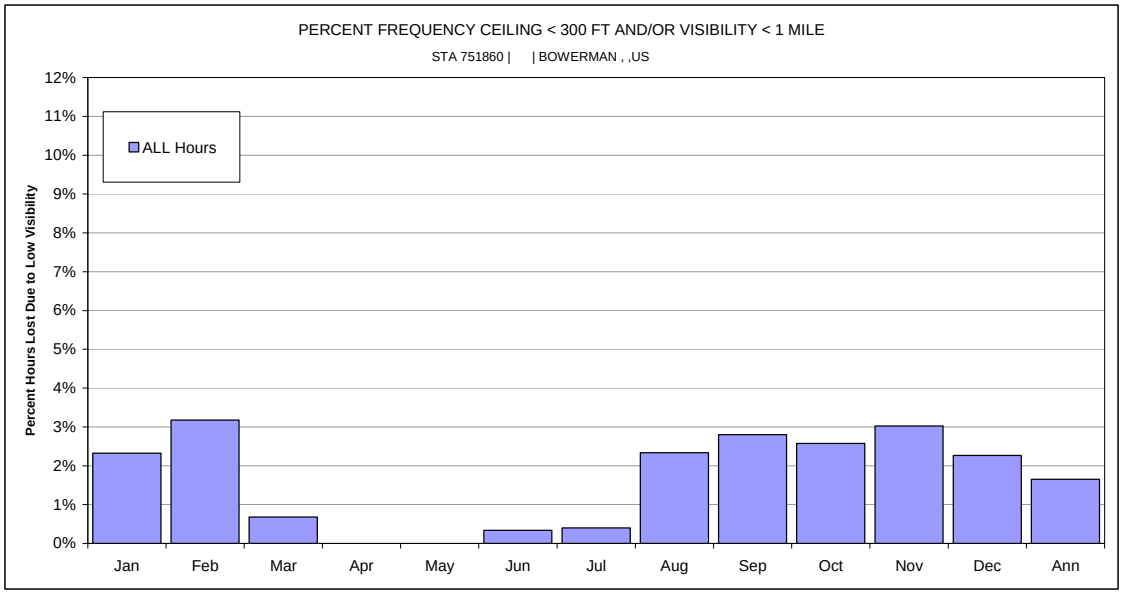
----------INTERNATIONAL STATION METEOROLOGICAL CLIMATE SUMMARY----------

STA 751860 | | BOWERMAN , ,US
LAT 46 58N :LONG 123 56W :ELEV 14(ft) :TYPE AWS WWAS V2.0 02101990
Worldwide Airfield Summaries (NCDC TD-9647)

Parameter Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	POR	#Obs.
ABS MAX TMP (F)	63	67	74	83	92	93	98	93	89	80	65	58	98	13	4367
MEAN MAX TMP (F)	46	49	51	55	61	64	68	69	68	61	52	48	58	13	4367
MEAN MIN TMP (F)	36	37	37	40	45	50	52	53	50	45	39	37	43	13	4367
ABS MIN TMP (F)	16	18	23	27	29	36	40	41	35	31	12	16	12	13	4367
MEAN NO DYS TMP = OR GTR 90(F)	0	0	0	0	0.1	0.1	0.6	0.1	0	0	0	0	0.9	13	4367
MEAN NO DYS TMP = OR LES 32(F)	8.6	6.8	7.7	2.6	0.1	0	0	0	0	0.5	5.2	6.7	38.2	13	4367
MEAN NO DYS TMP = OR LES 0(F)	0	0	0	0	0	0	0	0	0	0	0	0	0	13	4367
MEAN DEW PT TMP (F)	36	40	36	40	46	49	53	55	54	49	46	41	45	2	13522
MEAN REL HUM (PCT)	91	89	80	81	78	81	81	86	85	86	91	91	85	2	13522
MEAN PRESS ALT (FT)	-47	-36	-33	-63	-80	-82	-115	-101	-67	-37	-42	-32	-60	0	-50
MEAN PRECIP (IN)	10.61	8.53	7.65	5.27	3.04	2.45	1.5	1.94	3.41	7.5	12.96	10.9	75.8	13	4367
MEAN SNOW FALL (IN)	2.9	0.6	0.5	0	0	0	0	0	0	0	0.7	2.2	6.9	13	4366
MEAN NO DYS PRCP = OR GTR 0.1 IN	17.3	14.7	14.2	11.3	8.1	7	3.7	4.4	6.9	12.7	17.2	18.3	135.8	13	4367
MEAN NO DYS SNFL = OR GTR 1.5 IN	0.9	0.1	0.2	0	0	0	0	0	0	0	0.2	0.5	1.9	13	4366
MEAN NO DYS W/OCUR VSBY LES 1/2 MI	3	4	1	0	0	1.7	1.5	2.5	4	4.5	4	4.1	30.3	2	569
MEAN NO DYS TSTMS	0.4	0.2	0.6	0.4	0.5	0.2	0.2	0.4	0.8	1.1	0.6	0.4	5.8	13	4367
P FREQ WND SPD = OR GTR 17 KTS	19.4	25.7	15.1	19.5	7.8	6.7	5.1	1.6	3.5	6.4	12.8	15.9	11.6	2	13525
P FREQ WND SPD = OR GTR 28 KTS	2.9	4.6	0.4	0.1	0	0	0	0	0.1	0.5	1.1	0.8	0.9	2	13525

PERCENT FREQUENCY CEILING < 300 FT AND/OR VISIBILITY < 1 MILE

00-02 LST	2.2	2.4	0	0	0	0	0	5.4	3.3	3.9	4.5	2.7	2	2	1684
03-05 LST	3.3	5	0	0	0	2	2.7	7	6.7	7	0	2.2	3	2	1690
06-08 LST	4.3	10.8	5.4	0	0	0.7	0.5	3.2	8.5	7	5.6	9.4	4.6	2	1694
09-11 LST	4.3	4.8	0	0	0	0	0	0.5	1.1	0.5	3.3	2.2	1.4	2	1689
12-14 LST	0	1.2	0	0	0	0	0	0	0	0	1.7	0	0.2	2	1696
15-17 LST	1.1	0	0	0	0	0	0	0.5	0	0	4	1.6	0.6	2	1690
18-20 LST	2.3	0	0	0	0	0	0	0.5	0	0	2.8	0	0.5	2	1693
21-23 LST	1.1	1.2	0	0	0	0	0	1.6	2.8	2.2	2.3	0	0.9	2	1689
ALL Hours	2.32	3.18	0.68	0.00	0.00	0.34	0.40	2.34	2.80	2.57	3.02	2.26	1.65		



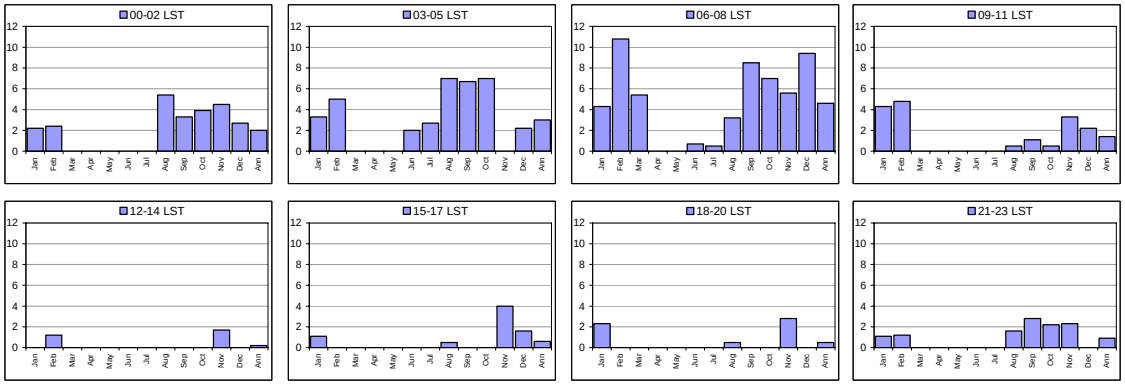


Figure 2-6: Flying Weather from Hoquiam/Bowerman (Note: Statistics reflect Ceiling of 300 feet vs. 500 feet)

SECTION 3

Review of Planning Standard Scenarios

Spill trajectory modelers have found the Outer Coast to be a challenging area for which to develop meaningful data. A new effort, sponsored by the Department of Ecology, attempts to improve trajectory models for this complicated region. Preliminary results from this effort, part of a larger planning evaluation project estimating the consequences of spills in Washington, were used to validate the assumptions made in this report for available response time and extent of major spill impacts occurring on the Outer Coast. Additional work may be warranted to better meld the two study efforts in the future.

3.1 Overview of Scenarios

In a separate effort sponsored by the Department of Ecology, large spills of bunker C oil were simulated off the Washington coast.[1] Two models in particular were released for review for this study. The northern scenario occurred in the vicinity of the Quillayute River,[2] while the southern scenario occurred at the mouth of Grays Harbor. Time constraints prevented full integration of the results of these models into this report. Their contribution was to confirm many of the assumptions on available response time and extent of impact that were made in preparing this report. Both analyses confirm the need for effective recovery and defensive strategies within the first 24 hours.

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[1] "Evaluation of the Consequences of Various Response Options Using Modeling of Fate, Effects and NRDA costs for Oil Spills into Washington Waters," Draft Report dated December 2005, by Deborah French-McCay et al, Applied Science Associates and Dagmar Schmidt Etkin, Environmental Research Consulting.

[2] Note that the spill site shown occurs within the Area To Be Avoided (ATBA).

3.2 Trajectory Modeling Results

3.2.1 Northern Spill Trajectory

Large areas of shoreline at risk of oiling within 18 hours

Figure 3-1 below demonstrates that, in the case of a large spill in the northern sector of the Outer Coast, the entire coastline and major inlets (Grays Harbor and Willapa Bay) stand a greater than one-in-ten change of being oiled. Keep in mind, however, that the threshold of oiling represented in this figure is equivalent to the first emergence of a visible sheen (approximately 0.01 micron thickness).

Figure 3-2 suggests that initial oiling can occur within the first 6, 12 or 18 hours along much of the coast, providing a relatively short time window in which to mount defensive measures. It further suggests that effects of the slick can enter Grays Harbor and encroach on the entrance to Willapa Bay within 36 hours.

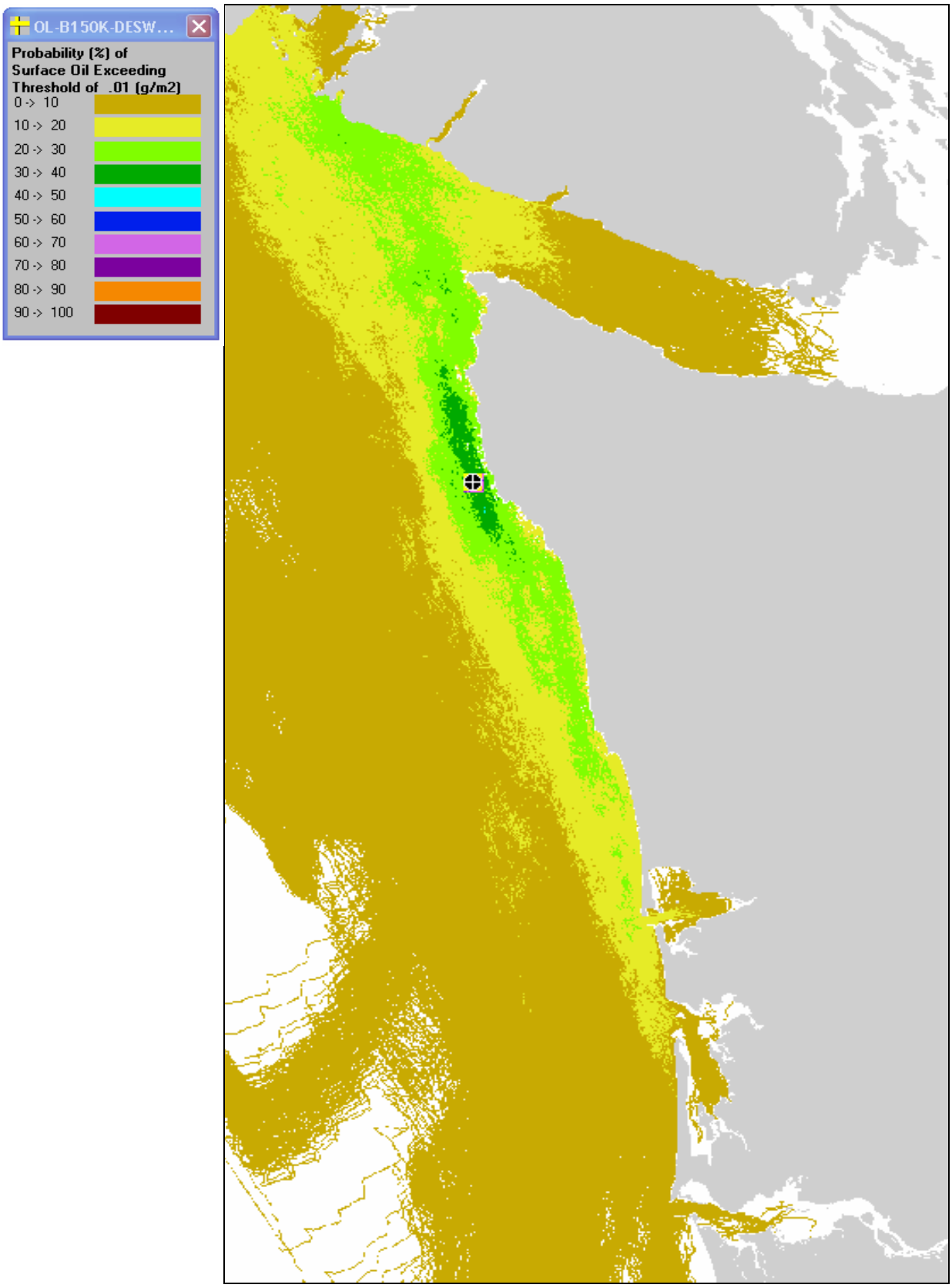


Figure 3-1: Northern Scenario – Probability of Oiling

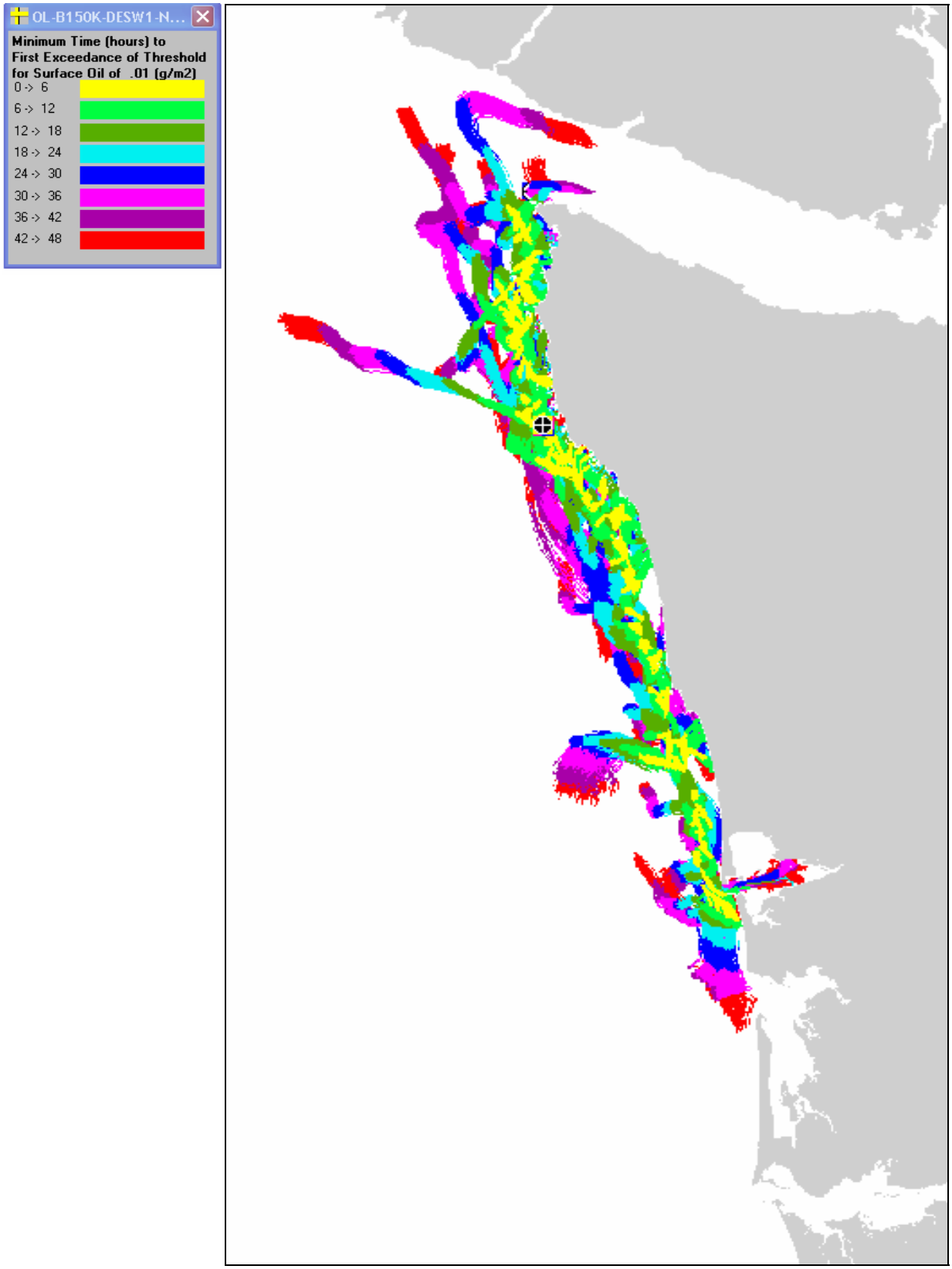


Figure 3-2: Northern Scenario – Time to First Oiling (available response time)

3.2.2 Southern Spill Trajectory

Inland shorelines at risk from nearshore spill in first 18 hours

In order to evaluate the effect of a spill at the mouth of a major tributary on a flood tide, the southern scenario was evaluated. Figure 3-3 demonstrates the possibility of significant inland migration, in addition to oceanfront oiling from a spill occurring at the mouth of a major tributary, in this case Grays Harbor. Figure 3-4 demonstrates that, again, response time in which to mount defensive measures is limited, with large portions of exposed and inland shoreline susceptible to oiling within the first 6, 12 or 18 hours.

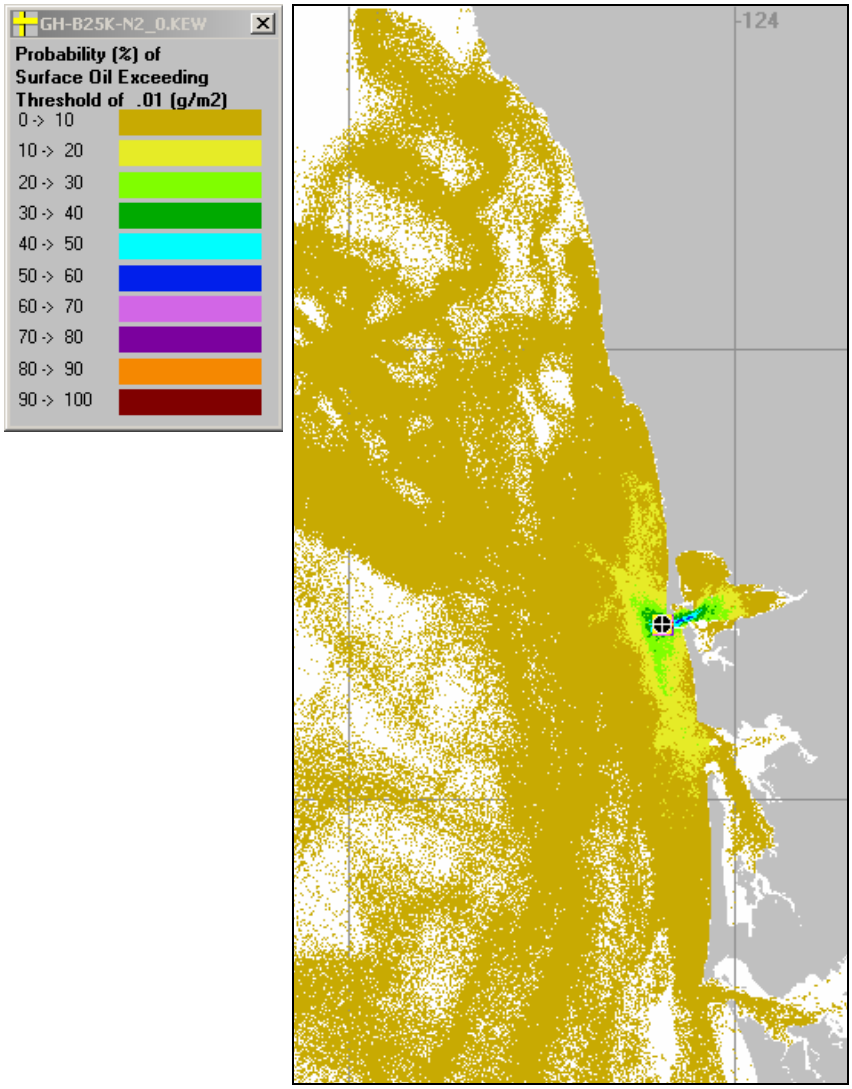


Figure 3-3: Southern Scenario – Probability of Oiling

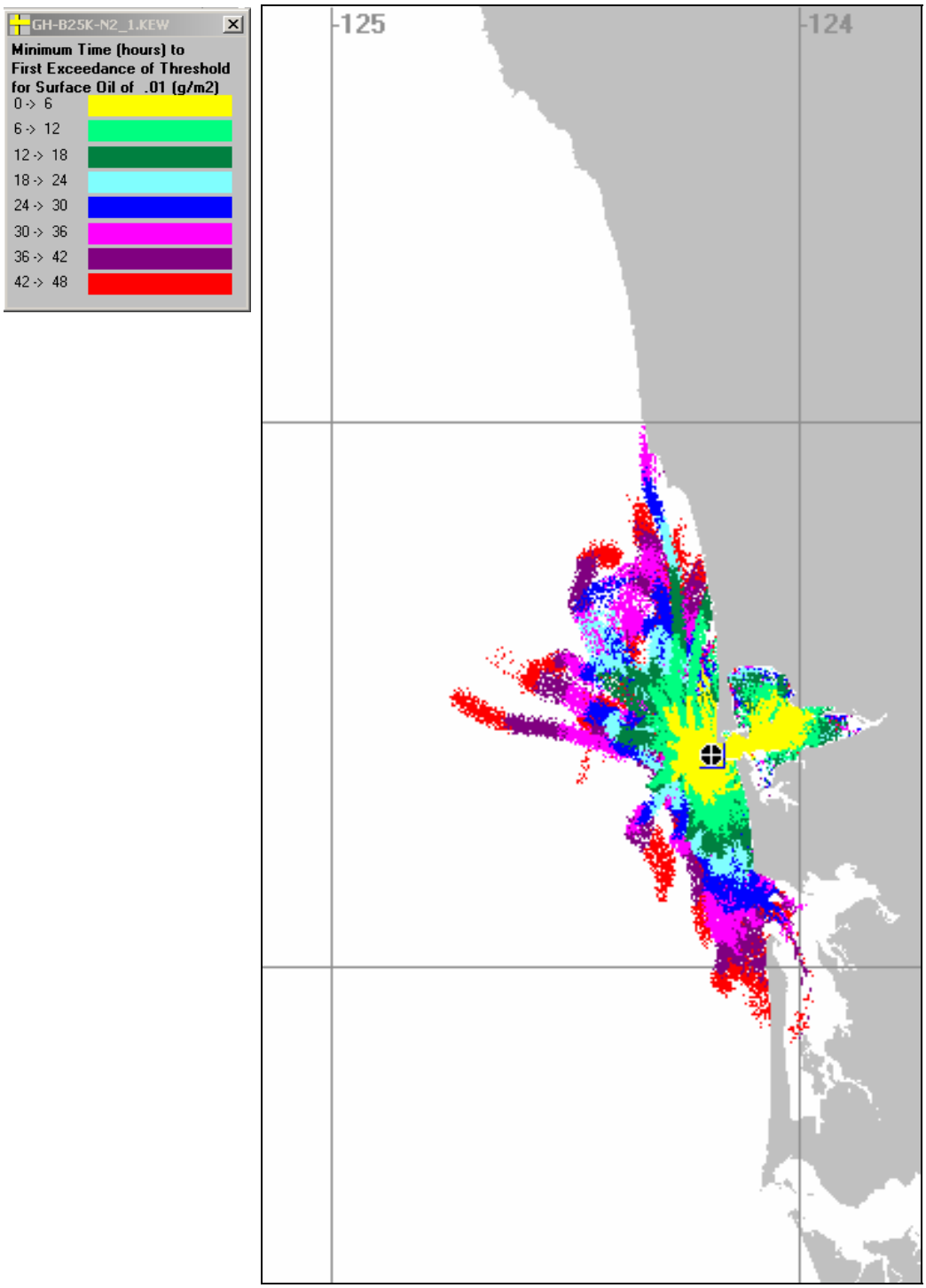


Figure 3-4: Southern Scenario – Time to First Oiling (available response time)

SECTION 4

Review of Response Strategies to Spills on the Outer Coast

Response strategies have been separated into two major segments: offshore containment and recovery (skimming) and nearshore protection and defensive strategies. The nearshore defensive measures were further segmented into exclusionary booming activities at smaller tributaries and inland protection at major tributaries. A conclusion is drawn that a properly organized fishing fleet can provide limited aid to offshore recovery operations and inshore protection strategies, while being of little use in effecting nearshore defensive strategies for smaller tributaries. Offshore skimming, and nearshore protection remain problematical. Within the parameters of the resources published in the Northwest Area Contingency Plan, the highest potential value of the Outer Coast fishing fleet appears to be in carrying out inland defensive strategies in Grays Harbor and Willapa Bay. In those locations, they may even represent a best alternative to dedicated resources. The Outer Coast fishing fleet could potentially contribute additional value to supporting response resource cascaded in from other regions. However, assessing the composition of those resources was beyond the scope of this report.

A large spill off the Outer Coast would create a response situation that is best analyzed by breaking the response activities down into two distinct operations, one of which requires further segmentation:

- On-water recovery operations offshore (offensive strategies)
- Shoreline protection (defensive strategies)
    - Minor tributaries (such as Boone Creek)
    - Major inlets (such as Grays Harbor)

4.1 Industry's Dedicated Vessels Certificated for Offshore Response

Summary of the offshore-capable response fleet

At the request of this study team, MSRC provided a list of dedicated resources known to be certificated for offshore response work. That list is shown below:

Table 4-1: MSRC-Provided Response List (November 2005)

MSRC Pacific Northwest Region Equipment & Vessels Capable of Deployment to the Outer Coast			
Vessel	**Homeport**	**USCG COI**	**Permitted Route or Operating Limitations**
Barges			
Barge 404	Astoria	Yes	Oceans
Barge 380	Port Angeles	Yes	Oceans
Kittiwake	Port Angeles	Yes	Coastwise (w/in 20 miles of land)
Ibis	Tacoma	Yes	Oceans
Pelican	Bellingham	Yes	Coastwise (w/in 20 miles of land)
OSRVs ("Motherships")			
Oregon Responder	Astoria	Yes	Oceans
WC Park Responder	Port Angeles	Yes	Oceans
Shearwater	Port Angeles	Yes	Oceans
Arctic Tern	Port Angeles	Yes	Oceans (w/in 100 miles of land)
Royal Tern	Anacortes	Yes	Oceans (w/in 100 miles of land)
Western Gull	Bellingham	Yes	Oceans (w/in 100 miles of land)
Aleutian Tern	Anacortes	No	Day operations, working with other vessels, within easy transit of shelter.
Plover	Tacoma	No	Day operations, working with other vessels, within easy transit of shelter.
Heron	Bellingham	No	Day operations, working with other vessels, within easy transit of shelter.
Grebe	Bellingham	No	Day operations, working with other vessels, within easy transit of shelter.
Widgeon	Seattle	No	Day operations, working with other vessels, within easy transit of shelter.
Workboats (FRVs)			
Eagle	Bellingham	No	Day operations, working with other vessels, within easy transit of shelter.
Osprey	Anacortes	No	Day operations, working with other vessels, within easy transit of shelter.
Loon	Port Angeles	No	Day operations, working with other vessels, within easy transit of shelter.
Mallard	Port Angeles	No	Day operations, working with other vessels, within easy transit of shelter.
Coot	Tacoma	No	Day operations, working with other vessels, within easy transit of shelter.
Teal	Anacortes	No	Day operations, working with other vessels, within easy transit of shelter.
Avocet	Seattle	No	Day operations, working with other vessels, within easy transit of shelter.

Continued next page

Vessel	Homeport	USCG COI	Permitted Route or Operating Limitations
Vessel of Opportunity Skimming Packages			
2 - GT 185	Astoria & Port Angeles	Complete with diesel-hydraulic power pack, outrigger arm, sweep boom and 500 bbl towable bladder.	
2 - Desmi Ocean Skimmers	Astoria & Everett	Complete with diesel-hydraulic power pack, outrigger arm, sweep boom and 500 bbl towable bladder.	
Boom			
35,040 feet of ocean (42" to 67") boom, plus 1,400 feet Fireboom.			

In addition to these resources, NRC maintains the response vessel *NRC Cape Flattery* on station at Neah Bay and a 34-foot response vessel at Westport.

68 skiffs among region's dedicated resources

The Northwest Equipment List was filtered to estimate the number of responder-controlled skiffs that may be available for overland delivery if needed. That list, which includes all vessels less than 20 feet in length controlled by the response industry and the Navy, totaled 68 vessels in Washington and northern Oregon.

4.2 Estimated Number of Vessels of Opportunity to Support On-Water Recovery Efforts

Offshore recovery efforts could benefit from vessels of opportunity

This analysis seeks to estimate the number of vessels that may be required if a major offshore containment and recovery effort were undertaken. As with the earlier study, it applies the "Dream Team" concept to support the dedicated response assets published in the Northwest Area Contingency Plan. That is, in a world of unconstrained resources tested by reasonableness, how many vessels of what type could maximize the effectiveness of a response?

It is presumed that all of the vessels listed in

Table 4-1 plus the NRC vessels at Neah Bay and Westport would be mobilized for an offshore recovery effort. If enhanced skimming techniques were appropriate to the offshore recovery effort,[1] four of the Inspected OSRVs and at least two of the uninspected OSRVs listed would require two boom towboats each. Vessels of opportunity meeting the definition of the category "FRVs" would be appropriate, weather permitting.

The asset list also identifies four vessel-of-opportunity skimming systems, each complete with its own sweep boom, outrigger and towable bladder for temporary storage of oil. While it is presumed that the OSROs have pre-identified suitable host vessels for these units, they are included in the vessel resource analysis below as consumers of vessels of opportunity.

In addition, an offshore effort of this magnitude would easily consume another 3 FRVs performing general logistical duties (ferrying spare parts, food and personnel) over and above the reverse logistic line established for the recovered oil (presumably handled by the five identified barges plus other assets that can be chartered in). This total demand for up to 15 assist boats is partially met by the dedicated workboat resources listed, a total of 7 vessels, leaving a potential shortfall of 8 assist vessels to be supplied from the vessel-of-opportunity fleet.

Table 4-2: Vessel Resource Analysis

DREAM TEAM ON-WATER OFFSHORE RESPONSE			
Type	**Number desired**	**Number Available**	**Potential Vessel of Opportunity Demand**
Mothership	4 (for VOSS)	0*	**4**
FRV	15	7	**8**
Skiff	0	n/a	**-**

* Number does not include contracted tugs or other pre-identified vessels that may be available and suitable for use as VOSS platforms

The census in Section 1 reported 185 vessels suitable for service as motherships and 195 suitable for service as FRVs. If we apply the 17%

[1] Enhanced skimming is a tactic whereby assist vessels tow lengths of boom in a Vee shape ahead of the skimming vessel to improve the encounter rate by "funneling" the oil to the skimming vessel. Whether such a tactic is used would be a judgment call made at the time and would depend on the oil thickness encountered, weather conditions and availability of equipment.

"turnout ratio" derived in the original study (the percentage of vessels of opportunity participating in an existing program expected to be available to respond to a request for services), the Outer Coast vessel-of-opportunity fleet is more than ample to help meet the potential shortfalls in FRVs and motherships for an offshore skimming effort.

A response such as this would certainly trigger the cascading of additional equipment from outside of the region. Even a doubling of the demand for vessels of opportunity, as more skimming resources were brought into the area, could be met by the Outer Coast fleet population, when properly organized.

4.3 A General Review of Outer Coast Defensive Strategies

Many of the GRP strategies were found to be difficult to execute

The investigators have concluded that Outer Coast defensive strategies (GRPs) are highly dependent upon helicopters, land vehicles and skiffs. The demands for each are summarized in the discussions that follow, and it can be presumed that vessels of opportunity are either unsuitable or cannot be relied upon to fill the gaps.

Over a period of two consecutive days chosen at random, a pair of Glosten investigators traveled along the Outer Coast visiting as many road-accessible GRPs as possible. Their efforts were designed to simulate the mission of an oil spill response crew assigned to implement these pre-identified defensive strategies. For the purposes of this exercise, the investigators' assumptions were that professional responders assigned to execute coastal GRPs would: 1) likely be dispatched from the Seattle metropolitan area, 2) use Ecology's published GRP manual for directions, 3) be sufficiently familiar with boom deployment and anchoring techniques to be able to evaluate on-site challenges, and 4) would not possess specific local knowledge of each site.

For the most part, the investigators found the information in Ecology's GRP manual to be accurate and easy to follow. While travel directions have remained consistent over time, it was obvious that the physical geography of the areas to be protected were in a constant state of flux due to wind, waves and in-stream flows. Simple issues such as hypothetically transporting 300' (or 1,000 lbs.) of containment boom 1/4 mile down a narrow trail emphasized the value of early logistical planning. The investigators cannot overemphasize the importance of locally knowledgeable guides, particularly on the larger rivers where high in-stream flows potentially make GRP deployments dangerous. Additionally, after observing the behavior of several rivers under both ebb and flood tide conditions, it was difficult to visualize a scenario that might allow spilled oil to flow very far upstream against the current.

One value-added outcome of this field exercise was to experience the extreme variability of coastal weather. With conditions changing almost hourly as weather fronts moved in off the ocean, the investigators encountered rain, dense fog, driving sleet, gusty winds and clear sunny skies. It is interesting to note that as the ocean beaches were subjected to roaring surf during this time, the beaches along the Strait of Juan de Fuca were generally calm.

SUMMARY OF GRPs VISITED FOR THIS STUDY

GRP OC-28 Copalis River

Date Visited: 10 November 2005

Tidal Stage: Tide falling from 7.3 to 3.1

Observations: Unable to locate published staging area at Copalis Beach Food Bank boat ramp. Many other unimproved boom deployment sites exist that are accessible both from Highway 109 and the banks of the Copalis River.

Copalis River Staging Area Aerial

GRP OC-27 Boone Creek

Date Visited: 10 November 2005

Tidal Stage: Visited on a tide falling from 7.3 to 3.1

Observations: Easy to locate off Highway-109. No supplemental comments on this GRP.

Boone Creek Aerial

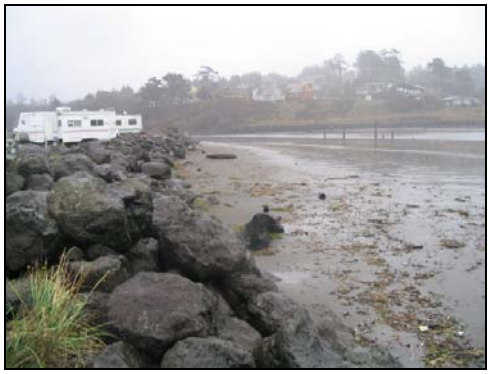
GRP OC-26a and 26b Joe Creek

Date Visited: 10 November 2005

Tidal Stage: Visited on a tide falling from 7.3 to 3.1

Observations: Excellent staging and access at Pacific Beach State Park. At the midpoint between the high and low tide, there was a substantial area of exposed mudflat surrounding Joe Creek. It could be potentially challenging to manhandle 600' to 1,000' of containment boom across the mudflats to the creek.

Joe Creek Aerial



Joe Creek on 10 November 2005

GRP OC-25a and 25b Moclips River

Date Visited: 10 November 2005

Tidal Stage: Visited on a tide falling from 7.3 to 3.1

Observations: Plausible strategy with easily identifiable access points. Without engaging a helicopter to drop boom at river's mouth, the best access appeared to be at the 2nd Street Bridge. A substantial number of abandoned pilings remain in the river.

Moclips River Aerial

Moclips River on 10 November 2005

Warning Placard at High Tide Resort Access

GRP OC-24 Wreck Creek

Date Visited: 10 November 2005

Tidal Stage: Visited on a tide falling from 7.3 to 3.1

Observations: Creek easily accessible from Highway-109 but unmarked. The creek is shallow and surrounded by beach on the ocean side of highway but forms a pool on the inland side.

Wreck Creek Aerial

Wreck Creek on 10 November 2005

GRP OC-23 Point Grenville

Date Visited: 10 November 2005

Tidal Stage: N/A

Observations: Unable to locate the Point Grenville access road from Highway 109. Approximate location is across the road from the Quinault Indian Nation's forestry compound. It is important to first contact the Quinault Nation at 360-276-4422 for local support before attempting to execute any GRPs from their land.

Point Grenville Aerial

GRP OC-22 Quinault River

Date Visited: 10 November 2005

Tidal Stage: Visited on a tide falling from 7.3 to 3.1

Observations: Note that a typographical error exists in the GRP manual such that waves do run up the river to the Highway 109 Bridge but do not travel as far as the Highway 101 Bridge. It is important to first contact the Quinault Nation at 360-276-4422 for local support before attempting to execute any GRPs from their land.

Quinault River Aerial

Quinault River on 10 November 2005

GRP OC-21 Duck Creek

Date Visited: 10 November 2005

Tidal Stage: N/A

Observations: GRP not visited. Quinault Indian Nation reported that this site is no longer accessible by back country roads.

Duck Creek Aerial

GRP OC-20 Camp Creek

Date Visited: 10 November 2005

Tidal Stage: N/A

Observations: GRP not visited. Quinault Indian Nation reported that this site is no longer accessible by backcountry roads.

Camp Creek Aerial

GRP OC-19 Raft River

Date Visited: 10 November 2005

Tidal Stage: N/A

Observations: GRP not visited. Both the Quinault Indian Nation and a local sport fisherman reported that this site is no longer accessible by backcountry roads.

Raft River Aerial

GRP OC-17 Queets River

Date Visited: 10 November 2005

Tidal Stage: Visited site close to maximum low on a tide falling from 7.3 to 3.1

Observations: Gravel boat ramp located 0.3 mile from the end of the paved road downstream from the Highway 101 Bridge. Using the car speedometer and floating debris, the river current was approximated at ± 5 knots at not a particularly full stage of river flow. Both investigators felt that this GRP was potentially dangerous to execute with a boat towing boom, but might be a candidate to execute with a boom vane. It is important to first contact the Quinault Nation at 360-276-4422 for local support before attempting to execute any GRPs from their land.

Queets River Aerial

Queets River on 10 November 2005

GRP OC-16 Kalaloch Creek

Date Visited: 10 November 2005

Tidal Stage: Visited near 3.1 low water

Observations: Accurate information published in GRP. No supplemental comments on this strategy.

Kalaloch Creek Aerial

Kalaloch Creek on 10 November 2005

GRP OC-15 Cedar Creek at Ruby Beach

Date Visited: 10 November 2005

Tidal Stage: Visited near 3.1 low water

Observations: At near slack water, the creek current was estimated at ± 3 knots. Due to terrain and distance from the staging area, boom would be best delivered creekside by a helicopter.

Cedar Creek at Ruby Beach Aerial

Cedar Creek at Ruby Beach on 10 November 2005

GRP OC-14 Hoh River

Date Visited: 10 November 2005

Tidal Stage: Visited on a tide rising from 3.1 to 6.9

Observations: Oil City lies on the north side of the river, while Hoh Village lies on the south side of the river. Access roads to each site are clearly marked, but the roads are separated from each other by approximately 6-miles along Highway 101. There is good access to the river at the end of the Hoh Village Road. The Oil City road was temporarily closed 9.5 miles from Highway 101, where at that point, the river is characterized by a series of small delta islands. The river appeared fast but quite open at the termination of the Hoh Village Road.

Hoh River Aerial

Hoh River on 10 November 2005

Oil City Vicinity on 10 November 2005

GRP OC-9b Quillayute River

Date Visited: 11 November 2005

Tidal Stage: Visited near a 7.9 high tide

Observations: Identified clearly marked boat ramp at the Dickey River and confluence of the Quillayute and Dickey Rivers. On the day of this inspection a 1' sea was running up the Quillayute River as far as the Dickey River inlet.

Quillayute River Aerial

Dickey River

Quillayute & Dickey Confluence

GRP OC-8 Ellen Creek

Date Visited: 11 November 2005

Tidal Stage: Visited at a 7.9 slack high tide

Observations: Unable to access Ellen Creek from the beach due to high surf and hazardous beach log conditions. If not using a helicopter to implement GRP, this strategy can only be done on the low tides.

Ellen Creek Aerial

Attempted Route to Ellen Creek on 11 November 2005

GRP OC-5a, 5b and 5c Sooes River

Date Visited: 11 November 2005

Tidal Stage: Visited on a tide falling from 7.9 to 2.0

Observations: Strong rips at mouth of the river on an outgoing tide. River current has the ability to overcome surf. It is important to first contact the Makah Tribe at for local support before attempting to execute any GRPs from their land.

Sooes River Aerial

Sooes River on 11 November 2005

GRP OC-4a and 4b Waatch River

Date Visited: 11 November 2005

Tidal Stage: Visited on a tide falling from 7.9 to 2.0

Observations: Strong current in river on an outgoing tide. It is important to first contact the Makah Tribe at for local support before attempting to execute any GRPs from their land.

Waatch River Aerials

Waatch River on 11 November 2005

4.3.1 Review of Geographic Response Plan Defensive Strategies for Offshore Spills Affecting Smaller Tributaries

Outer Coast GRP strategies were based on an earlier collaborative effort, led by the State, to identify sensitive areas needing protection during a marine oil spill. Very few Outer Coast GRPs were ever validated beyond overflights and discussions with local residents. Individual GRP locations are subject to broad variations in accessibility and in-stream flows, both on an annual and on a monthly basis. Consequently, during some months, stream flows may be so reduced as to make travel in a skiff impossible. In another season, increased water depth may result in stream flows so fast as to make skiff usage hazardous.

Implementation of the priority booming strategies by spill source requires a relatively small amount of containment boom. However, time and logistical constraints to support such an effort should not be minimized. Locating and accessing each GRP site is challenging. Maintaining deployed GRPs over time will likely require local support.

Throughout this exercise, the authors employed their best professional judgment in proposing the resources assumed necessary to safely implement each GRP addressed. Though not specifically addressed, some locations might benefit from the use of alternate technologies such as vanes to place boom instead of using traditional skiff placement. The authors acknowledge that during an actual response, those assigned to execute specific GRPs could encounter differing conditions, safety parameters and resource requirements compared with those proposed in this document.

4.3.1.1 A Spill Originating in the South/Central Coast Region

Strategies found to rely heavily on helicopter support

Were a spill to originate at sea in the vicinity of Grays Harbor or the south/central Washington Coast, the GRP identifies several defensive strategies to be taken. These strategies and the assets needed to carry them out are discussed in detail in Appendix A. The marine assets and strategies are summarized below. Note that all of the defensive strategies require skiffs and/or helicopters.

Table 4-3: Strategy and Resource Summary – South

Priority	Strategy	Location	Boom Req'd	Access	Marine Assets Deployed
1	OC-22	Quinault River	1,500'	No safe access from sea. Road access possible.	2 – 55HP skiffs
2	OC-17	Queets River	1,000'	No safe access from sea. Road access possible.	2 – 55HP skiffs
3	OC-19	Raft River	3,000'	No safe access from sea. Remote.	Helo and 2 – 55HP skiffs
4	OC-25a	Moclips River	600'	No safe access from sea. Remote.	Helo and 2 – 55HP skiffs
4	OC-25b	Moclips River	200'	No safe access from sea. Remote.	Helo and 1 – 25HP skiff
5	OC-28	Copalis River	400'	No safe access from sea. Road access possible.	2 – 25HP skiffs
6	OC-26a	Joe Creek	1,000'	No safe access from sea. Remote.	Helo and 2 – 55HP skiffs
6	OC-26a	Joe Creek	600'	No safe access from sea. Remote.	Helo and 2 – 55HP skiffs
Total			**8,300'**		

The total number of skiffs required for GRP execution is 15. In addition to GRP execution, the vessel demand estimates prepared in the June 2005 report considered additional duties associated with shoreline cleanup assessment teams (SCATs), wildlife recovery assistance and beach precleaning. The

study team believes that, because of surf conditions, beach precleaning would be best served from the land side. As with the June study, the team believes that at least two SCAT and two wildlife recovery teams would be needed, and could benefit from having two motherships, two FRVs and two skiffs assigned to them.

Table 4-4 below summarizes the total expected demand for vessels of opportunity in the early stages of a spill response – before cascading resources begin to arrive.

Table 4-4: Summary of Potential Vessel-of-Opportunity Demand

Dream Team **Summary of the Number of Vessels of Opportunity that could be Utilized in a Large Spill in the South/Central Coast Region** **(excluding Inland GRPs at major inlets)**			
Type	**Number desired**	**Dedicated Number Available**	**Potential Vessel of Opportunity Demand**
Mothership	6	0*	**6**
FRV	17	7	**10**
Skiff	17	68[2]	**-**

* Number does not include contracted tugs or other pre-identified vessels that may be available and suitable for use as VOSS platforms

The utility of any of the vessels of opportunity listed above in effecting GRPs or assisting with other duties are predicated on river flows being such that their missions can be accomplished safely. An assessment of the available helicopter resources (representing an alternative means of transportation on the Outer Coast) is outside the scope of this study.

4.3.1.2 A Spill Originating in the North/Central Coast Region

Were a spill to originate at sea in the vicinity of the Straits of Juan de Fuca or the north/central Washington Coast, the GRP identifies several defensive strategies to be taken. These strategies and the assets needed to carry them out are discussed in detail in Appendix A and are summarized below. Again,

[2] There are 68 skiffs reported in the Northwest Area List. It is presumed that all of them can be delivered overland to the spill site within the first 12 hours.

note that most of the defensive strategies require skiffs and/or helicopters. The requirements for skiffs can be met from dedicated resources. An assessment of the available helicopter resources is outside the scope of this study.

Table 4-5: Strategy and Resource Summary – North

Priority	Strategy	Location	Boom Req'd	Access	Marine Assets Deployed
1	OC-4a	Waatch River	400'	No safe access from sea. Road access possible	2 - 55HP skiffs
1	OC-4b	Waatch River	300'	No safe access from sea. Road access possible	2 - 55HP skiffs
1	OC-5a	Sooes River	500'	No safe access from sea. Road access possible	2 - 55HP skiffs
1	OC-5b	Sooes River	1,400'	No safe access from sea. Road access possible	2 - 55HP skiffs
1	OC-5c	Sooes River	600'	No safe access from sea. Road access possible	2 - 55HP skiffs
1	OC-8	Ellen Creek	200'	No safe access from sea. Remote.	ATV or Helo
1	OC-9a	Quillayute River	1,400'	Marine side, weather permitting	1- FRV (weather permitting) or 2 - 55HP skiffs
1	OC-9b	Quillayute River	1,000'	Marine side, weather permitting	2 - 55HP skiffs
1	OC-17	Queets River	1,000'	No safe access from sea. Road access possible	2 - 55HP skiffs
2	OC-14	Hoh River	700'	No safe access from sea. Road access possible	2 - 55HP skiffs
3	OC-6	Ozette River	400'	No safe access from sea. Remote.	Helo and 1 - 25HP skiff
4	OC-16	Kalaloch Creek	400'	No safe access from sea. Remote.	ATV or Helo
4	OC-15	Cedar Creek at Ruby Beach	300'	No safe access from sea. Remote.	Helo
5	OC-12	Goodman Creek	200'	No safe access from sea. Remote.	Helo
5	OC-13	Mosquito Creek	200'	No safe access from sea. Remote.	Helo
6	OC-7	Cedar Creek at Ozette	100'	No safe access from sea. Remote.	Helo
Total			**9,100'**		

Summarizing Table 4-5 above, GRPs could consume 17 skiffs and an FRV. Applying the same vessel demand from wildlife recovery and SCAT team transportation from the South/Central Coast analysis yields the summary demand shown in

Table 4-6 below.

Table 4-6: Summary of Potential Vessel-of-Opportunity Demand

Dream Team Summary of the Number of Vessels of Opportunity that could be Utilized in a Large Spill in the North/Central Coast Region (excluding Inland GRPs at major inlets)			
Type	**Number desired**	**Dedicated Number Available**	**Potential Vessel of Opportunity Demand**
Mothership	6	0*	**6**
FRV	18	7	**11**
Skiff	19	60	**-**

* Number does not include contracted tugs or other pre-identified vessels that may be available and suitable for use as VOSS platforms

4.3.2 Review of Geographic Response Plan Defensive Strategies for Offshore Spills Affecting Major Tributaries

Spills that occur close enough to the entrance to the major bays at Grays Harbor and Willapa Bay to trigger inland defensive strategies can benefit from the existence of the vessel-of-opportunity fleet.

4.3.2.1 Grays Harbor

Grays Harbor fleet sufficiently large to support defensive strategies

In the event of an offshore spill on a flood tide in the vicinity of Grays Harbor, many inland defensive strategies would be triggered. These are discussed in detail in Appendix A and are summarized below. Grays Harbor defensive strategies could consume as many as 4 motherships, 3 FRVs and many skiffs. Without mobilizing dedicated resources other than containment boom from outside the port, this demand can be supported by the local population of motherships and FRVs, each numbering in the 80s.

May be a better alternative than relying on assets from outside

Keep in mind the potential difficulty of mobilizing resources from outside of Grays Harbor. Weather can prevent vessels from steaming to and entering Grays Harbor over the bar. The local fleet, supplemented by spill responders, small boats and equipment mobilized overland, provides an attractive alternative to dedicated resources from outside, *provided that* the fleet is properly organized, trained and vetted.

Table 4-7: Vessel Resource Analysis – Grays Harbor

Dream Team Additional Vessel Demand for Executing Inland GRPs at Grays Harbor			
Vessel Type	**Number desired**	**Number Available Locally or Overland***	**Shortfall**
Mothership	4	14[3]	-
FRV	3	1 dedicated + 14[4]	-
Skiff	26	68[5]	-

[3] Applying the 17% turnout ratio to the census of 83 vessels produces an expected count of 14 available motherships.

[4] In addition to the NRC vessel stationed at Westport, applying the 17% turnout ratio to the census of 85 vessels produces an expected count of 14 additional FRVs.

[5] There are 68 skiffs reported in the Northwest Area List. It is presumed that all of them can be delivered overland to the spill site within the first 12 hours.

Table 4-8: Detailed List of Resources for Inland Defensive Strategies at Grays Harbor

Priority	Strategy	Location	Boom	20' Stakebed	1-Ton Stakebed	Pick-up	14' Skiff	18' Skiff	FRV	Mothership	Personnel	Helicopter	Anchor Gear	Recovery Assets
1	GH-12	Bowerman Basin	4,000'	1				3			10		Yes	
2	GH-1	Oyhut Sink	3,000'					1	1	1	8		Yes	
3	GH-31	Tide Gate at Westport	100'			1	1				2		Yes	
4	GH-29	Elk River	600'					2		1	8		Yes	
5	GH-30	Elk River	1,500'					2		1	8		Yes	Yes
6	GH-27	Johns River	600'		1			2			7		Yes	
7	GH-28	Johns River	1,000'		1			2			7		Yes	Yes
8	GH-9	Grass Creek	200'		1		1				3		Yes	
9	GH-10	Point New	300'		1			1			4		Yes	
10	GH-11	Point New	1,000'		1			2			8		Yes	
11	GH-7	Gillis Slough	500'		1			1			4		Yes	
12	GH-6	Humptulips River and Jessie Slough	1,000'		1			2			8		Yes	
13	GH-5	Campbell Slough	300'		1		1				3		Yes	
14	GH-3	Humptulips River (Jessie Slough)	200'		1		1				3		Yes	
15	GH-4	Humptulips River	200'		1		1				3		Yes	
16	GH-8	Chenois Creek	300'		1		1				3		Yes	
17	GH-14	Chehalis River	2,000'					1	1	1	10		Yes	Yes
18	GH-13	Hoquiam River	800'					1	1		7		Yes	Yes
Total			**17,600'**	**1**	**11**	**1**	**6**	**20**	**3**	**4**	**106**			

4.3.2.2 Willapa Bay

Willapa Bay could improve its defensive posture by organizing local assets

In the event of an offshore spill on a flood tide in the vicinity of Willapa Bay, many inland defensive strategies would be triggered. These are discussed in detail in Appendix A and are summarized below. The demand for five FRVs in Willapa Bay could be met by the local population of FRVs (46). The demand for motherships could be partially met by the local fleet (numbering around 12). This local fleet could be augmented by additional resources from the lower Columbia River and Grays Harbor, as long as weather permits transit and the dredged channels within Willapa Bay remain navigable.

Table 4-9: Vessel Resource Analysis

Dream Team Additional Vessel Demand for Executing Inland GRPs at Willapa Bay			
Vessel Type	**Number desired**	**Number Available Locally or Overland***	**Shortfall**
Mothership	5	2[6]	**3**
FRV	5	8[7]	**-**
Skiff	11	68	**-**

As with Grays Harbor, a properly trained, vetted and organized local fleet in Willapa Bay represents an attractive alternative to mobilization of dedicated resources from outside of the Bay. It is believed that the shortfall in motherships can be overcome with alternative installation methods or establishment of local priorities for protection.

[6] Applying the 17% turnout ratio to the census of 12 vessels produces an expected count of 2 available Motherships.

[7] Applying the 17% turnout ratio to the census of 46 vessels produces an expected count of 8 available FRVs.

Table 4-10: Detailed List of Resources for Inland Defensive Strategies at Willapa Bay

Priority	Strategy	Location	Boom	20' Stakebed	1-Ton Stakebed	Pick-up	14' Skiff	18' Skiff	FRV	Mothership	Personnel	Helicopter	Anchor Gear
1	WB-1	North Cove	900'					1	1	1	7		Yes
2	WB-2	North Cove	1,500'					1	1	1	7		Yes
3	WB-47	Grassy Island (south)	1,700'					2	1	1	10		Yes
4	WB-48	Grassy Island (north)	1,000'					2	1	1	10		Yes
5	WB-3	Kindred Slough	2,400'					2	1	1	9		Yes
6	WB-4	Kindred Slough (tide gate)	100'			1					2		Yes
7	WB-5	Teal Duck Slough (tide gate)	100'			1					2		Yes
8	WB-6	Cedar River	300'		1			1			3		Yes
9	WB-7	North River	600'					1			5		Yes
10	WB-8	Smith Creek	400'		1			1			5		Yes
11	WB-18	Bone River	300'										
12	WB-19	Wilson Point Marsh	100'										
13	WB-20	Niawiakim River	800'										
14	WB-21	Palix River	1,200'										
15	WB-12	Mailboat Slough (middle channel)	100'										
16	WB-15	Willapa River	1,000'										
17	WB-9	Fleiss Creek	200'										
18	WB-10	Johnson Slough Tide Gate	100'										
19	WB-16	Potter Slough (south entrance)	250'										
20	WB-17	Potter Slough (north entrance)	250'										
Total			**13,300'**					**11**	**5**	**5**			

4.4 A Summary of Potential Demand for Vessels of Opportunity in the Event of a Major Spill Affecting the Outer Coast Region

It is useful to summarize the potential total demand for vessels of opportunity on the Outer Coast. Strictly from a standpoint of potential vessel demand in support of operations, the Southern Spill scenario represents the worst case. It would not only trigger an offshore recovery effort be mounted, but also coastal and inshore defensive strategies as well. With the expectation that oil could reach both Grays Harbor and Willapa Bay, the potential demand for vessels would be cumulative and is summarized in Table 4-11 below. One can conclude that the fleet population as it existed in the fourth quarter of 2005 is sufficiently large to support the demand for vessels of opportunity.

Table 4-11: Summary Table of Vessel Demand for a Major Outer Coast Event

Dream Team **Summary of the Number of Vessels of Opportunity that could be Utilized in a Large Spill in the South/Central Coast Region** **Including Inland GRPs at Grays Harbor and Willapa Bay**				
Type	**Number desired**	**Dedicated Number Available**	**Potential Vessel of Opportunity Demand**	**Aggregate Vessel of Opportunity Supply**
Mothership	15	0*	**15**	31[8]
FRV	25	7	**18**	33[9]
Skiff	54	68	**-**	

One can conclude from this that sufficient numbers of potentially attractive vessels are available to maximize the utility of the existing spill response fleet in Washington state *if properly organized*. It must be noted that this report does not attempt to assess the adequacy of the existing spill response fleet.

[8] Applying the 17% turnout ratio to a total Outer Coast census of 185 potential motherships produces an expected count of 31 vessels.

[9] Applying the 17% turnout ratio to a total Outer Coast census of 195 potential FRVs produces an expected count of 33 vessels.

In a large spill, additional resources would likely be brought in (cascaded) from other regions. One can conclude that a large supply of excess resources appear to be available to accommodate that additional demand as well, *if properly organized*.

It must be noted, though, that weather, seas and geography severely constrain the utility of the entire fleet in accomplishing both offensive and defensive strategies.

SECTION 5

Additional Requirements to Meet a Coastal Response

The focus of this study was to determine whether the Outer Coast fishing fleet could provide sufficient numbers of vessels of opportunity to maximize response effectiveness. The study concludes that the Outer Coast fishing fleet is a well distributed and highly valuable resource. There are strong indications, however, that fishing vessel numbers are not the limiting factor in Outer Coast response. With ocean conditions, geographical obstacles and weather constraints potentially limiting the efficacy of open water and nearshore mechanical response efforts, planners should investigate additional technologies in mounting a cleanup campaign on the Outer Coast.

5.1 Beach Cleanup

A historical analysis of the past two Outer Coast spills (*Nestucca* in 1985 and *Tenyo Maru* in 1990) shows that a significant amount of the spilled oil eventually made landfall on the beach. Though not technology intensive, beach cleanup requires large amounts of labor, materials (PPE, sorbents, hand tools, etc.) and logistical support. Beach cleanup operations are likely to be disruptive from a land use perspective, and difficult to execute along rocky and cobble strewn shorelines.

Beyond solving those obvious quantitative matériel problems, the qualitative issue of experienced field supervision of unskilled labor looms large. Labor productivity declines rapidly when the span of control exceeds one supervisor per ten workers. Safety issues associated with helicopter and overland transportation and the placement of workers in a remote and harsh environment exceed the training offered in traditional HAZWOPER classes.

Industry contractors have mutual aid agreements to cascade workers from other regions into the Northwest. Local Indian tribes offer additional resources for labor and support services, especially when response demands do not conflict with their traditional enterprises. Finally, the Washington Department of Natural Resources maintains seasonal fire fighting crews and has established permanent support bases that could also serve as resources for beach cleanup activities. While these are excellent potential resources, beach cleanup operations remain the least efficient and possibly least desirable response option.

5.2 Logistics

Oil spill response on the Outer Coast is arguably a greater exercise in logistics management than in cleanup strategy. Long distances between population centers and lack of services within them stretch response managers' ability to support their operations. Logistical challenges can be identified according to the basic categories of:

- Transportation
- Food and Lodging
- Waste Disposal

Predictably in large spills, transportation issues will be most acute in the availability of helicopters to support beach cleanup efforts. Few helicopter operators are based along the coast, and those located there are likely to be engaged in timber harvesting. It is therefore incumbent on an adequately air-supported response to cascade in helicopters from elsewhere. Additionally, fire season commitments could potentially reduce the number of helicopters available for dispatch, further lengthening the supply chain out-of-region.

Coastal food and lodging resources reach capacity during the months of June through August, the height of the tourist season. Base camp contractors, those that specialize in providing remote field operations with food and lodging, offer some potential relief, but, like helicopters, can become overcommitted during fire season.

Lastly, whether officially declared or not, waste disposal begins on response-day-one. Planners should anticipate the immediate management of waste streams of contaminated beach soils, spent sorbents and oiled wildlife carcasses. With waste volumes likely to exceed the capacity of local disposal facilities, interim storage and subsequent bulk transportation off-site will become a sub-project within the response.

5.3 Use of Alternative Technologies: Dispersants and In-Situ Burning

The potential use of alternative technologies is often aired in oil spill response drills where the difficulty of execution can be glossed over with optimism. Under ocean conditions, the successful execution of both burning and dispersants will be a challenge that forces responders across the threshold of academic knowledge and into practical application.

With the operating limitations established in this report as a factual background, the authors view alternative technologies as increasingly important tools in coastal spill response. This is particularly true for dispersants, which may offer a significantly more effective alternative to mechanical containment, recovery and beach cleanup in the region.

A P P E N D I X A

Detailed Discussion of Defensive Strategies for Offshore Spills Affecting Major Inlets on the Outer Coast

Geographic Response Plan Strategies for Nearshore Spills Affecting Grays Harbor

I. SPILL SOURCE: Oil Entering Grays Harbor on a Flood Tide from Source Outside the Bay

Priority 1 GRP GH-12 Bowerman Basin Boom Length: 4,000'

Strategy: Install boom across basin on west side of piles. Booms must be installed at half tide (either flood or ebb). Piles are not exposed at high tide, and basin goes dry at low tide.

PROPOSED IMPLEMENTATION: Access by land to avoid running aground unless locally knowledgeable boat operators can assure deployment from a mothership by water. Deploy boom from truck and set with skiffs.

- 20' stakebed truck or equivalent
- 4,000' boom with a minimum of four anchor sets
- 3 - 18' skiffs each with 55-HP outboard motor
- 10 - personnel

Priority 2 GRP GH-1 Oyhut Sink Boom Length: 2,000'

Site of Staging Area

Oyhut Sink

Strategy: Install boom across entrance to marsh. Sand spits at entrance are dynamic, and the position of the entrance is likely to change, which may require more boom than what is listed here. Winter storms will impact the site.

PROPOSED IMPLEMENTATION: Add 1,000' more boom than listed. Transport boom via mothership from marina staging area as close to site as water depth will allow. Implement with a combination of FRVs and skiffs.

- 3,000' boom with a minimum of three anchor sets
- 1 - mothership
- 1 - FRV
- 1 - 18' skiff with 55-HP outboard motor
- 8 - personnel

Priority 3 GRP GH-31 Tide Gate at Westport Boom Length: 100'

Strategy: Close tide gate, or install boom across drainage

PROPOSED IMPLEMENTATION: Access by land.

- Pick-up truck
- 100' boom
- Screw anchors / ground tackle
- 1 - 14' skiff with 25-HP outboard motor
- 2 - personnel

Priority 4 GRP GH-29 Elk River Boom Length: 600'

Strategy: Divert oil from shoreline to GH-30 for collection. Install boom using a small boat. Strong currents may make installation difficult.

PROPOSED IMPLEMENTATION: Use local oyster barge as a mothership to transport boom from staging. Deploy boom from mothership using skiffs to simultaneously implement both GH-29 and GH-30.

- 1 - oyster barge mothership
- 600' boom
- Screw anchors / ground tackle
- 2 - 18' skiffs each with 55-HP outboard motors
- 8 - personnel

Priority 5 GRP GH-30 Elk River Boom Length: 1,500'

Strategy: Install boom at angle using small boat to collect oil at east side of bridge. Strong currents may make installation difficult.

PROPOSED IMPLEMENTATION: Use local oyster barge as a mothership to transport boom from staging. Deploy boom from mothership using skiffs to simultaneously implement both GH-29 and GH-30.

- 1 - oyster barge mothership
- 1,500' boom
- Screw anchors / ground tackle
- 2 - 18' skiffs each with 55-HP outboard motors
- Recovery assets and tankage
- 8 - personnel

Priority 6 GRP GH-27 Johns River Boom Length: 600'

Strategy: Install boom across river.

PROPOSED IMPLEMENTATION: Access by land. Deploy boom from trucks to simultaneously implement both GH-27 and GH-28. Deploy boom from truck and set with skiffs.

- 1-ton stakebed truck
- 600' boom
- Screw anchors / ground tackle
- 2 - 18' skiffs each with 55-HP outboard motor
- 7 - personnel

Priority 7 GRP GH-28 Johns River Boom Length: 1,000'

Strategy: Install boom at angle from boat launch site on south shore to north end of bridge; collect oil at boat launch.

PROPOSED IMPLEMENTATION: Access by land. Deploy boom from trucks to simultaneously implement both GH-27 and GH-28. Deploy boom from truck and set with skiffs.

- 1-ton stakebed truck
- 1,000' boom
- Screw anchors / ground tackle
- 2 - 18' skiffs each with 55-HP outboard motors
- Recovery assets and tankage
- 7 - personnel

Priority 8 GRP GH-9 Grass Creek Boom Length: 200'

Strategy: Install boom across mouth of creek just west of railroad bridge.

PROPOSED IMPLEMENTATION: Access by land. Deploy boom from truck and set with skiffs.

- 1-ton stakebed truck
- 200' boom
- Screw anchors / ground tackle
- 1 - 14' skiff with 25-HP outboard motor
- 3 - personnel

Priority 9 GRP GH-10 Point New Boom Length: 300'

Strategy: Install boom across entrance to salt marshes. Helicopter deployment is required at low water.

PROPOSED IMPLEMENTATION: Potential to simultaneously implement both GH-10 and GH-11. Probable deployment by water at high tide from staging site at Grass Creek. Alternate water deployment from a different staging area may be possible with locally knowledgeable boat operators who can assure deployment from a mothership without running aground. Because of boom and anchor weight, this is approaching the limits of a helicopter deployment with the locally available Bell-206 or MD-500 helicopters.

- 1-ton stakebed truck
- 300' boom
- Screw anchors / ground tackle
- 1 - 18' skiff with 55-HP outboard motor
- 4 - personnel

Priority 10 GRP GH-11 Point New Boom Length: 1,000'

Strategy: Install boom across entrance to salt marshes. Helicopter deployment is required at low water.

PROPOSED IMPLEMENTATION: Potential to simultaneously implement both GH-10 and GH-11. Probable deployment by water at high tide from staging site at Grass Creek. Alternate water deployment from a different staging area may be possible with locally knowledgeable boat operators who can assure deployment from a mothership without running aground. Because of boom and anchor weight, this exceeds the capability of a helicopter deployment with the locally available Bell-206 or MD-500 helicopters. A helicopter with the lifting capacity of a Bell-210 would be required to manage the recommended boom, but deploying a 1,000' continuous boom would be a challenging. Deploying smaller sections would require personnel on the mudflats. Consequently, successful deployment of this GRP by helicopter seems improbable.

- 1-ton stakebed truck
- 1,000' boom
- Screw anchors / ground tackle
- 2 - 18' skiff with 55-HP outboard motor
- 8 - personnel

Priority 11 GRP GH-7 Gillis Slough Boom Length: 500'

Gillis Slough

Strategy: Install boom across mouth of slough, south of Hwy 109. Use small work boat.

PROPOSED IMPLEMENTATION: Access by land. Deployment may be most efficient at high tide.

- 1-ton stakebed truck
- 500' boom
- Screw anchors / ground tackle
- 1 - 18' skiff with 55-HP outboard motor
- 4 - personnel

Priority 12 GRP GH-6 Humptulips River & Jessie Slough Boom Length: 1,000'

Humptulips River & Jessie Slough

Strategy: Install boom across mouth of river, south of Hwy 109. Use small work boat.

PROPOSED IMPLEMENTATION: Access by land.

- 1-ton stakebed truck
- 1,000' boom
- Screw anchors / ground tackle
- 2 - 18' skiff with 55-HP outboard motor
- 8 - personnel

Priority 13 GRP GH-5 Campbell Slough Boom Length: 300'

Campbell Slough

Strategy: Install boom across mouth of slough, south of Hwy 109. Use small work boat. Consider effects of high & low tide during deployment.

PROPOSED IMPLEMENTATION: Access by land. Preference to deploy at high tide to avoid restrictions imposed by mudflats.

- 1-ton stakebed truck
- 300' boom
- Screw anchors / ground tackle
- 1 - 14' skiff with 25-HP outboard motor
- 3 - personnel

Priority 14 GRP GH-3 Humptulips River (Jessie Slough) Boom Length: 200'

Humptulips River (Jessie Slough)

Strategy: Install boom across slough at Burrows Road crossing.

PROPOSED IMPLEMENTATION: Access by land.

- 1-ton stakebed truck
- 200' boom
- Screw anchors / ground tackle
- 1 - 14' skiff with 25-HP outboard motor
- 3 - personnel

Priority 15 GRP GH-4 Humptulips River Boom Length: 200'

Humptulips River

Strategy: Install boom across river at Hwy 109 crossing.

PROPOSED IMPLEMENTATION: Access by land. Execute at high tide only.

- 1-ton stakebed truck
- 200' boom
- Screw anchors / ground tackle
- 1 - 14' skiff with 25-HP outboard motor
- 3 - personnel

Priority 16 GRP GH-8 Chenois Creek Boom Length: 300'

Chenois Creek

Strategy: Install boom across creek west of Hwy 109 bridge. Deploy from bank.

PROPOSED IMPLEMENTATION: Access by land. Preference to deploy at high tide to avoid restrictions imposed by shallow water.

- 1-ton stakebed truck
- 300' boom
- Screw anchors / ground tackle
- 1 - 14' skiff with 25-HP outboard motor
- 3 - personnel

Priority 17 GRP GH-14 Chehalis River Boom Length: 2,000'

Chehalis River

Strategy: Install boom at 45-60 degree angle across river for collection on the south shore.

PROPOSED IMPLEMENTATION: Transport boom via mothership from marina staging area to site. Implement with a combination of FRVs and skiffs. Temporary storage will be required to support collection efforts.

- 2,000' boom with a minimum of four anchor sets
- 1 - mothership
- 1 - FRV
- 1 - 18' skiff with 55-HP outboard motor
- Recovery assets and tankage
- 10 - personnel

Priority 18 GRP GH-13 Hoquiam River Boom Length: 800'

Hoquiam River

Strategy: Install boom at angle across river just above mouth for collection on east shore.

PROPOSED IMPLEMENTATION: Transport boom via mothership from paper mill staging area to site. Implement with FRV and skiff. Temporary storage will be required to support collection efforts.

- 800' boom with a minimum of two anchor sets
- 1 - FRV
- 1 - 18' skiff with 55-HP outboard motor
- Recovery assets and tankage
- 7 - personnel

II. BOOM REQUIREMENTS - SUMMARY BY SPILL SOURCE

Table A-1: Oil Entering Grays Harbor on a Flood Tide from Source Outside of Bay

Priority	Strategy	Location	Boom	20' Stakebed	1-Ton Stakebed	Pick-up	14' Skiff	18' Skiff	FRV	Mothership	Personnel	Helicopter	Anchor Gear	Recovery Assets
1	GH-12	Bowerman Basin	4,000'	1				3			10		Yes	
2	GH-1	Oyhut Sink	3,000'					1	1	1	8		Yes	
3	GH-31	Tide Gate at Westport	100'			1	1				2		Yes	
4	GH-29	Elk River	600'					2		1	8		Yes	
5	GH-30	Elk River	1,500'					2		1	8		Yes	Yes
6	GH-27	Johns River	600'		1			2			7		Yes	
7	GH-28	Johns River	1,000'		1			2			7		Yes	Yes
8	GH-9	Grass Creek	200'		1		1				3		Yes	
9	GH-10	Point New	300'		1			1			4		Yes	
10	GH-11	Point New	1,000		1			2			8		Yes	
11	GH-7	Gillis Slough	500'		1			1			4		Yes	
12	GH-6	Humptulips River and Jessie Slough	1,000'		1			2			8		Yes	
13	GH-5	Campbell Slough	300'		1		1				3		Yes	
14	GH-3	Humptulips River (Jessie Slough)	200'		1		1				3		Yes	
15	GH-4	Humptulips River	200'		1		1				3		Yes	
16	GH-8	Chenois Creek	300'		1		1				3		Yes	
17	GH-14	Chehalis River	2,000'					1	1	1	10		Yes	Yes
18	GH-13	Hoquiam River	800'					1	1		7		Yes	Yes
Total			**17,600'**	**1**	**11**	**1**	**6**	**20**	**3**	**4**	**106**			

Geographic Response Plan Strategies for Nearshore Spills Affecting Willapa Bay (Dream Teams)

I. SPILL SOURCE: Oil Entering Willapa Bay on a Flood Tide from Source Outside of Bay

Priority 1 GRP WB-1 North Cove Boom Length: 900'

Staging Area at Tokeland Marina

North Cove Site

Strategy: Deploy boom across the west opening to marsh. Area nearly dry at low tide.

PROPOSED IMPLEMENTATION: Access by water only at high tide. Combine resources and execute consecutively with WB-2.

- 1 - mothership
- 1 - FRV
- 1 - 18' skiff with 55-HP outboard motor
- 900' boom
- 3 - anchor sets
- 7 - personnel

Priority 2 GRP WB-2 North Cove Boom Length: 1,500'

Staging Area at Tokeland Marina

North Cove Site

Strategy: Deploy boom at angle to close off east entrance to marsh. Place boom during flood tide or will need ATVs or helicopter. Area nearly dry at low tide.

PROPOSED IMPLEMENTATION: Combine resources and execute consecutively with WB-1. Preferred access by water at high tide only. Mudflats make access with ATV and crew questionable. Because of boom and anchor weight, this exceeds the capability of a helicopter deployment with the locally available Bell-206 or MD-500 helicopters. A helicopter with the lifting capacity of a Bell-210 would be required to manage the boom weight, but deploying a 1,500' continuous boom would be a challenging. Deploying smaller sections would require personnel on the mudflats. Consequently, successful deployment of this GRP by helicopter seems improbable.

- 1 - mothership
- 1 - FRV
- 1 - 18' skiff with 55-HP outboard motor
- 1,500' boom
- 3 - anchor sets
- 7 - personnel

Priority 3 GRP WB-47 Grassy Island (south) Boom Length: 1,700'

Staging Area at Nahcotta Marina

Grassy Island

Strategy: Deploy boom at south end of Grassy Island, high tide only.

PROPOSED IMPLEMENTATION: Combine resources and execute consecutively with WB-48. Access by water at high tide only. Deploy from an oyster barge mothership, or equivalent, operated by a locally knowledgeable individual.

- 1 - mothership
- 1 - FRV
- 2 - 18' skiffs each with 55-HP outboard motors
- 1,700' boom
- 5 - sets anchor gear
- 10 - personnel

Priority 4 GRP WB-48 Grassy Island (north) Boom Length: 1,000'

Staging Area at Nahcotta Marina

Grassy Island

Strategy: Deploy boom at north end of Grassy Island, high tide only. Entrance to marsh is variable and may be blocked with sand.

PROPOSED IMPLEMENTATION: Combine resources and execute consecutively with WB-47. Access by water at high tide only. Deploy from an oyster barge mothership, or equivalent, operated by a locally knowledgeable individual.

- 1 - mothership
- 1 - FRV
- 2 - 18' skiffs each with 55-HP outboard motors
- 1,000' boom
- 4 - sets anchor gear
- 10 - personnel

Priority 5 GRP WB-3 Kindred Slough Boom Length: 2,400'

Staging Area at Tokeland Marina

Kindred Slough

Strategy: Install boom at an angle across slough entrance. Site can be boomed only at high tide.

PROPOSED IMPLEMENTATION: Access by water at high tide only. Deploy from an oyster barge mothership, or equivalent, operated by a locally knowledgeable individual.

- 1 - mothership
- 1 - FRV
- 2 - 18' skiffs each with 55-HP outboard motors
- 2,400' boom
- 6 - sets anchor gear
- 9 - personnel

Priority 6 GRP WB-4 Kindred Slough (tide gate) Boom Length: 100'

Kindred Slough (tide gate)

Strategy: Close tide gate. Deploy boom in front of tide gate if gate cannot be closed or if it leaks.

PROPOSED IMPLEMENTATION: Preferred access by land, alternate access by helicopter.

- 1 - 4WD pick-up truck
- 100' boom
- Ground tackle / screw anchors
- 2 - personnel

Priority 7 GRP WB-5 Teal Duck Slough (tide gate) Boom Length: 100'

Teal Duck Slough (tide gate)

Strategy: Close tide gate. Deploy boom in front of tide gate if gate cannot be closed or if it leaks.

PROPOSED IMPLEMENTATION: Preferred access by land, alternate access by helicopter.

- 1 - 4WD pick-up truck
- 100' boom
- Ground tackle / screw anchors
- 2 - personnel

Priority 8 GRP WB-6 Cedar River Boom Length: 300'

Cedar River

Strategy: Install boom at angle across river mouth downstream of bridge at Highway 105. River may have tide gate (need to verify).

PROPOSED IMPLEMENTATION: Access by land.

- One 1-ton stakebed truck
- 300' boom
- Ground tackle / screw anchors
- 1 - 18' skiff with 55-HP outboard motor
- 3 - personnel

Priority 9 GRP WB-7 North River Boom Length: 600'

North River and Smith Creek

Strategy: Install boom at an angle across river at bridge on Highway 105.

PROPOSED IMPLEMENTATION: Combine resources and execute consecutively with WB-8. Access by land.

- One 1-ton stakebed truck
- 600' boom
- Ground tackle / screw anchors
- 1 - 18' skiff with 55-HP outboard motor
- 5 - personnel

Priority 10 GRP WB-8 Smith Creek Boom Length: 400'

North River and Smith Creek

Strategy: Install boom across.

PROPOSED IMPLEMENTATION: Combine resources and execute consecutively with WB-7. Access by land.

- One 1-ton stakebed truck
- 400' boom
- Ground tackle / screw anchors
- 1 - 18' skiff with 55-HP outboard motor
- 5 - personnel

II. BOOM REQUIREMENTS - SUMMARY BY SPILL SOURCE

Table A-2: Oil Entering Willapa Bay on a Flood Tide from Source Outside of Bay

Priority	Strategy	Location	Boom	20' Stakebed	1-Ton Stakebed	Pick-up	14' Skiff	18' Skiff	FRV	Mothership	Personnel	Helicopter	Anchor Gear
1	WB-1	North Cove	900'					1	1	1	7		Yes
2	WB-2	North Cove	1,500'					1	1	1	7		Yes
3	WB-47	Grassy Island (south)	1,700'					2	1	1	10		Yes
4	WB-48	Grassy Island (north)	1,000'					2	1	1	10		Yes
5	WB-3	Kindred Slough	2,400'					2	1	1	9		Yes
6	WB-4	Kindred Slough (tide gate)	100'			1					2		Yes
7	WB-5	Teal Duck Slough (tide gate)	100'			1					2		Yes
8	WB-6	Cedar River	300'		1			1			3		Yes
9	WB-7	North River	600'					1			5		Yes
10	WB-8	Smith Creek	400'		1			1			5		Yes
11	WB-18	Bone River	300'										
12	WB-19	Wilson Point Marsh	100'										
13	WB-20	Niawiakim River	800'										
14	WB-21	Palix River	1,200'										
15	WB-12	Mailboat Slough (middle channel)	100'										
16	WB-15	Willapa River	1,000'										
17	WB-9	Fleiss Creek	200'										
18	WB-10	Johnson Slough Tide Gate	100'										
19	WB-16	Potter Slough (south entrance)	250'										
20	WB-17	Potter Slough (north entrance)	250'										
Total			**13,300'**										

THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community

PROJECT MEMORANDUM

Weather-Related Operational Statistics for Vessel Departures from Major Ports Along the Western Coast of Washington State

TO: Paul Smith, Ken FitzGerald
DATE: 27 October 2005
FILE No.: 05051, Phase 2
FROM: S. Anil Kumar, Ph.D., P.E.

References: 1. The Glosten Associates, "Oil Spill Response Vessel Capabilities in the State of Washington: Use of Commercial Fishing Vessels to Augment Oil Spill Response Resources," File No. 05051, June 2005.

This memorandum is part of a study on the application of a scenario-based approach to identifying vessel shortfalls in responding to an oil spill offshore the Washington coast. It presents weather-related operational statistics for vessel departures from major ports along the western coast of Washington state.

The statistics are presented for areas in the vicinity of the following major ports along the western coast of Washington state: Neah Bay, Grays Harbor, Willapa Bay, and Lower Columbia River (Ilwaco and Astoria). These are the identified potential sites from which a vessel of opportunity may respond to an oil spill near the coast.

For each of these sites, plots are developed of the probability, by month, that the significant wave height does not exceed 3 ft, 7 ft, and 10 ft over a duration of up to 48 hours. The plots thus show the probability of finding favorable weather operability windows of various durations in a given month, for a vessel of opportunity.

Grays Harbor

Wave climatology data are available from three data buoys in the vicinity of Grays Harbor:

- NDBC buoy 46043 was deployed at 46.9° N 124.2° W, just offshore Grays Harbor. It has less than one year of data, from May through November 1987.
- Scripps buoy 46211 has been deployed at 46.86° N 124.24° W, just offshore Grays Harbor. It has one year of data, from September 2004 through August 2005.
- NDBC buoy 46041 has been deployed at 47.34° N 124.75° W, 45 nautical miles northwest of Aberdeen, WA (Grays Harbor). It has about 15 years of data, between June 1987 and August 2005.

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The data from buoys 46043 and 46211 are insufficient for a meaningful statistical analysis, however buoy 46041 provides substantial data. Therefore, the data from buoy 46041 were processed and analyzed statistically. Figure 1 presents the probability that the significant wave height does not exceed 3 ft, 7 ft, and 10 ft respectively over a duration of up to 48 hours. From Figure 1, for example, the probability that the significant wave height in the vicinity of Grays Harbor does not exceed 7 ft over a 24-hour period is about 39%. In other words, there is a 39% probability of a 24-hour-long weather operability window for a boat that can operate in up to 7 ft seas.

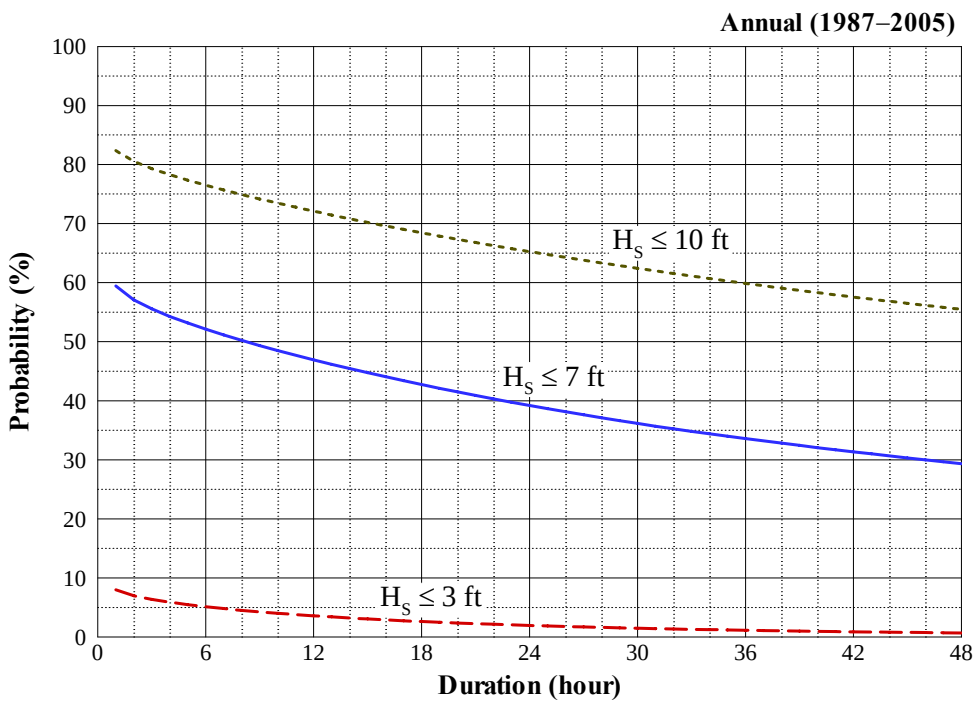

Figure 1. Annual Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

Table 1 presents the probability, by month, that there exists a 24-hour weather operability window for a fishing vessel that can operate in up to 7 ft seas in the vicinity of Grays Harbor. Detailed tables and plots of weather operability by month are presented in the Appendix A.

Table 1. 24-Hour Weather Operability for Fishing Vessels (7 ft-Seas Limit) in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

Period	Weather Operability (%)
January	13.3
February	16.6
March	20.0
April	26.4
May	50.7
June	62.7
July	80.4
August	76.7
September	50.1
October	29.1
November	10.4
December	8.8
Annual	**39.2**

Lower Columbia River

Wave climatology data are available from two data buoys in the vicinity of Ilwaco and Astoria, at the mouth of the Columbia River:

- NDBC buoy 46010 was deployed at 46.2° N, 124.2° W, just offshore the mouth of the Columbia river. It has about nine years of data between January 1979 and April 1991.

- NDBC buoy 46029 has been deployed at 46.12° N 124.51° W, offshore the mouth of the Columbia river. It has about 14 years of data between March 1984 and August 2005.

Both buoys provide a sufficiently large data set for a meaningful statistical analysis. However, buoy 46010 being closer to the mouth of the Columbia river, its data were analyzed. Figure 2 presents the probability that the significant wave height does not exceed 3 ft, 7 ft, and 10 ft respectively over a duration of up to 48 hours. From Figure 2, for example, the probability that the significant wave height in the vicinity of Ilwaco and Astoria does not exceed 7 ft over a 24-hour period is about 35%. In other words, there is a 35% probability of a 24-hour-long weather operability window for a boat that can operate in up to 7 ft seas.

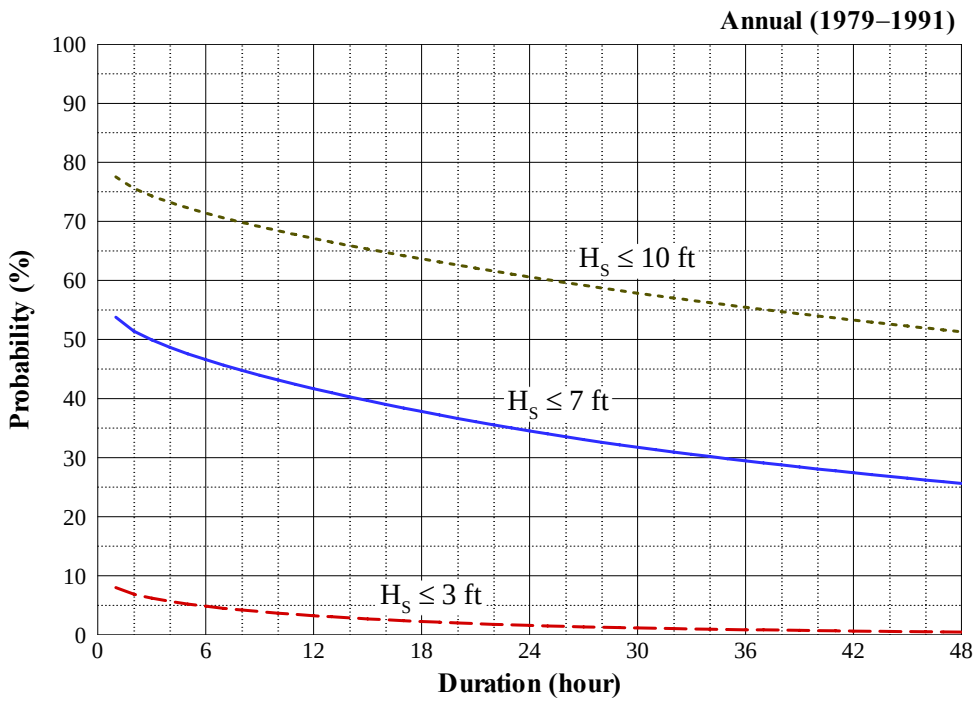

Figure 2. Annual Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

Table 2 presents the probability, by month, that there exists a 24-hour weather operability window for a fishing vessel that can operate in up to 7 ft seas in the vicinity of Ilwaco and Astoria. Detailed tables and plots of weather operability by month are presented in the Appendix B.

Table 2. 24-Hour Weather Operability for Fishing Vessels (7 ft-Seas Limit) in the Vicinity of Ilwaco and Astoria (From NDBC Buoy 46010)

Period	Weather Operability (%)
January	12.8
February	19.1
March	17.6
April	30.4
May	41.9
June	43.4
July	68.0
August	74.3
September	62.0
October	33.9
November	15.2
December	17.6
Annual	**34.5**

Neah Bay

NDBC buoy 46087 has been deployed at 48.49° N 124.73° W, near Neah Bay. It has only one year of data, from September 2004 through August 2005. The data are not sufficient for a full representation of the wave climatology, however they are still used to obtain weather operability statistics in the vicinity of Neah Bay because of the paucity of data. The statistics may have much uncertainty associated with them and, as such, are to be treated with caution.

Figure 3 presents the probability that the significant wave height does not exceed 3 ft, 7 ft, and 10 ft respectively over a duration of up to 48 hours. From Figure 3, for example, the probability that the significant wave height in the vicinity of Neah Bay does not exceed 7 ft over a 24-hour period is about 47%. In other words, there is a 47% probability of a 24-hour-long weather operability window for a boat that can operate in up to 7 ft seas.

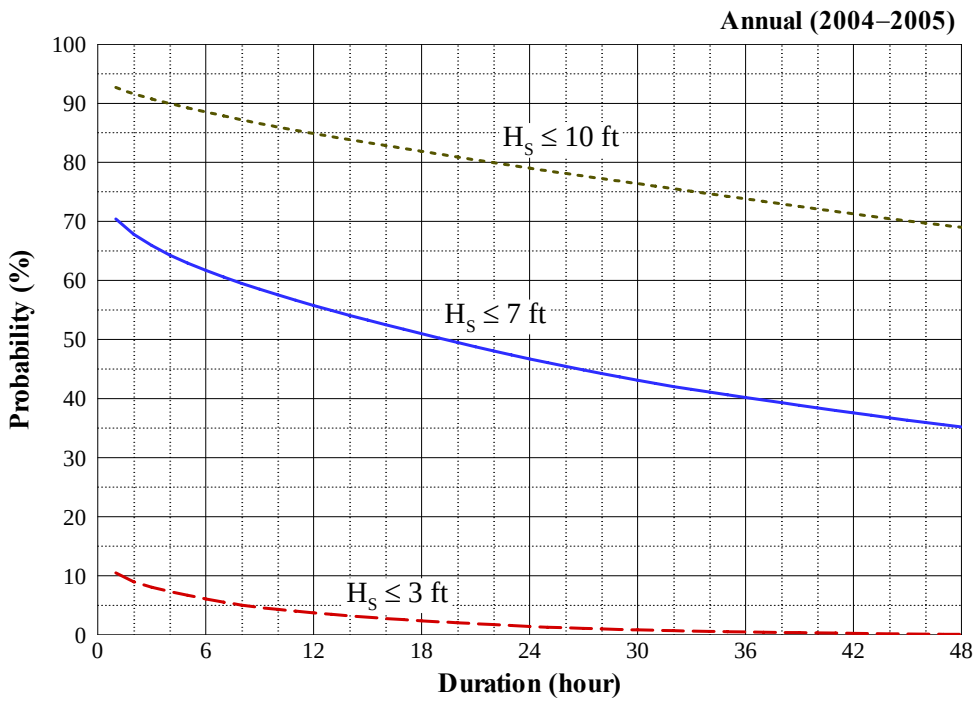

Figure 3. Annual Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

Table 3 presents the probability, by month, that there exists a 24-hour weather operability window for a fishing vessel that can operate in up to 7 ft seas in the vicinity of Neah Bay. Detailed tables and plots of weather operability by month are presented in the Appendix C.

Table 3. 24-Hour Weather Operability for Fishing Vessels (7 ft-Seas Limit) in the Vicinity of Neah Bay (From NDBC Buoy 46087)

Period	Weather Operability (%)
January	32.4
February	26.1
March	28.5
April	41.0
May	71.0
June	65.5
July	63.4
August	83.6
September	39.5
October	27.4
November	19.5
December	11.2
Annual	**46.7**

APPENDIX

Weather Operability by Month for Fishing Vessels in the Vicinity of:

A. **Grays Harbor**

B. **Ilwaco and Astoria (The Mouth of the Columbia River)**

C. **Neah Bay**

Appendix A

Weather Operability by Month for Fishing Vessels in the Vicinity of Grays Harbor

Weather operability statistics were obtained using NDBC buoy 46041. Buoy 46041 has been deployed at 47.34° N 124.75° W, 45 nautical miles northwest of Aberdeen, WA (Grays Harbor). It has about 15 years of data, between June 1987 and August 2005:

1987: 7 months (06 to 12)
1988: 12 months
1989: 9 months (03 to 05, 07 to 12)
1990: 12 months
1991: 11 months (02 to 12)
1992: 12 months
1993: 12 months
1994: 10 months (01 to 08, 11 to 12)
1995: 10 months (01 to 08, 11 to 12)
1996: 12 months
1997: 6 months (01 to 06)
1998: 6 months (06 to 11)
1999: 7 months (06 to 12)
2000: 12 months
2001: 10 months (03 to 12)
2002: 8 months (01 to 02, 07 to 12)
2003: 12 months
2004: 12 months
2005: 8 months (01 to 08)

Table A 1. Probability (%) that the Significant Wave Height, $H_S \leq 10$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	82.37	63.52	72.13	71.87	84.37	95.87	96.41	99.33	97.63	94.26	83.40	62.31	55.21
2	80.54	60.15	69.49	69.40	81.89	94.84	95.60	99.07	97.02	92.93	81.47	59.24	52.25
3	79.32	58.01	67.73	67.79	80.33	94.12	94.99	98.85	96.51	91.94	80.17	57.26	50.36
4	78.29	56.30	66.35	66.47	79.04	93.57	94.45	98.66	96.03	91.05	79.01	55.60	48.71
5	77.37	54.86	65.14	65.30	77.86	93.05	93.94	98.46	95.59	90.19	77.97	54.12	47.31
6	76.51	53.55	64.06	64.23	76.73	92.54	93.45	98.29	95.16	89.41	76.98	52.76	46.01
7	75.69	52.30	63.04	63.23	75.64	92.03	92.98	98.11	94.74	88.66	76.04	51.50	44.79
8	74.92	51.11	62.12	62.27	74.57	91.53	92.53	97.93	94.35	87.96	75.13	50.33	43.62
9	74.18	50.00	61.24	61.32	73.55	91.04	92.11	97.76	94.00	87.30	74.27	49.23	42.50
10	73.47	48.90	60.40	60.41	72.56	90.57	91.69	97.59	93.66	86.66	73.41	48.20	41.47
11	72.78	47.85	59.59	59.53	71.60	90.09	91.30	97.42	93.33	86.02	72.58	47.21	40.47
12	72.11	46.83	58.82	58.66	70.67	89.63	90.91	97.24	93.00	85.40	71.77	46.24	39.52
13	71.45	45.81	58.07	57.87	69.75	89.17	90.53	97.06	92.68	84.79	70.96	45.30	38.60
14	70.82	44.87	57.34	57.09	68.87	88.74	90.16	96.89	92.37	84.18	70.17	44.41	37.72
15	70.21	43.94	56.63	56.33	67.99	88.31	89.79	96.71	92.09	83.58	69.40	43.52	36.87
16	69.60	43.02	55.92	55.61	67.13	87.91	89.43	96.53	91.81	82.98	68.64	42.67	36.05
17	69.02	42.12	55.25	54.93	66.30	87.51	89.07	96.35	91.53	82.39	67.91	41.85	35.28
18	68.45	41.25	54.60	54.25	65.49	87.11	88.72	96.18	91.26	81.80	67.19	41.06	34.53
19	67.88	40.39	53.96	53.58	64.72	86.70	88.37	96.00	90.98	81.23	66.48	40.29	33.79
20	67.34	39.57	53.34	52.92	63.95	86.30	88.02	95.82	90.70	80.69	65.78	39.53	33.09
21	66.80	38.78	52.75	52.28	63.20	85.90	87.68	95.64	90.42	80.14	65.10	38.78	32.42
22	66.27	37.99	52.18	51.66	62.46	85.51	87.34	95.47	90.15	79.60	64.42	38.06	31.75
23	65.75	37.21	51.61	51.06	61.76	85.14	86.99	95.29	89.89	79.06	63.76	37.35	31.10
24	**65.25**	**36.47**	**51.07**	**50.46**	**61.06**	**84.78**	**86.65**	**95.11**	**89.64**	**78.53**	**63.13**	**36.65**	**30.47**
25	64.76	35.74	50.55	49.87	60.39	84.43	86.31	94.93	89.40	78.02	62.52	35.96	29.88
26	64.28	35.04	50.04	49.28	59.74	84.08	85.97	94.76	89.16	77.51	61.91	35.29	29.31
27	63.81	34.35	49.54	48.72	59.10	83.74	85.63	94.59	88.92	77.02	61.31	34.63	28.75
28	63.34	33.67	49.04	48.16	58.46	83.40	85.29	94.42	88.68	76.55	60.72	33.98	28.19
29	62.88	33.01	48.55	47.60	57.83	83.06	84.94	94.25	88.43	76.09	60.13	33.33	27.68
30	62.43	32.40	48.05	47.05	57.20	82.73	84.60	94.08	88.18	75.62	59.56	32.71	27.19
31	61.99	31.81	47.57	46.51	56.56	82.39	84.28	93.91	87.93	75.17	58.98	32.10	26.71
32	61.55	31.22	47.09	45.98	55.93	82.06	83.96	93.74	87.69	74.74	58.42	31.50	26.24
33	61.13	30.66	46.62	45.47	55.31	81.73	83.63	93.57	87.45	74.30	57.88	30.90	25.79
34	60.70	30.10	46.16	44.96	54.72	81.40	83.31	93.40	87.21	73.87	57.35	30.33	25.33
35	60.29	29.53	45.70	44.44	54.13	81.08	83.00	93.23	86.97	73.45	56.84	29.77	24.89
36	59.88	28.99	45.24	43.95	53.55	80.76	82.68	93.06	86.73	73.03	56.33	29.20	24.47
37	59.47	28.45	44.77	43.48	52.96	80.45	82.37	92.89	86.49	72.61	55.82	28.64	24.07
38	59.07	27.95	44.32	43.03	52.38	80.14	82.06	92.73	86.27	72.19	55.32	28.11	23.66
39	58.69	27.47	43.89	42.58	51.82	79.83	81.75	92.58	86.04	71.77	54.83	27.60	23.27
40	58.31	27.01	43.45	42.15	51.28	79.52	81.45	92.42	85.82	71.36	54.33	27.11	22.87
41	57.93	26.54	43.03	41.71	50.74	79.21	81.14	92.27	85.59	70.96	53.85	26.64	22.49
42	57.57	26.08	42.61	41.32	50.21	78.90	80.84	92.11	85.37	70.58	53.36	26.17	22.11
43	57.21	25.63	42.21	40.92	49.68	78.59	80.54	91.96	85.14	70.20	52.91	25.69	21.76
44	56.85	25.19	41.81	40.53	49.17	78.30	80.25	91.81	84.93	69.82	52.46	25.25	21.42
45	56.50	24.76	41.40	40.14	48.68	78.02	79.95	91.66	84.71	69.45	52.02	24.80	21.08
46	56.16	24.34	40.98	39.76	48.19	77.73	79.66	91.52	84.49	69.09	51.60	24.37	20.75
47	55.83	23.94	40.57	39.39	47.70	77.45	79.36	91.37	84.27	68.72	51.17	23.97	20.42
48	55.49	23.54	40.16	39.01	47.23	77.17	79.07	91.22	84.06	68.36	50.74	23.58	20.09

Table A 2. Probability (%) that the Significant Wave Height, $H_S \leq 7$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	59.45	30.18	36.77	41.80	52.08	74.98	82.08	93.97	92.10	76.24	54.95	29.64	25.15
2	57.09	27.71	33.45	38.95	49.32	72.27	80.10	92.77	90.91	73.48	51.87	27.30	22.81
3	55.55	26.08	31.55	37.24	47.48	70.39	78.75	91.92	89.97	71.63	49.93	25.79	21.36
4	54.29	24.86	30.08	35.83	45.92	68.84	77.73	91.17	89.13	70.11	48.30	24.52	20.27
5	53.17	23.86	28.96	34.68	44.50	67.43	76.76	90.47	88.33	68.71	46.87	23.35	19.28
6	52.14	22.96	27.94	33.62	43.17	66.13	75.84	89.82	87.58	67.39	45.55	22.32	18.40
7	51.17	22.13	27.02	32.61	41.87	64.92	74.97	89.18	86.88	66.14	44.34	21.35	17.56
8	50.24	21.34	26.13	31.64	40.66	63.79	74.14	88.56	86.18	64.96	43.18	20.42	16.79
9	49.36	20.59	25.28	30.71	39.49	62.67	73.32	87.97	85.52	63.84	42.10	19.52	16.08
10	48.51	19.91	24.46	29.79	38.45	61.63	72.54	87.40	84.86	62.73	41.04	18.68	15.41
11	47.71	19.27	23.73	28.93	37.43	60.62	71.78	86.85	84.20	61.66	40.01	17.91	14.78
12	46.93	18.66	22.99	28.12	36.44	59.65	71.03	86.33	83.55	60.65	39.00	17.19	14.18
13	46.19	18.10	22.28	27.37	35.50	58.76	70.29	85.82	82.92	59.65	38.06	16.50	13.59
14	45.46	17.57	21.61	26.62	34.59	57.90	69.57	85.31	82.30	58.70	37.14	15.84	13.02
15	44.76	17.06	20.97	25.89	33.68	57.08	68.85	84.80	81.72	57.75	36.23	15.23	12.49
16	44.08	16.55	20.40	25.19	32.77	56.29	68.14	84.29	81.12	56.83	35.36	14.61	11.95
17	43.41	16.08	19.86	24.47	31.90	55.52	67.44	83.78	80.55	55.93	34.50	14.02	11.43
18	42.76	15.65	19.36	23.77	31.02	54.77	66.74	83.27	79.99	55.04	33.67	13.44	10.94
19	42.12	15.22	18.86	23.09	30.17	54.05	66.05	82.77	79.43	54.20	32.85	12.89	10.51
20	41.51	14.79	18.40	22.43	29.34	53.35	65.37	82.28	78.86	53.38	32.06	12.34	10.12
21	40.91	14.40	17.94	21.78	28.55	52.67	64.69	81.81	78.30	52.56	31.29	11.81	9.75
22	40.33	14.02	17.50	21.16	27.79	52.00	64.02	81.33	77.76	51.75	30.56	11.31	9.43
23	39.76	13.65	17.06	20.56	27.08	51.33	63.35	80.86	77.22	50.94	29.84	10.83	9.12
24	**39.21**	**13.29**	**16.63**	**19.99**	**26.39**	**50.66**	**62.69**	**80.40**	**76.70**	**50.14**	**29.14**	**10.38**	**8.83**
25	38.66	12.95	16.23	19.45	25.71	49.99	62.04	79.94	76.19	49.33	28.44	9.94	8.54
26	38.14	12.62	15.85	18.92	25.08	49.33	61.42	79.50	75.67	48.51	27.76	9.53	8.27
27	37.63	12.30	15.50	18.43	24.47	48.68	60.83	79.06	75.15	47.71	27.11	9.15	8.02
28	37.13	11.97	15.15	17.95	23.88	48.05	60.24	78.62	74.64	46.92	26.47	8.81	7.80
29	36.64	11.65	14.83	17.47	23.29	47.42	59.67	78.19	74.14	46.14	25.86	8.47	7.58
30	36.17	11.33	14.52	17.01	22.71	46.79	59.11	77.76	73.65	45.39	25.28	8.15	7.36
31	35.71	11.01	14.24	16.57	22.17	46.17	58.58	77.34	73.15	44.65	24.71	7.84	7.16
32	35.26	10.70	13.96	16.13	21.65	45.56	58.06	76.91	72.67	43.94	24.17	7.57	6.98
33	34.83	10.41	13.67	15.71	21.17	44.97	57.55	76.50	72.20	43.26	23.66	7.32	6.82
34	34.41	10.13	13.40	15.29	20.73	44.38	57.03	76.08	71.73	42.59	23.15	7.07	6.67
35	34.00	9.85	13.14	14.88	20.33	43.79	56.52	75.66	71.26	41.94	22.65	6.82	6.51
36	33.60	9.58	12.92	14.50	19.94	43.21	56.01	75.25	70.80	41.31	22.15	6.58	6.36
37	33.20	9.31	12.69	14.16	19.56	42.66	55.51	74.84	70.35	40.69	21.66	6.34	6.19
38	32.82	9.04	12.46	13.83	19.20	42.11	55.00	74.44	69.91	40.09	21.21	6.10	6.04
39	32.44	8.77	12.23	13.51	18.83	41.58	54.50	74.04	69.48	39.51	20.78	5.89	5.88
40	32.08	8.51	12.00	13.18	18.48	41.05	54.01	73.65	69.05	38.94	20.37	5.68	5.72
41	31.71	8.26	11.77	12.86	18.15	40.53	53.53	73.25	68.62	38.39	19.96	5.48	5.57
42	31.36	8.02	11.54	12.54	17.83	40.02	53.05	72.86	68.19	37.86	19.56	5.28	5.42
43	31.01	7.79	11.31	12.22	17.53	39.51	52.57	72.46	67.75	37.34	19.15	5.09	5.29
44	30.67	7.57	11.08	11.92	17.23	39.01	52.10	72.08	67.33	36.83	18.77	4.91	5.15
45	30.33	7.37	10.85	11.62	16.95	38.52	51.63	71.70	66.91	36.33	18.41	4.73	5.03
46	30.00	7.16	10.63	11.32	16.67	38.03	51.17	71.32	66.49	35.83	18.05	4.56	4.90
47	29.67	6.95	10.41	11.02	16.40	37.54	50.71	70.95	66.08	35.34	17.70	4.39	4.77
48	29.35	6.74	10.18	10.73	16.13	37.06	50.25	70.59	65.67	34.86	17.35	4.25	4.66

Table A 3. Probability (%) that the Significant Wave Height, $H_S \leq 3$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	7.99	0.65	1.70	3.23	3.12	7.72	13.75	18.52	20.92	12.59	4.29	1.68	0.39
2	6.98	0.44	1.37	2.66	2.70	6.63	11.79	16.34	18.66	11.31	3.70	1.37	0.16
3	6.36	0.33	1.25	2.35	2.48	6.04	10.64	14.96	17.20	10.52	3.31	1.14	0.08
4	5.89	0.24	1.17	2.13	2.27	5.57	9.78	13.88	16.06	9.88	3.00	1.02	0.02
5	5.48	0.16	1.10	1.93	2.10	5.20	9.02	12.92	15.08	9.29	2.74	0.91	0
6	5.12	0.10	1.03	1.75	1.93	4.87	8.38	12.12	14.17	8.72	2.53	0.81	0
7	4.80	0.05	0.96	1.58	1.77	4.58	7.86	11.40	13.39	8.24	2.32	0.72	0
8	4.51	0.02	0.90	1.43	1.61	4.30	7.40	10.72	12.67	7.81	2.11	0.66	0
9	4.24	0	0.83	1.27	1.46	4.03	7.00	10.12	12.04	7.41	1.93	0.60	0
10	4.00	0	0.76	1.12	1.31	3.79	6.61	9.59	11.48	7.05	1.75	0.55	0
11	3.79	0	0.69	1.00	1.22	3.59	6.24	9.13	10.95	6.68	1.58	0.50	0
12	3.58	0	0.62	0.91	1.12	3.40	5.90	8.69	10.44	6.35	1.42	0.47	0
13	3.39	0	0.55	0.81	1.03	3.23	5.59	8.30	9.95	6.03	1.27	0.45	0
14	3.22	0	0.48	0.72	0.94	3.09	5.31	7.91	9.53	5.73	1.13	0.42	0
15	3.06	0	0.41	0.66	0.86	2.95	5.03	7.55	9.12	5.44	1.01	0.39	0
16	2.90	0	0.34	0.59	0.79	2.81	4.77	7.20	8.74	5.17	0.89	0.37	0
17	2.75	0	0.31	0.52	0.71	2.70	4.52	6.88	8.39	4.91	0.78	0.34	0
18	2.61	0	0.28	0.45	0.65	2.58	4.27	6.56	8.05	4.66	0.69	0.31	0
19	2.48	0	0.25	0.40	0.58	2.47	4.03	6.25	7.75	4.44	0.60	0.29	0
20	2.37	0	0.23	0.35	0.53	2.37	3.83	5.96	7.48	4.24	0.51	0.26	0
21	2.26	0	0.22	0.30	0.48	2.28	3.65	5.68	7.21	4.05	0.44	0.23	0
22	2.15	0	0.21	0.25	0.44	2.19	3.48	5.42	6.95	3.88	0.37	0.21	0
23	2.05	0	0.20	0.22	0.39	2.10	3.31	5.16	6.71	3.70	0.31	0.18	0
24	**1.95**	**0**	**0.18**	**0.19**	**0.34**	**2.00**	**3.15**	**4.92**	**6.47**	**3.52**	**0.25**	**0.15**	**0**
25	1.86	0	0.17	0.16	0.31	1.92	3.00	4.68	6.25	3.36	0.20	0.13	0
26	1.78	0	0.16	0.14	0.28	1.84	2.85	4.45	6.05	3.21	0.14	0.12	0
27	1.70	0	0.15	0.11	0.25	1.76	2.72	4.23	5.86	3.08	0.11	0.10	0
28	1.62	0	0.14	0.08	0.22	1.69	2.60	4.00	5.67	2.95	0.09	0.08	0
29	1.55	0	0.13	0.06	0.20	1.62	2.50	3.78	5.48	2.83	0.07	0.06	0
30	1.48	0	0.12	0.04	0.17	1.56	2.41	3.55	5.30	2.71	0.06	0.05	0
31	1.41	0	0.10	0.03	0.14	1.49	2.32	3.33	5.13	2.62	0.05	0.03	0
32	1.35	0	0.09	0.02	0.12	1.44	2.23	3.12	4.97	2.53	0.05	0.02	0
33	1.30	0	0.08	0.01	0.10	1.38	2.16	2.94	4.82	2.44	0.04	0.01	0
34	1.24	0	0.07	0	0.08	1.33	2.09	2.78	4.67	2.35	0.03	0	0
35	1.19	0	0.06	0	0.07	1.28	2.01	2.62	4.53	2.27	0.02	0	0
36	1.14	0	0.05	0	0.05	1.22	1.94	2.47	4.39	2.18	0.01	0	0
37	1.09	0	0.03	0	0.03	1.17	1.87	2.32	4.25	2.10	0	0	0
38	1.05	0	0.02	0	0.02	1.12	1.80	2.18	4.10	2.02	0	0	0
39	1.00	0	0.01	0	0.01	1.08	1.74	2.04	3.96	1.94	0	0	0
40	0.96	0	0	0	0	1.03	1.67	1.92	3.82	1.87	0	0	0
41	0.92	0	0	0	0	0.98	1.61	1.79	3.68	1.79	0	0	0
42	0.88	0	0	0	0	0.94	1.54	1.67	3.56	1.74	0	0	0
43	0.84	0	0	0	0	0.89	1.48	1.55	3.44	1.68	0	0	0
44	0.80	0	0	0	0	0.85	1.42	1.45	3.32	1.63	0	0	0
45	0.77	0	0	0	0	0.80	1.37	1.34	3.22	1.57	0	0	0
46	0.74	0	0	0	0	0.76	1.31	1.23	3.13	1.52	0	0	0
47	0.71	0	0	0	0	0.71	1.27	1.12	3.05	1.48	0	0	0
48	0.68	0	0	0	0	0.67	1.22	1.03	2.96	1.43	0	0	0

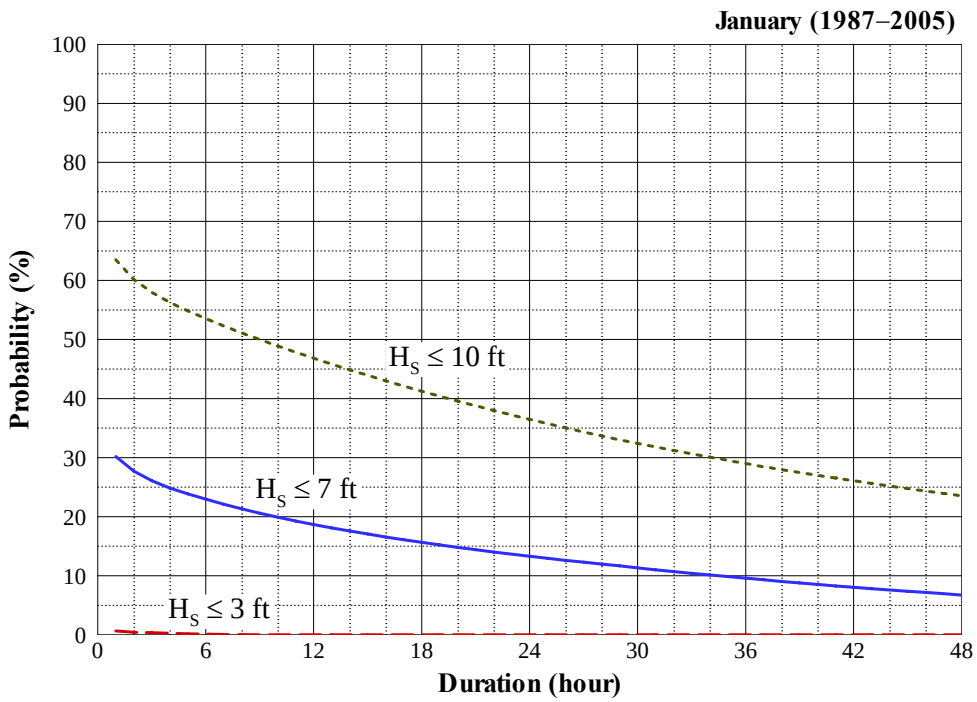

Figure A 1. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

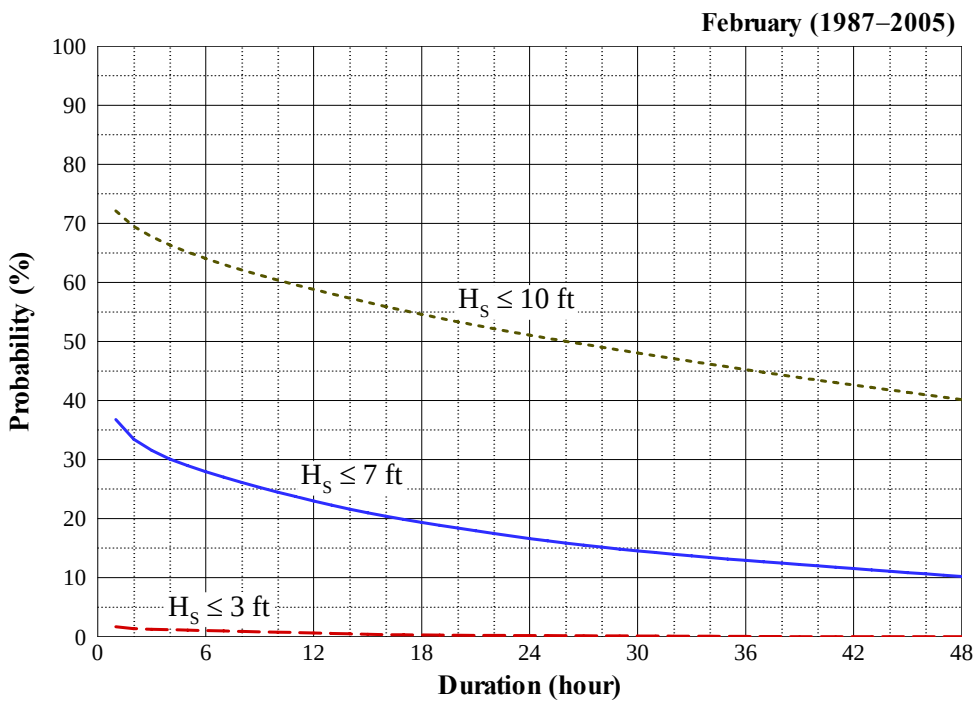

Figure A 2. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

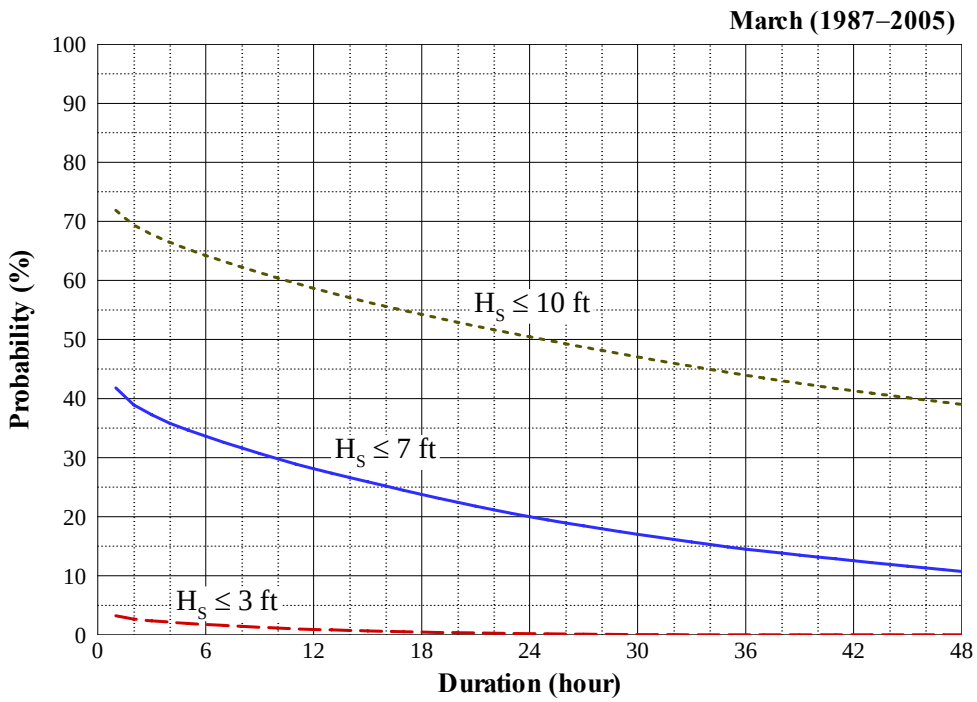

Figure A 3. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

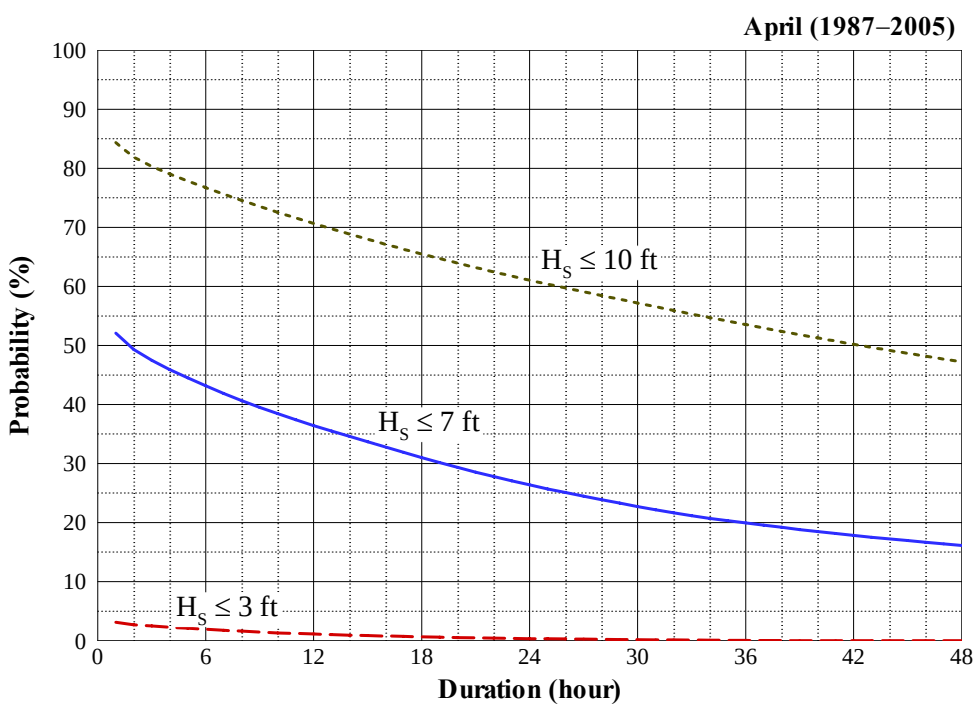

Figure A 4. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

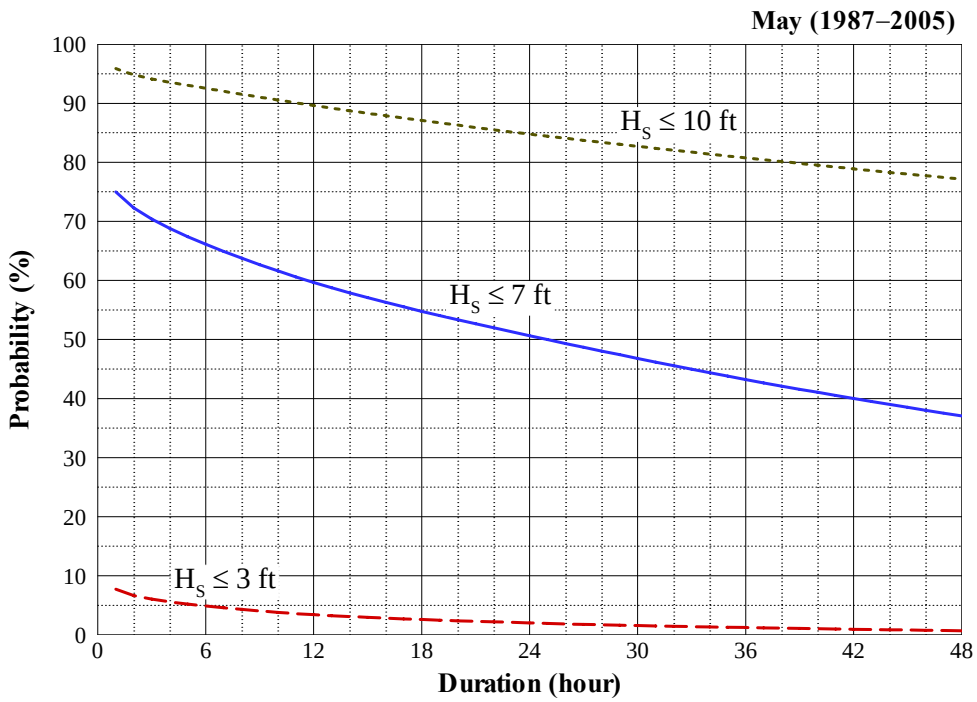

Figure A 5. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

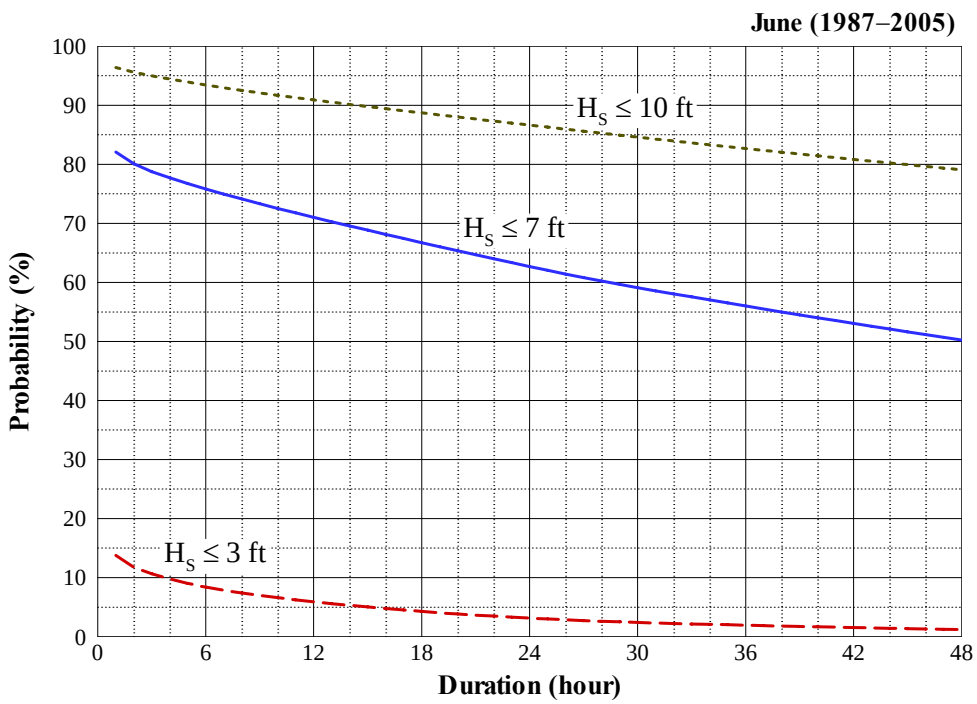

Figure A 6. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

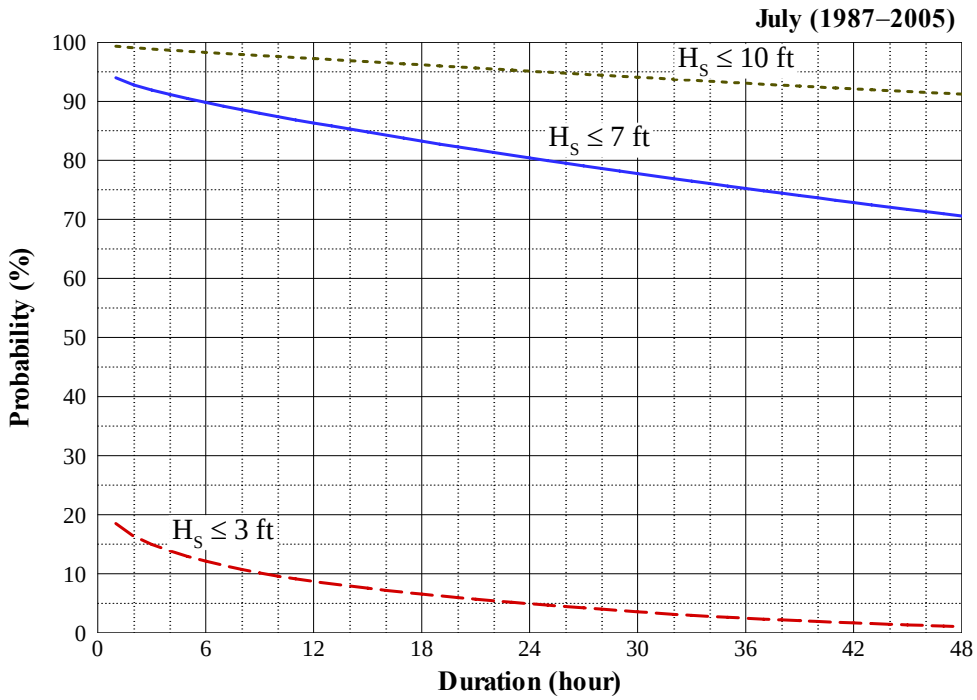

Figure A 7. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

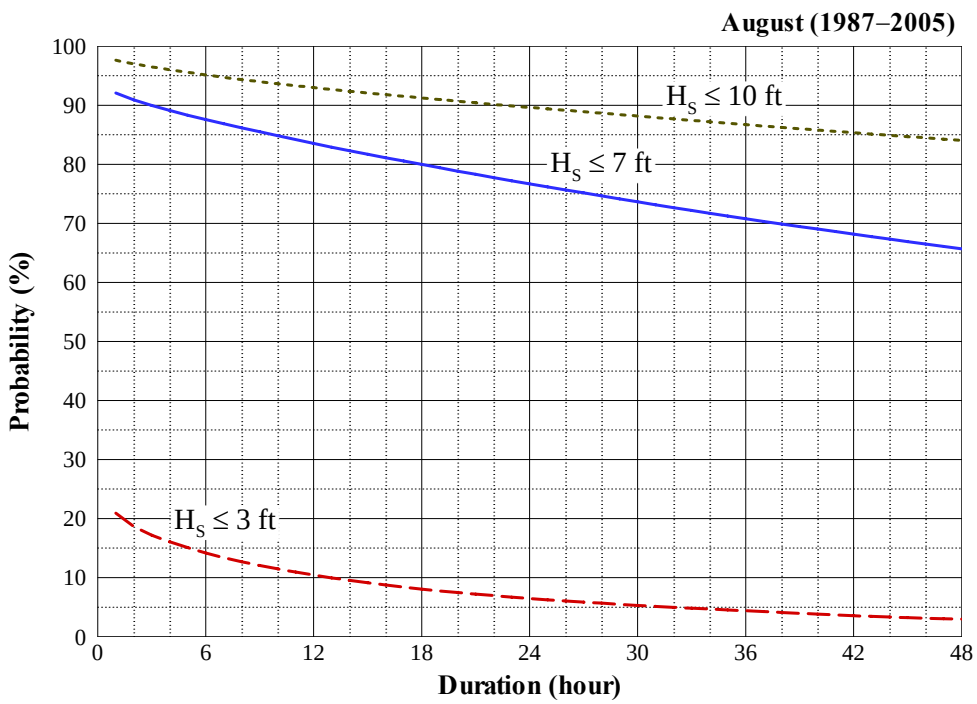

Figure A 8. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

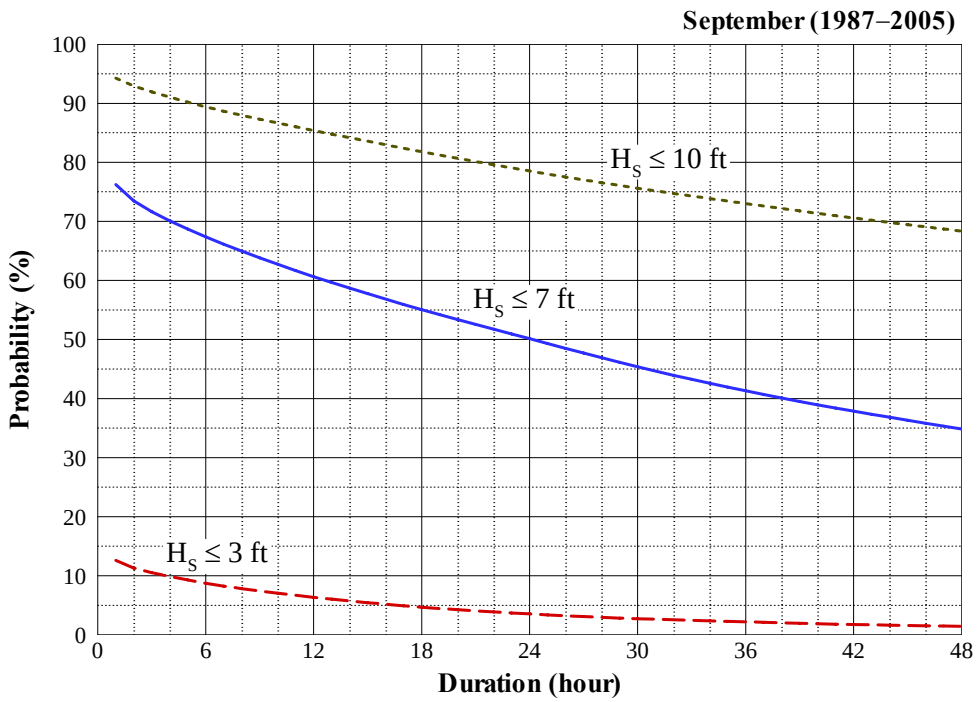

Figure A 9. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

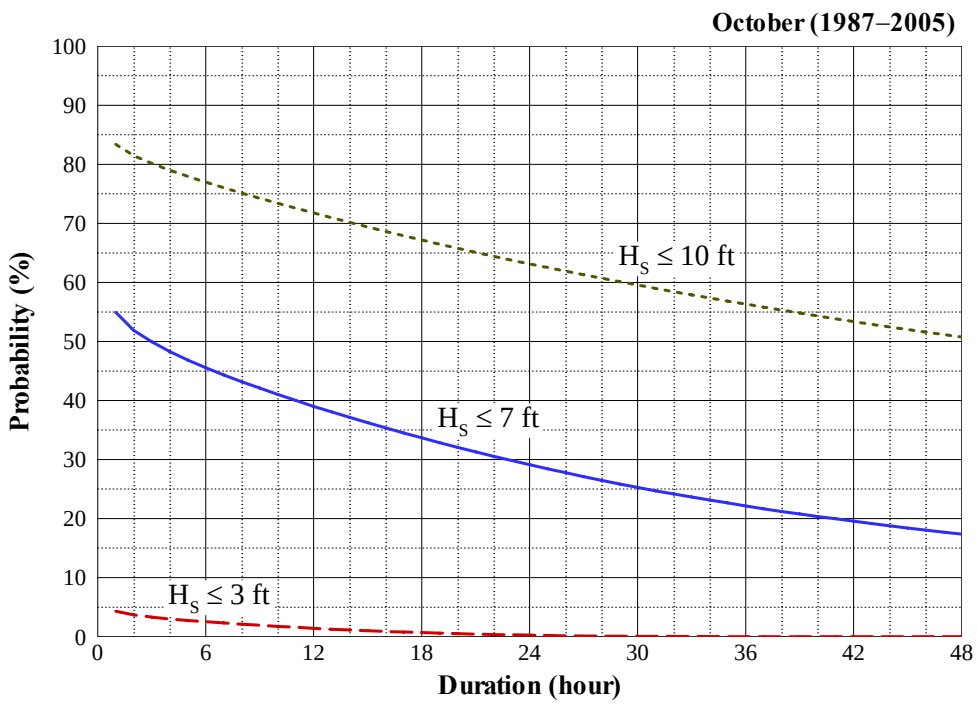

Figure A 10. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

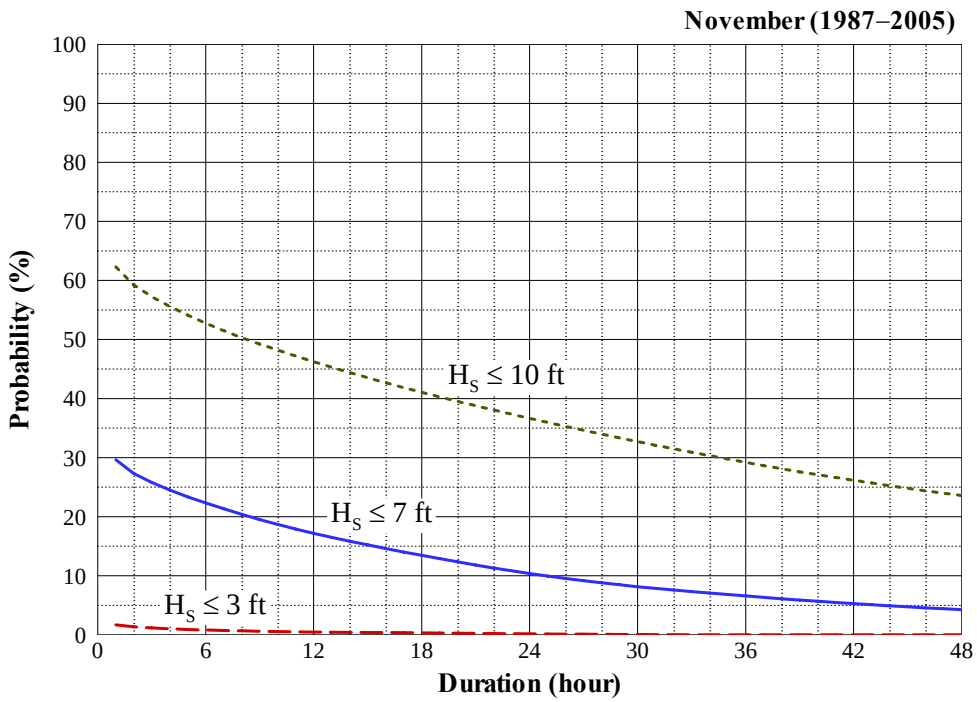

Figure A 11. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

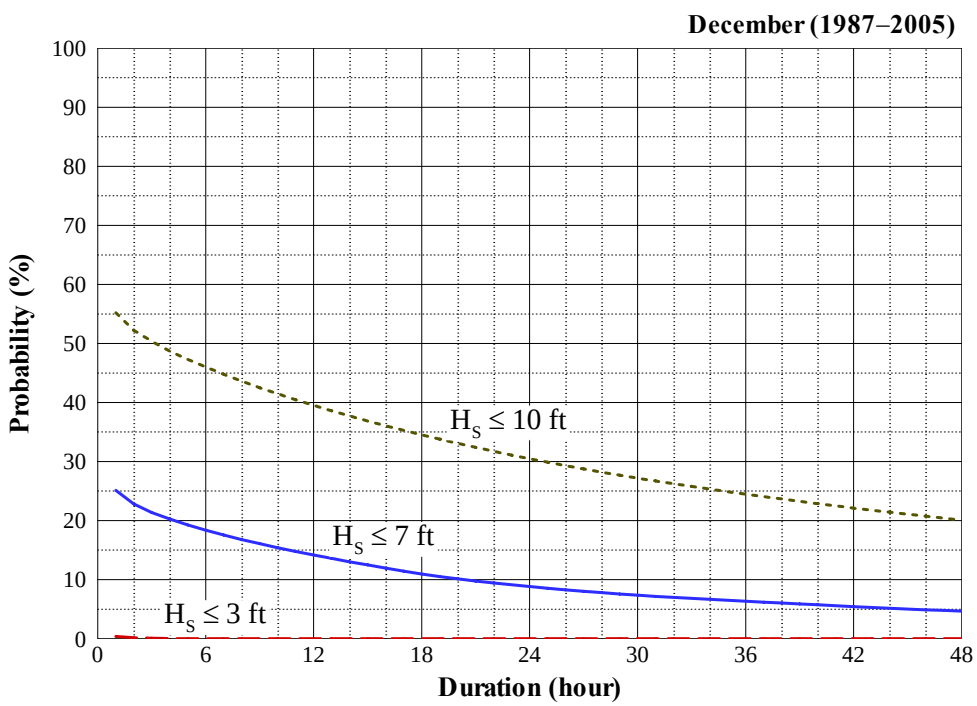

Figure A 12. Weather Operability for Fishing Vessels in the Vicinity of Grays Harbor (From NDBC Buoy 46041)

Appendix B

Weather Operability by Month for Fishing Vessels in the Vicinity of Ilwaco and Astoria (The Mouth of the Columbia River)

Weather operability statistics were obtained using data from NDBC buoy 46010. Buoy 46010 was deployed at 46.2° N, 124.2° W, just offshore the mouth of the Columbia river. It has about nine years of data between January 1979 and April 1991:

1979: 2 months (01 to 02)
1980: 12 months
1981: 11 months (01 to 05, 07 to 12)
1982: 6 months (01 to 02, 09 to 12)
1983: 11 months (01 to 04, 06 to 12)
1984: 7 months (01 to 03, 09 to 12)
1985: 11 months (01 to 10, 12)
1986: 7 months (01, 04, 06 to 11)
1987: 12 months
1988: 7 months (01, 03 to 05, 10 to 12)
1989: 11 months (01 to 04, 06 to 12)
1990: 12 months
1991: 4 months (01 to 04)

Table B 1. Probability (%) that the Significant Wave Height, $H_S \leq 10$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	77.54	61.13	63.39	72.01	82.78	95.67	86.02	85.85	91.71	95.06	84.50	61.07	67.36
2	75.61	57.87	60.44	68.58	81.03	94.52	85.25	85.54	91.63	94.30	82.66	57.89	65.15
3	74.31	55.86	58.54	66.33	79.82	93.75	84.60	85.27	91.56	93.77	81.35	55.81	63.55
4	73.24	54.21	57.15	64.48	78.91	93.03	84.00	85.00	91.51	93.33	80.22	54.10	62.15
5	72.28	52.73	55.93	62.85	78.08	92.35	83.39	84.75	91.46	92.90	79.27	52.57	60.89
6	71.41	51.47	54.90	61.39	77.32	91.68	82.78	84.51	91.41	92.48	78.38	51.16	59.70
7	70.59	50.29	53.96	60.09	76.62	91.01	82.18	84.30	91.36	92.09	77.58	49.83	58.57
8	69.84	49.18	53.08	58.90	75.94	90.38	81.61	84.13	91.30	91.72	76.83	48.61	57.53
9	69.12	48.08	52.25	57.78	75.26	89.76	81.07	83.96	91.25	91.36	76.11	47.56	56.53
10	68.43	47.04	51.46	56.74	74.62	89.13	80.56	83.79	91.20	91.00	75.39	46.60	55.54
11	67.77	46.02	50.69	55.76	73.98	88.53	80.06	83.63	91.15	90.66	74.69	45.68	54.60
12	67.12	45.04	49.91	54.80	73.34	87.95	79.57	83.46	91.10	90.33	74.00	44.76	53.70
13	66.49	44.12	49.14	53.88	72.73	87.37	79.07	83.29	91.05	90.00	73.34	43.95	52.83
14	65.89	43.24	48.41	53.00	72.14	86.82	78.58	83.12	91.00	89.67	72.69	43.16	52.05
15	65.31	42.40	47.72	52.14	71.54	86.27	78.08	82.95	90.95	89.35	72.06	42.40	51.29
16	64.75	41.59	47.08	51.31	70.97	85.74	77.59	82.79	90.89	89.02	71.44	41.67	50.57
17	64.20	40.79	46.47	50.48	70.40	85.21	77.09	82.64	90.84	88.69	70.83	40.93	49.89
18	63.66	40.02	45.86	49.67	69.84	84.68	76.60	82.49	90.79	88.36	70.26	40.21	49.22
19	63.13	39.26	45.29	48.88	69.28	84.18	76.08	82.35	90.74	88.03	69.69	39.50	48.57
20	62.61	38.53	44.73	48.08	68.73	83.67	75.57	82.22	90.69	87.70	69.11	38.81	47.93
21	62.09	37.81	44.18	47.29	68.20	83.17	75.05	82.08	90.64	87.37	68.56	38.12	47.30
22	61.59	37.09	43.65	46.49	67.65	82.68	74.56	81.96	90.59	87.04	68.02	37.46	46.69
23	61.09	36.40	43.16	45.71	67.10	82.23	74.07	81.84	90.54	86.71	67.49	36.80	46.07
24	**60.60**	**35.72**	**42.69**	**44.95**	**66.57**	**81.77**	**73.57**	**81.72**	**90.48**	**86.37**	**66.97**	**36.14**	**45.47**
25	60.11	35.04	42.24	44.19	66.02	81.34	73.08	81.61	90.43	86.02	66.43	35.52	44.89
26	59.64	34.37	41.81	43.47	65.49	80.90	72.58	81.49	90.38	85.66	65.91	34.91	44.32
27	59.18	33.72	41.39	42.76	64.96	80.45	72.12	81.39	90.33	85.30	65.39	34.33	43.78
28	58.73	33.06	40.99	42.05	64.43	79.97	71.73	81.30	90.28	84.95	64.88	33.75	43.28
29	58.28	32.42	40.61	41.34	63.91	79.49	71.35	81.22	90.23	84.59	64.38	33.19	42.78
30	57.85	31.81	40.27	40.65	63.41	79.00	70.98	81.13	90.18	84.23	63.91	32.69	42.27
31	57.44	31.23	39.93	39.99	62.89	78.55	70.62	81.05	90.13	83.87	63.44	32.18	41.79
32	57.03	30.67	39.59	39.42	62.37	78.09	70.26	80.96	90.07	83.53	62.96	31.69	41.31
33	56.63	30.12	39.23	38.87	61.86	77.63	69.93	80.88	90.02	83.20	62.51	31.21	40.83
34	56.24	29.58	38.86	38.36	61.34	77.20	69.61	80.79	89.97	82.87	62.05	30.73	40.35
35	55.85	29.06	38.48	37.85	60.82	76.77	69.29	80.71	89.92	82.53	61.60	30.25	39.87
36	55.46	28.55	38.11	37.34	60.30	76.31	68.96	80.66	89.87	82.22	61.16	29.79	39.39
37	55.08	28.05	37.75	36.85	59.79	75.85	68.62	80.60	89.82	81.90	60.73	29.33	38.90
38	54.71	27.58	37.40	36.40	59.27	75.42	68.28	80.55	89.77	81.59	60.29	28.89	38.42
39	54.35	27.15	37.05	35.95	58.75	74.99	67.95	80.50	89.72	81.27	59.87	28.48	37.95
40	53.99	26.72	36.71	35.49	58.24	74.56	67.63	80.45	89.66	80.96	59.45	28.07	37.50
41	53.64	26.29	36.37	35.05	57.70	74.15	67.31	80.42	89.61	80.64	59.03	27.69	37.04
42	53.29	25.87	36.03	34.63	57.17	73.74	67.00	80.38	89.56	80.32	58.60	27.33	36.59
43	52.95	25.46	35.68	34.20	56.64	73.33	66.68	80.35	89.51	80.01	58.18	26.99	36.16
44	52.62	25.09	35.34	33.80	56.12	72.92	66.36	80.32	89.46	79.69	57.76	26.67	35.75
45	52.28	24.71	35.00	33.40	55.61	72.51	66.05	80.28	89.41	79.38	57.34	26.36	35.33
46	51.96	24.33	34.67	33.01	55.10	72.10	65.73	80.25	89.36	79.06	56.91	26.05	34.95
47	51.63	23.95	34.36	32.60	54.60	71.69	65.41	80.21	89.31	78.76	56.50	25.74	34.56
48	51.31	23.57	34.06	32.20	54.11	71.28	65.10	80.18	89.25	78.46	56.11	25.42	34.17

Table B 2. Probability (%) that the Significant Wave Height, $H_S \leq 7$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	53.80	30.94	33.76	37.51	53.96	69.43	70.07	79.20	85.10	82.12	58.36	32.85	36.52
2	51.42	28.34	31.56	34.71	51.26	66.16	67.08	78.11	84.03	80.20	55.34	30.59	33.91
3	49.93	26.86	30.35	33.12	49.55	64.00	65.16	77.33	83.27	78.93	53.45	29.10	32.21
4	48.69	25.63	29.35	31.80	48.12	62.22	63.47	76.62	82.56	77.77	51.91	27.95	30.91
5	47.59	24.55	28.53	30.58	46.92	60.68	61.99	75.90	81.96	76.68	50.54	26.94	29.76
6	46.60	23.57	27.79	29.50	45.80	59.31	60.62	75.28	81.39	75.70	49.29	26.02	28.76
7	45.67	22.67	27.13	28.46	44.70	57.99	59.30	74.70	80.87	74.79	48.11	25.15	27.89
8	44.78	21.78	26.48	27.53	43.61	56.73	58.01	74.17	80.35	73.91	47.04	24.31	27.08
9	43.95	20.94	25.81	26.68	42.57	55.58	56.80	73.66	79.89	73.05	46.03	23.52	26.30
10	43.15	20.14	25.18	25.85	41.63	54.52	55.69	73.16	79.43	72.20	45.09	22.76	25.58
11	42.40	19.42	24.57	25.09	40.68	53.49	54.68	72.66	79.00	71.41	44.17	22.05	24.89
12	41.68	18.78	24.00	24.35	39.74	52.48	53.71	72.19	78.63	70.62	43.27	21.35	24.24
13	40.98	18.15	23.45	23.65	38.84	51.49	52.78	71.76	78.27	69.86	42.39	20.66	23.60
14	40.30	17.54	22.94	22.97	37.98	50.53	51.85	71.36	77.91	69.10	41.52	20.03	22.97
15	39.65	16.98	22.45	22.35	37.13	49.57	50.94	70.97	77.55	68.36	40.69	19.43	22.36
16	39.02	16.44	22.02	21.74	36.27	48.68	50.03	70.61	77.19	67.64	39.86	18.90	21.74
17	38.41	15.90	21.63	21.18	35.47	47.79	49.16	70.27	76.83	66.91	39.04	18.37	21.17
18	37.81	15.39	21.26	20.63	34.66	46.92	48.31	69.93	76.47	66.17	38.23	17.86	20.60
19	37.22	14.91	20.89	20.09	33.89	46.08	47.44	69.61	76.12	65.46	37.43	17.36	20.04
20	36.65	14.43	20.52	19.58	33.13	45.21	46.59	69.29	75.76	64.74	36.65	16.88	19.50
21	36.08	13.97	20.16	19.07	32.37	44.35	45.75	68.96	75.40	64.02	35.89	16.41	18.98
22	35.55	13.56	19.80	18.57	31.68	43.51	44.96	68.66	75.04	63.33	35.20	16.00	18.49
23	35.03	13.17	19.46	18.09	31.01	42.69	44.19	68.35	74.68	62.64	34.54	15.59	18.02
24	**34.52**	**12.78**	**19.13**	**17.62**	**30.36**	**41.92**	**43.44**	**68.05**	**74.32**	**61.96**	**33.88**	**15.17**	**17.59**
25	34.02	12.40	18.83	17.16	29.70	41.15	42.69	67.76	73.96	61.27	33.23	14.77	17.17
26	33.53	12.03	18.53	16.71	29.05	40.38	41.97	67.47	73.62	60.58	32.61	14.38	16.77
27	33.06	11.69	18.24	16.28	28.40	39.61	41.28	67.18	73.28	59.89	32.02	14.01	16.39
28	32.60	11.37	17.97	15.86	27.80	38.89	40.63	66.91	72.94	59.20	31.43	13.64	16.03
29	32.17	11.09	17.74	15.45	27.26	38.19	39.99	66.64	72.60	58.53	30.85	13.32	15.69
30	31.75	10.82	17.52	15.05	26.72	37.52	39.36	66.37	72.25	57.87	30.28	13.02	15.37
31	31.34	10.56	17.30	14.67	26.25	36.87	38.73	66.11	71.91	57.20	29.72	12.74	15.05
32	30.94	10.31	17.07	14.28	25.81	36.24	38.09	65.88	71.57	56.56	29.18	12.45	14.74
33	30.56	10.06	16.87	13.91	25.40	35.62	37.50	65.64	71.26	55.93	28.65	12.19	14.47
34	30.19	9.82	16.66	13.53	25.00	35.02	36.92	65.40	70.97	55.30	28.14	11.94	14.21
35	29.82	9.59	16.45	13.15	24.62	34.42	36.35	65.16	70.68	54.66	27.64	11.68	13.94
36	29.46	9.36	16.24	12.79	24.24	33.79	35.78	64.96	70.39	54.06	27.17	11.43	13.67
37	29.11	9.14	16.02	12.45	23.88	33.19	35.20	64.76	70.10	53.49	26.71	11.18	13.41
38	28.76	8.92	15.81	12.12	23.53	32.59	34.65	64.55	69.81	52.91	26.25	10.94	13.14
39	28.42	8.70	15.60	11.81	23.21	31.99	34.09	64.35	69.52	52.34	25.80	10.69	12.89
40	28.08	8.49	15.39	11.50	22.89	31.39	33.56	64.14	69.23	51.77	25.37	10.47	12.63
41	27.76	8.28	15.20	11.20	22.57	30.81	33.02	63.97	68.94	51.19	24.94	10.25	12.39
42	27.44	8.07	15.00	10.92	22.27	30.23	32.51	63.81	68.65	50.62	24.54	10.05	12.15
43	27.13	7.86	14.81	10.63	21.96	29.68	31.99	63.64	68.36	50.04	24.18	9.84	11.91
44	26.82	7.65	14.62	10.36	21.66	29.13	31.48	63.47	68.07	49.47	23.83	9.64	11.69
45	26.51	7.44	14.42	10.09	21.35	28.60	30.98	63.30	67.78	48.90	23.49	9.45	11.46
46	26.21	7.25	14.23	9.84	21.05	28.07	30.51	63.13	67.49	48.32	23.16	9.26	11.24
47	25.92	7.06	14.04	9.57	20.76	27.54	30.03	62.96	67.20	47.76	22.82	9.06	11.03
48	25.63	6.88	13.84	9.33	20.50	27.01	29.56	62.79	66.91	47.23	22.49	8.87	10.83

Table B 3. Probability (%) that the Significant Wave Height, $H_S \leq 3$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	7.99	3.66	4.80	2.74	4.00	6.57	9.86	19.41	19.36	17.24	6.47	3.34	3.18
2	6.88	3.11	4.05	2.33	3.07	5.48	8.69	17.16	17.00	15.21	5.44	2.64	2.65
3	6.19	2.75	3.67	2.06	2.56	4.76	8.00	15.66	15.57	13.91	4.83	2.10	2.33
4	5.65	2.49	3.37	1.83	2.16	4.11	7.48	14.59	14.47	12.84	4.31	1.76	2.07
5	5.20	2.25	3.14	1.65	1.81	3.56	7.05	13.64	13.57	11.94	3.88	1.49	1.88
6	4.83	2.05	2.97	1.52	1.54	3.13	6.65	12.85	12.76	11.14	3.50	1.29	1.71
7	4.49	1.88	2.80	1.38	1.32	2.77	6.30	12.12	12.03	10.43	3.18	1.13	1.55
8	4.19	1.73	2.68	1.24	1.14	2.41	6.02	11.49	11.36	9.76	2.90	1.01	1.43
9	3.92	1.58	2.56	1.12	0.97	2.09	5.74	10.98	10.71	9.16	2.62	0.89	1.31
10	3.67	1.45	2.46	1.01	0.84	1.78	5.48	10.49	10.10	8.60	2.39	0.80	1.19
11	3.44	1.32	2.35	0.92	0.72	1.49	5.23	10.03	9.55	8.09	2.19	0.75	1.07
12	3.24	1.22	2.27	0.84	0.61	1.28	5.01	9.59	9.04	7.62	2.00	0.70	0.96
13	3.05	1.13	2.19	0.75	0.52	1.11	4.79	9.18	8.56	7.16	1.83	0.65	0.87
14	2.87	1.05	2.12	0.67	0.46	1.01	4.57	8.77	8.08	6.72	1.67	0.60	0.79
15	2.70	0.98	2.04	0.60	0.41	0.91	4.36	8.37	7.65	6.32	1.50	0.54	0.72
16	2.54	0.92	1.97	0.54	0.37	0.82	4.18	7.96	7.24	5.93	1.34	0.49	0.67
17	2.39	0.86	1.89	0.50	0.32	0.75	4.00	7.55	6.85	5.57	1.18	0.45	0.61
18	2.25	0.81	1.82	0.45	0.29	0.67	3.80	7.21	6.46	5.22	1.04	0.43	0.56
19	2.12	0.77	1.74	0.41	0.26	0.63	3.62	6.89	6.10	4.92	0.91	0.40	0.51
20	2.00	0.73	1.67	0.37	0.23	0.58	3.47	6.58	5.78	4.64	0.78	0.38	0.45
21	1.88	0.69	1.59	0.34	0.21	0.53	3.31	6.28	5.47	4.36	0.66	0.35	0.40
22	1.78	0.65	1.54	0.31	0.20	0.48	3.17	5.99	5.18	4.10	0.56	0.32	0.35
23	1.68	0.63	1.48	0.28	0.18	0.43	3.03	5.72	4.92	3.88	0.47	0.30	0.29
24	**1.59**	**0.60**	**1.42**	**0.26**	**0.17**	**0.39**	**2.89**	**5.45**	**4.66**	**3.69**	**0.42**	**0.27**	**0.24**
25	1.50	0.58	1.37	0.23	0.15	0.34	2.75	5.19	4.41	3.50	0.37	0.25	0.20
26	1.42	0.55	1.33	0.20	0.14	0.29	2.61	4.94	4.19	3.32	0.35	0.23	0.16
27	1.35	0.52	1.30	0.17	0.12	0.27	2.48	4.70	4.00	3.13	0.34	0.22	0.12
28	1.28	0.50	1.27	0.14	0.11	0.24	2.34	4.48	3.81	2.96	0.32	0.21	0.09
29	1.21	0.47	1.24	0.11	0.09	0.22	2.20	4.28	3.62	2.80	0.31	0.19	0.07
30	1.15	0.45	1.21	0.10	0.08	0.19	2.08	4.07	3.47	2.67	0.30	0.18	0.05
31	1.10	0.42	1.18	0.09	0.06	0.17	1.96	3.90	3.33	2.54	0.29	0.17	0.04
32	1.05	0.41	1.15	0.07	0.05	0.14	1.84	3.75	3.21	2.41	0.27	0.16	0.03
33	1.00	0.39	1.12	0.06	0.03	0.12	1.72	3.60	3.09	2.30	0.26	0.14	0.01
34	0.95	0.38	1.09	0.04	0.02	0.10	1.62	3.46	2.97	2.18	0.25	0.13	0
35	0.90	0.37	1.06	0.03	0	0.07	1.52	3.33	2.85	2.07	0.24	0.12	0
36	0.86	0.35	1.03	0.01	0	0.05	1.43	3.19	2.73	1.97	0.22	0.10	0
37	0.82	0.34	1.00	0	0	0.02	1.33	3.05	2.61	1.87	0.21	0.09	0
38	0.78	0.33	0.97	0	0	0	1.23	2.92	2.49	1.78	0.20	0.08	0
39	0.74	0.31	0.94	0	0	0	1.13	2.78	2.38	1.69	0.19	0.07	0
40	0.70	0.30	0.91	0	0	0	1.03	2.65	2.26	1.62	0.17	0.05	0
41	0.66	0.29	0.88	0	0	0	0.93	2.53	2.14	1.55	0.16	0.04	0
42	0.63	0.28	0.85	0	0	0	0.83	2.41	2.03	1.49	0.15	0.03	0
43	0.60	0.26	0.82	0	0	0	0.73	2.31	1.95	1.44	0.14	0.01	0
44	0.57	0.25	0.79	0	0	0	0.65	2.21	1.86	1.38	0.12	0	0
45	0.54	0.24	0.76	0	0	0	0.59	2.10	1.79	1.32	0.11	0	0
46	0.52	0.22	0.73	0	0	0	0.55	2.00	1.73	1.26	0.10	0	0
47	0.49	0.21	0.70	0	0	0	0.52	1.90	1.66	1.21	0.09	0	0
48	0.47	0.20	0.67	0	0	0	0.48	1.80	1.59	1.15	0.08	0	0

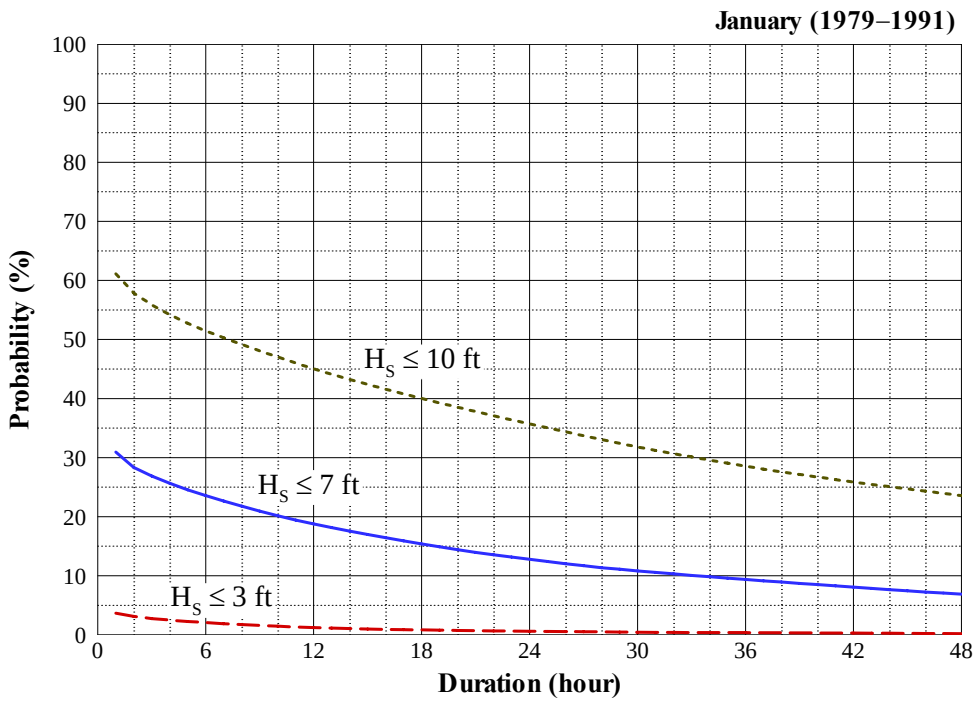

Figure B 1. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

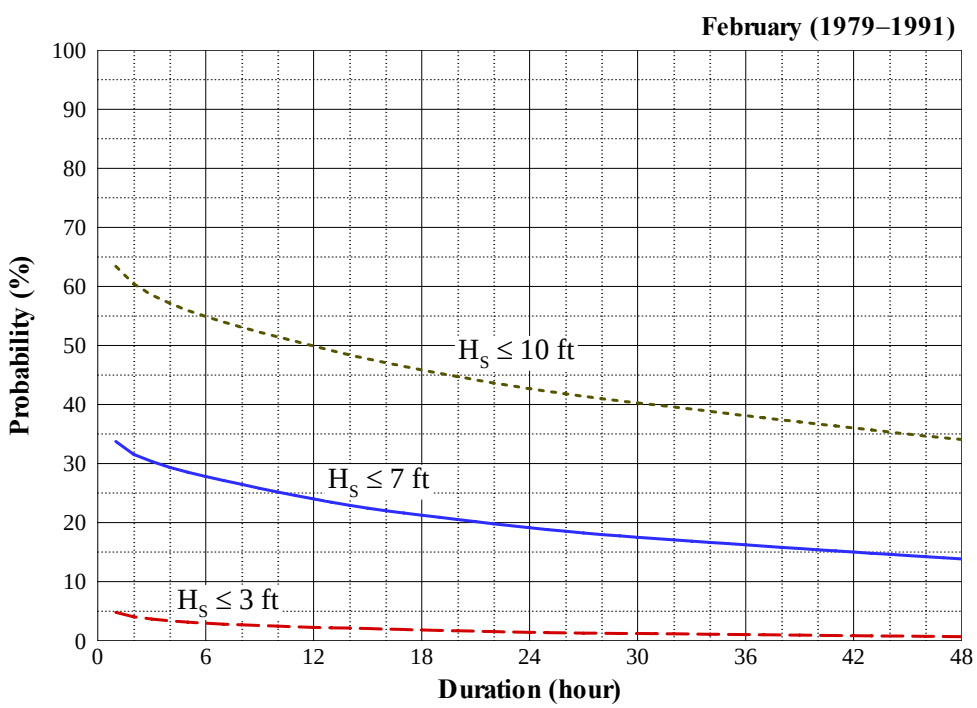

Figure B 2. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

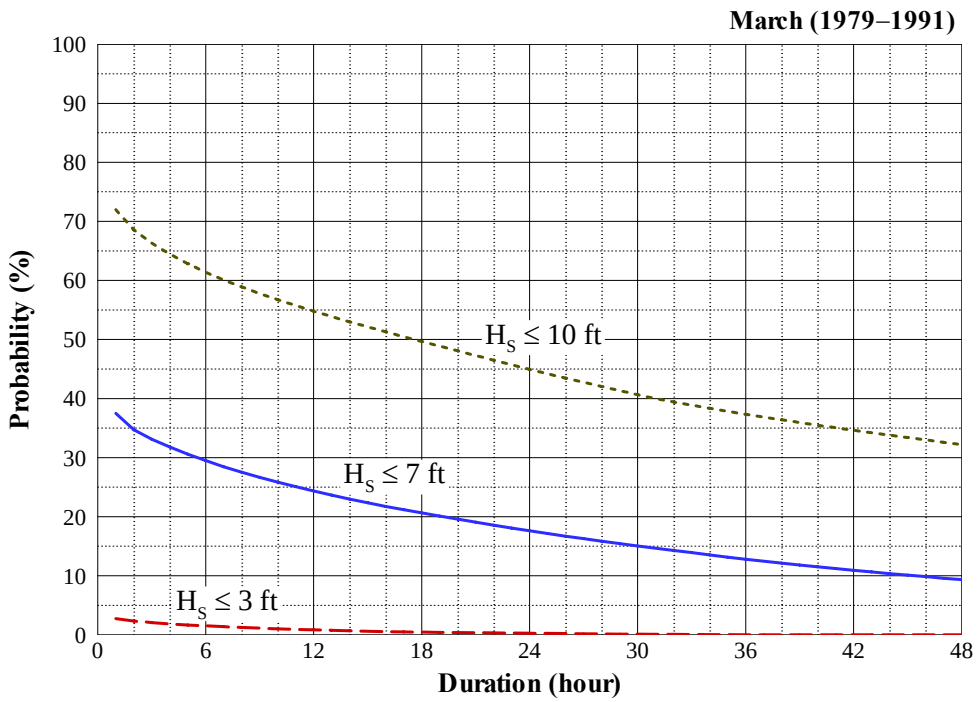

Figure B 3. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

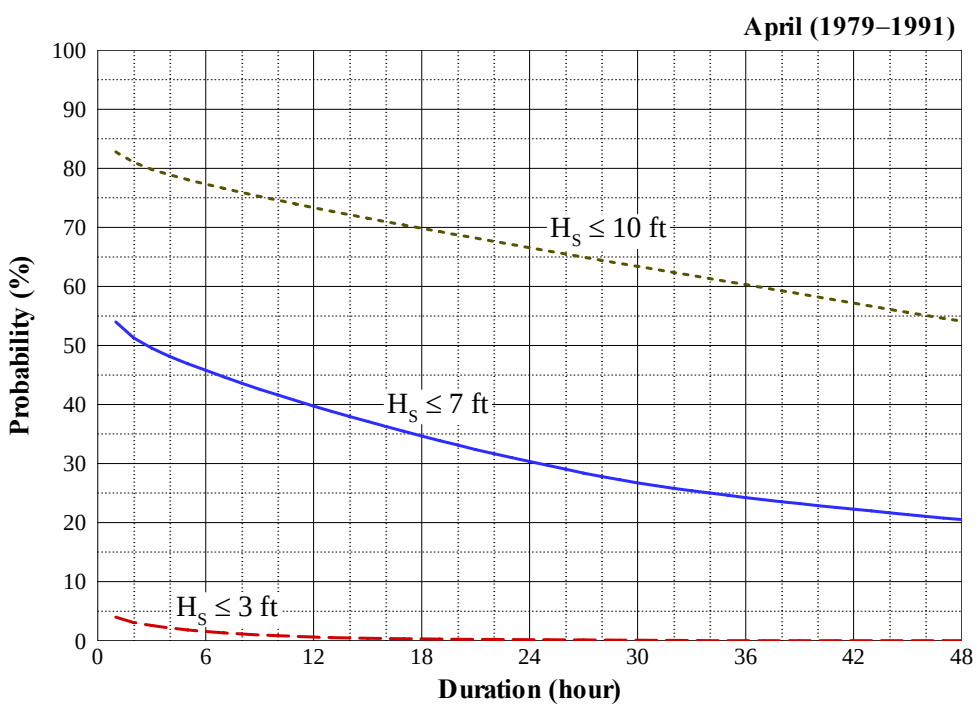

Figure B 4. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

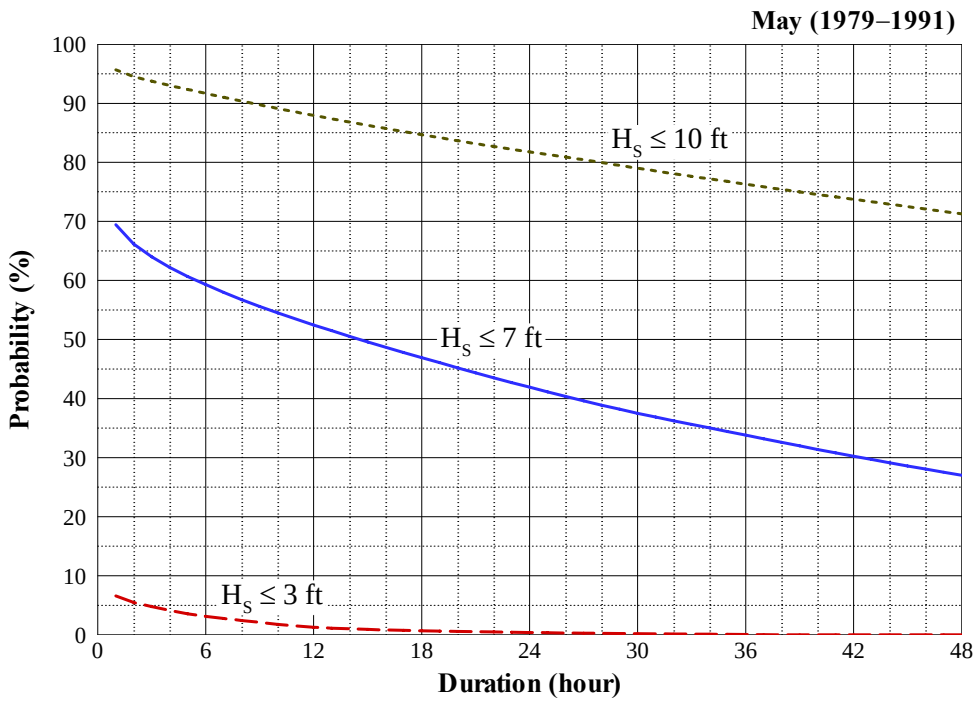

Figure B 5. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

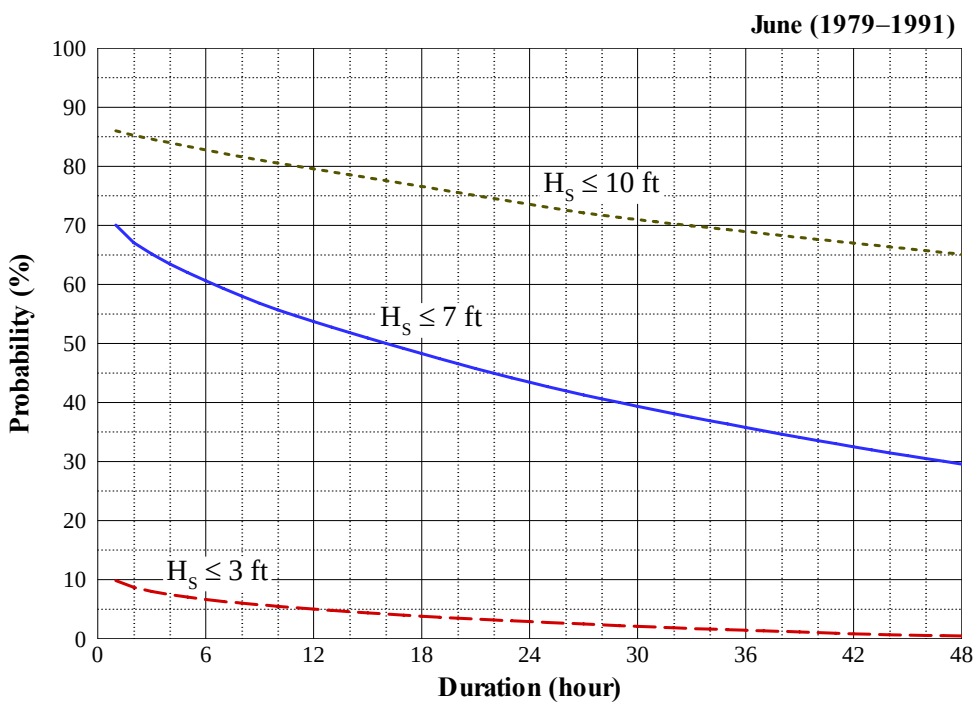

Figure B 6. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

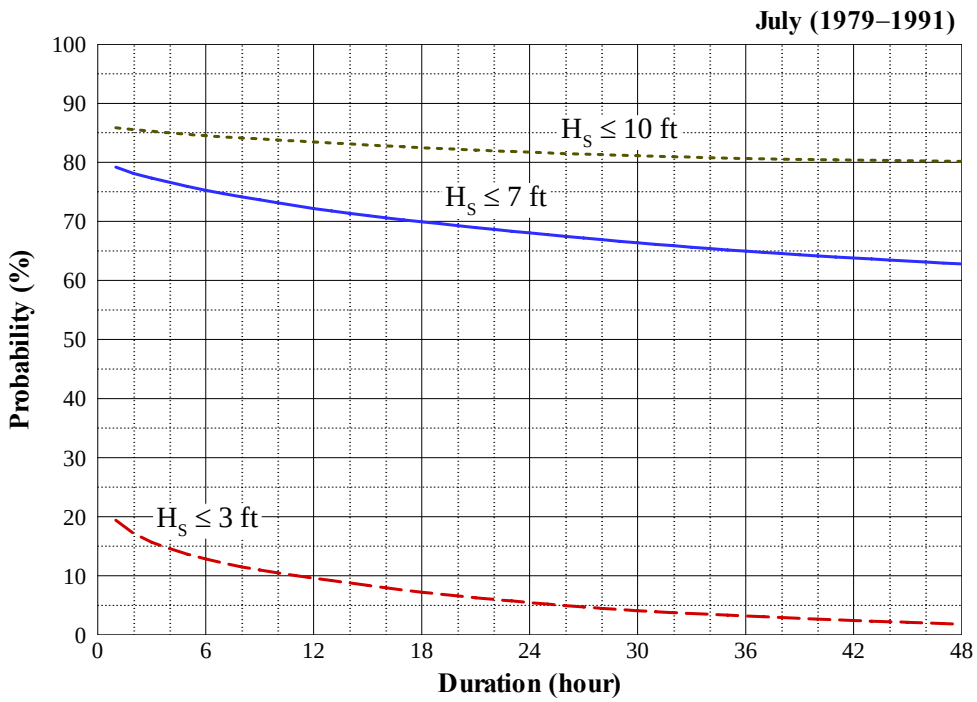

Figure B 7. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

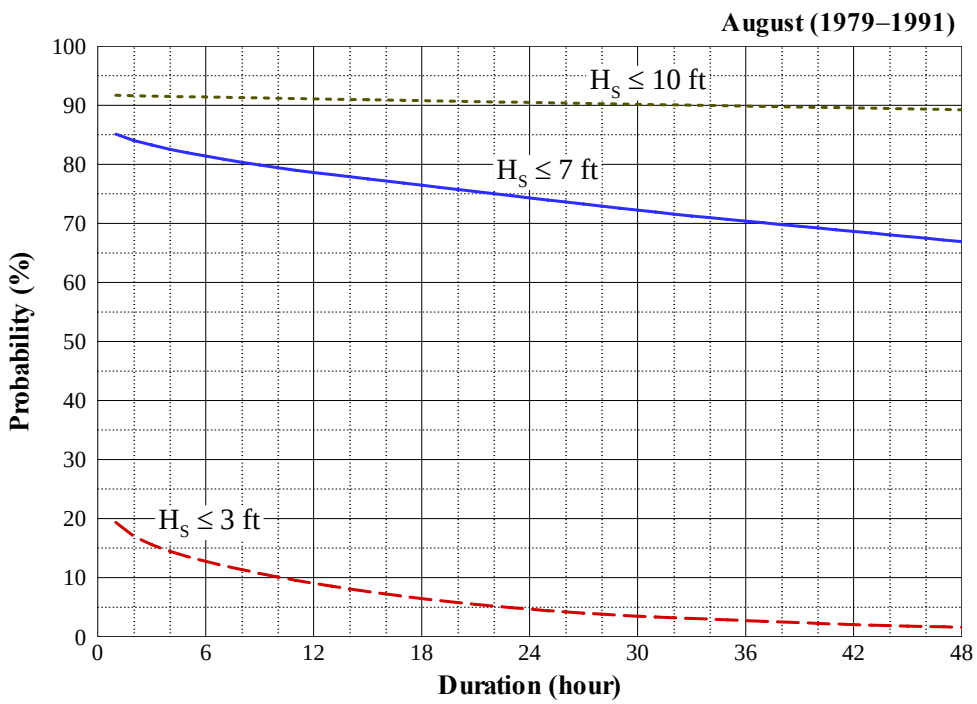

Figure B 8. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

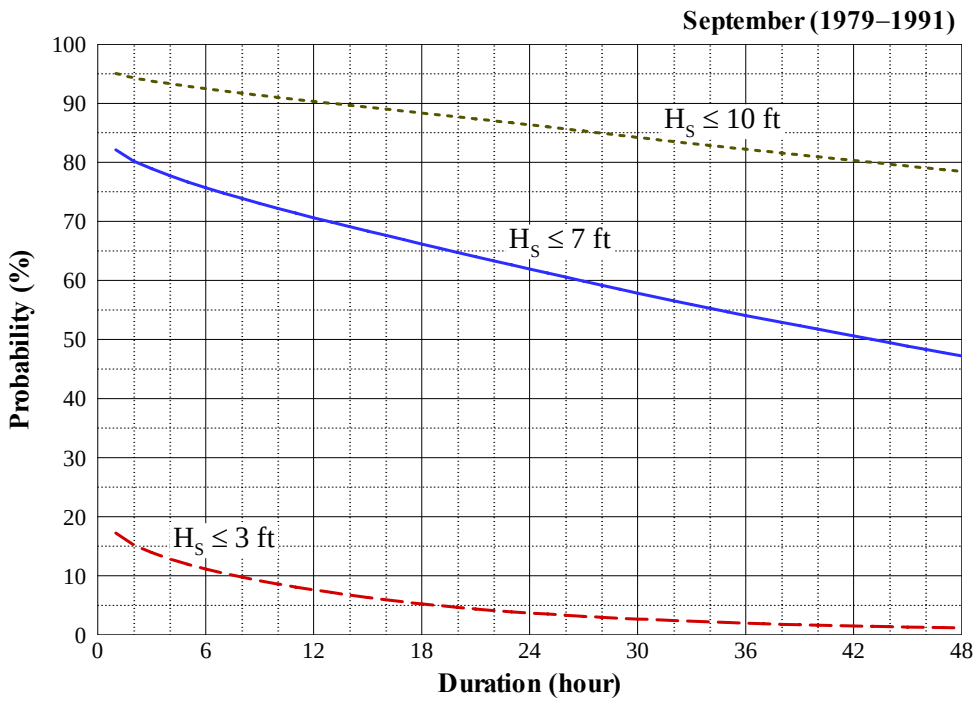

Figure B 9. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

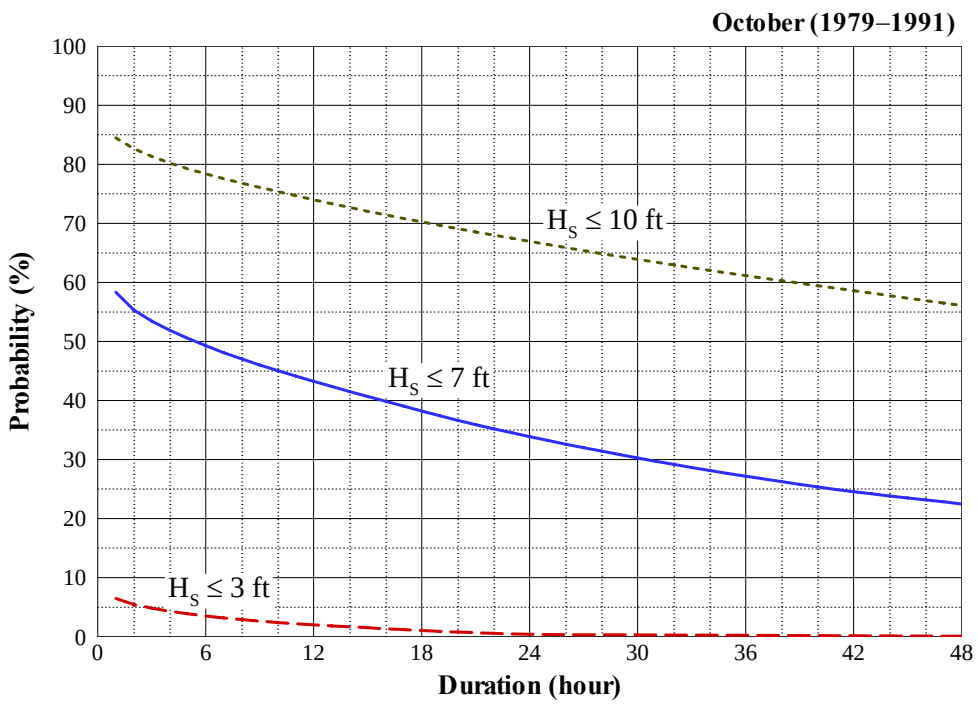

Figure B 10. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

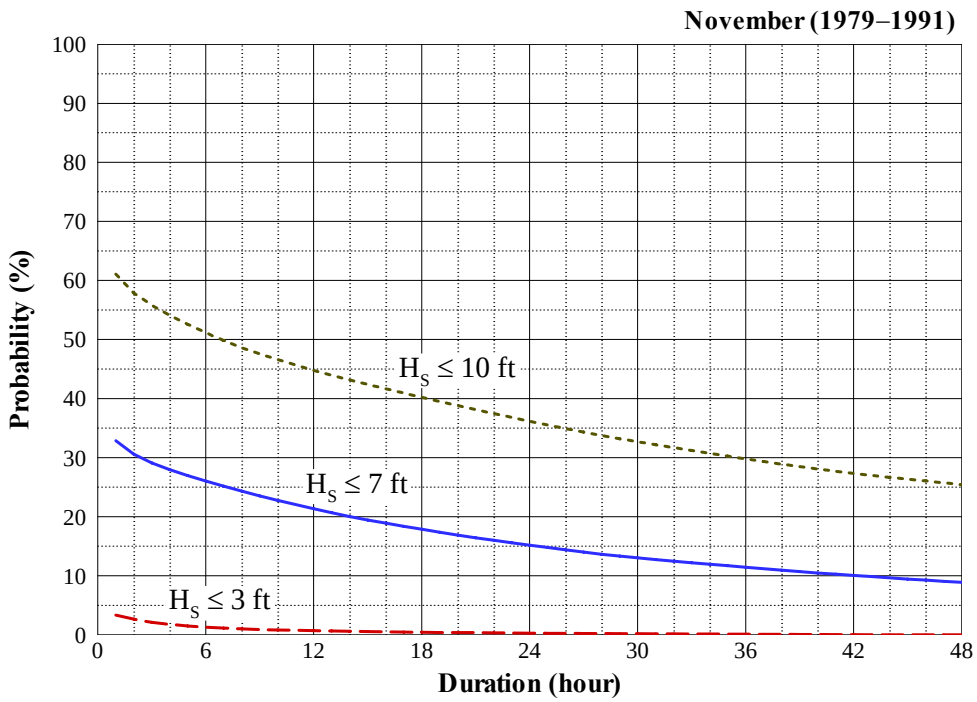

Figure B 11. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

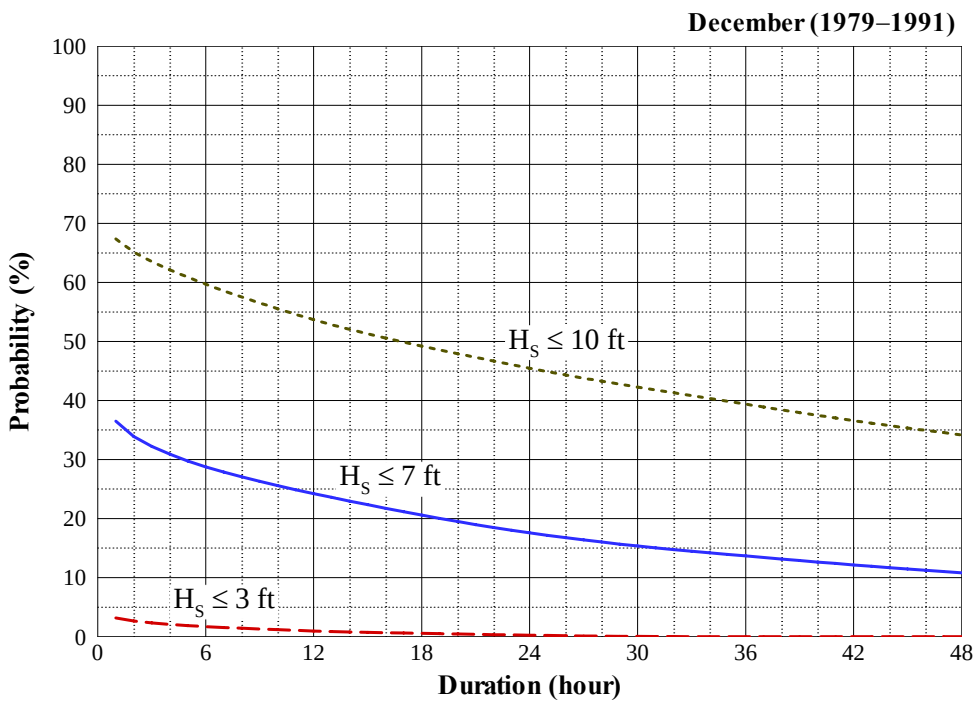

Figure B 12. Weather Operability for Fishing Vessels in the Vicinity of the Mouth of the Columbia River (From NDBC Buoy 46010)

Appendix C

Weather Operability by Month for Fishing Vessels in the Vicinity of Neah Bay

Weather operability statistics were obtained from NDBC buoy 46087. Buoy 46087 has been deployed at 48.49° N 124.73° W, near Neah Bay. It has only one year of data, from September 2004 through August 2005.

Table C 1. Probability (%) that the Significant Wave Height, $H_S \leq 10$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	92.69	91.35	91.06	87.89	87.80	96.62	98.88	99.77	99.73	95.13	84.14	79.56	87.63
2	91.58	90.00	89.57	86.27	85.27	96.35	98.60	99.61	99.53	94.30	83.20	77.05	84.81
3	90.73	88.92	88.53	85.06	83.31	96.08	98.46	99.46	99.33	93.46	82.39	75.38	82.80
4	89.98	87.84	87.63	83.98	81.49	95.81	98.32	99.31	99.13	92.77	81.59	73.99	81.18
5	89.24	86.76	86.74	82.91	79.80	95.54	98.18	99.15	98.92	92.07	80.78	72.60	79.70
6	88.55	85.81	85.84	81.83	78.12	95.26	98.04	99.00	98.72	91.52	79.97	71.21	78.63
7	87.87	84.87	84.95	80.75	76.58	94.99	97.90	98.84	98.52	90.96	79.17	69.82	77.55
8	87.21	84.05	84.20	79.68	75.04	94.72	97.76	98.69	98.32	90.40	78.36	68.43	76.48
9	86.57	83.24	83.46	78.74	73.49	94.45	97.62	98.53	98.11	89.85	77.55	67.04	75.54
10	86.00	82.43	82.71	77.79	72.37	94.32	97.48	98.38	97.91	89.43	76.75	65.79	74.60
11	85.43	81.62	81.97	76.72	71.39	94.18	97.34	98.22	97.71	89.01	75.94	64.53	73.79
12	84.89	80.81	81.22	75.64	70.55	94.05	97.20	98.07	97.58	88.60	75.13	63.28	73.12
13	84.35	80.00	80.48	74.56	69.71	93.91	97.06	97.92	97.44	88.18	74.33	62.03	72.45
14	83.84	79.19	79.73	73.49	69.14	93.78	96.91	97.76	97.31	87.76	73.52	60.92	71.77
15	83.34	78.38	79.14	72.41	68.58	93.64	96.77	97.61	97.17	87.34	72.72	59.81	71.10
16	82.85	77.70	78.54	71.33	68.02	93.51	96.63	97.45	97.04	86.93	71.91	58.69	70.43
17	82.36	77.03	77.94	70.26	67.46	93.37	96.49	97.30	96.90	86.51	71.10	57.58	69.76
18	81.88	76.35	77.35	69.18	66.90	93.23	96.35	97.14	96.77	86.09	70.30	56.47	69.09
19	81.39	75.68	76.75	68.10	66.34	93.10	96.21	96.99	96.63	85.68	69.49	55.36	68.41
20	80.90	75.00	76.16	67.03	65.78	92.96	96.07	96.83	96.50	85.26	68.68	54.24	67.74
21	80.42	74.32	75.56	65.95	65.22	92.83	95.93	96.68	96.36	84.84	67.88	53.27	67.07
22	79.94	73.65	74.96	64.87	64.66	92.69	95.79	96.53	96.23	84.42	67.07	52.30	66.40
23	79.48	72.97	74.37	63.80	64.10	92.56	95.65	96.37	96.09	84.01	66.40	51.46	65.73
24	**79.02**	**72.30**	**73.77**	**62.72**	**63.53**	**92.42**	**95.51**	**96.22**	**95.96**	**83.59**	**65.73**	**50.63**	**65.05**
25	78.56	71.62	73.17	61.64	62.97	92.29	95.37	96.06	95.83	83.17	65.05	49.79	64.38
26	78.13	70.95	72.73	60.57	62.55	92.15	95.23	95.91	95.69	82.75	64.38	48.96	63.71
27	77.69	70.27	72.28	59.49	62.13	92.02	95.09	95.75	95.56	82.34	63.71	48.12	63.04
28	77.26	69.60	71.83	58.41	61.71	91.88	94.95	95.60	95.42	81.92	63.04	47.43	62.37
29	76.83	68.92	71.39	57.34	61.29	91.75	94.81	95.44	95.29	81.50	62.37	46.73	61.69
30	76.40	68.24	70.94	56.26	60.87	91.61	94.67	95.29	95.15	81.09	61.69	46.04	61.02
31	75.97	67.57	70.49	55.18	60.45	91.48	94.53	95.14	95.02	80.67	61.02	45.34	60.35
32	75.54	66.89	70.05	54.11	60.03	91.34	94.39	94.98	94.88	80.25	60.35	44.65	59.68
33	75.11	66.22	69.60	53.03	59.61	91.20	94.25	94.83	94.75	79.83	59.68	43.95	59.01
34	74.68	65.54	69.15	51.95	59.19	91.07	94.11	94.67	94.61	79.42	59.01	43.26	58.33
35	74.25	64.87	68.70	50.88	58.77	90.93	93.97	94.52	94.48	79.00	58.33	42.56	57.66
36	73.83	64.19	68.26	49.80	58.35	90.80	93.83	94.36	94.34	78.58	57.66	41.86	56.99
37	73.40	63.51	67.81	48.72	57.92	90.66	93.69	94.21	94.21	78.16	56.99	41.17	56.32
38	72.97	62.84	67.36	47.65	57.50	90.53	93.55	94.05	94.07	77.75	56.32	40.47	55.65
39	72.54	62.16	66.92	46.57	57.08	90.39	93.41	93.90	93.94	77.33	55.65	39.78	54.97
40	72.11	61.49	66.47	45.49	56.66	90.26	93.27	93.75	93.81	76.91	54.97	39.08	54.30
41	71.69	60.81	66.02	44.55	56.24	90.12	93.13	93.59	93.67	76.50	54.30	38.39	53.63
42	71.27	60.14	65.57	43.61	55.82	89.99	92.99	93.44	93.54	76.08	53.63	37.69	52.96
43	70.86	59.46	65.28	42.67	55.40	89.85	92.85	93.28	93.40	75.66	52.96	37.00	52.29
44	70.46	58.78	64.98	41.86	54.98	89.72	92.71	93.13	93.27	75.24	52.29	36.30	51.61
45	70.08	58.11	64.83	41.05	54.56	89.58	92.57	92.97	93.13	74.83	51.61	35.61	50.94
46	69.72	57.43	64.68	40.38	54.28	89.45	92.43	92.82	93.00	74.41	50.94	35.05	50.27
47	69.36	56.76	64.53	39.70	54.00	89.31	92.29	92.66	92.86	73.99	50.27	34.49	49.60
48	69.01	56.08	64.38	39.03	53.72	89.18	92.15	92.51	92.73	73.71	49.60	33.94	48.93

Table C 2. Probability (%) that the Significant Wave Height, $H_S \leq 7$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	70.41	59.32	63.93	50.47	53.30	87.96	89.62	87.80	95.08	71.63	60.75	42.28	43.95
2	67.83	56.22	61.10	46.84	50.77	86.47	87.10	85.33	93.87	67.87	57.93	40.33	39.79
3	65.91	53.92	58.57	44.15	49.09	85.25	85.55	83.40	92.86	65.23	55.38	38.94	37.23
4	64.30	52.16	56.33	42.13	48.25	84.17	84.29	81.78	91.92	63.00	53.23	37.55	34.81
5	62.95	50.54	54.40	40.51	47.55	83.22	83.17	80.54	91.25	60.92	51.34	36.16	33.07
6	61.72	49.05	52.46	39.03	46.99	82.41	82.05	79.54	90.64	59.11	49.60	34.77	31.32
7	60.56	47.57	50.67	37.95	46.42	81.60	80.93	78.61	90.10	57.44	47.85	33.52	29.57
8	59.50	46.22	48.88	37.15	45.86	80.79	79.80	77.68	89.56	56.05	46.37	32.27	28.23
9	58.51	44.87	47.09	36.61	45.30	79.97	78.82	76.83	89.02	54.66	45.03	31.15	27.02
10	57.57	43.51	45.46	36.07	44.74	79.16	77.84	75.99	88.55	53.55	43.68	30.04	25.81
11	56.65	42.16	43.96	35.53	44.18	78.35	76.86	75.14	88.15	52.43	42.34	29.07	24.60
12	55.77	41.22	42.47	34.99	43.76	77.54	75.88	74.29	87.74	51.32	41.00	28.10	23.39
13	54.91	40.27	40.98	34.46	43.34	77.00	74.90	73.44	87.34	50.21	39.65	27.12	22.18
14	54.09	39.32	39.49	33.92	42.92	76.46	73.91	72.59	86.94	49.10	38.44	26.43	20.97
15	53.29	38.51	38.00	33.38	42.64	75.91	72.93	71.66	86.60	48.12	37.23	25.73	19.76
16	52.51	37.84	36.51	32.84	42.36	75.37	72.09	70.73	86.26	47.15	36.02	25.04	18.55
17	51.75	37.16	35.17	32.30	42.08	74.83	71.25	69.81	85.93	46.18	34.81	24.34	17.47
18	50.99	36.49	33.83	31.76	41.80	74.29	70.41	68.88	85.59	45.20	33.60	23.64	16.40
19	50.24	35.81	32.49	31.23	41.66	73.75	69.57	67.95	85.25	44.23	32.39	22.95	15.32
20	49.50	35.14	31.15	30.69	41.52	73.21	68.72	67.03	84.92	43.26	31.18	22.25	14.25
21	48.77	34.46	29.81	30.15	41.37	72.67	67.88	66.10	84.58	42.28	30.11	21.56	13.31
22	48.06	33.78	28.47	29.61	41.23	72.12	67.04	65.17	84.24	41.31	29.17	20.86	12.50
23	47.37	33.11	27.27	29.07	41.09	71.58	66.20	64.25	83.91	40.33	28.23	20.17	11.83
24	**46.72**	**32.43**	**26.08**	**28.53**	**40.95**	**71.04**	**65.50**	**63.40**	**83.57**	**39.50**	**27.42**	**19.47**	**11.16**
25	46.09	31.76	24.89	28.00	40.81	70.37	64.94	62.63	83.23	38.67	26.61	18.78	10.48
26	45.46	31.08	23.70	27.46	40.67	69.69	64.38	61.93	82.90	37.83	25.81	18.08	9.81
27	44.85	30.41	22.50	26.92	40.53	69.01	63.82	61.31	82.56	37.00	25.00	17.39	9.27
28	44.24	29.73	21.31	26.38	40.39	68.34	63.25	60.70	82.22	36.16	24.19	16.69	8.74
29	43.66	29.05	20.27	25.84	40.39	67.66	62.55	60.15	81.89	35.33	23.39	16.13	8.20
30	43.10	28.38	19.23	25.44	40.39	66.98	61.85	59.61	81.55	34.49	22.58	15.58	7.80
31	42.56	27.70	18.48	25.03	40.39	66.31	61.15	59.07	81.21	33.66	21.77	15.02	7.39
32	42.04	27.03	17.74	24.63	40.39	65.63	60.45	58.53	80.88	32.82	20.97	14.47	7.12
33	41.55	26.35	17.14	24.23	40.39	64.95	59.75	57.99	80.54	31.99	20.30	14.05	6.99
34	41.09	25.68	16.69	23.82	40.39	64.41	59.05	57.45	80.20	31.15	19.62	13.77	6.86
35	40.63	25.00	16.24	23.42	40.39	63.87	58.35	56.91	79.87	30.32	18.95	13.49	6.72
36	40.18	24.32	15.80	23.02	40.39	63.33	57.64	56.37	79.53	29.49	18.41	13.21	6.59
37	39.73	23.65	15.35	22.61	40.39	62.79	56.94	55.83	79.19	28.65	17.88	12.94	6.45
38	39.29	22.97	15.05	22.21	40.39	62.25	56.24	55.29	78.86	27.82	17.34	12.66	6.32
39	38.85	22.30	14.75	21.80	40.39	61.71	55.54	54.75	78.52	26.98	16.80	12.38	6.18
40	38.42	21.62	14.46	21.40	40.39	61.16	54.84	54.21	78.18	26.15	16.26	12.24	6.05
41	38.01	21.08	14.16	21.00	40.39	60.62	54.14	53.67	77.85	25.31	15.73	12.10	5.91
42	37.59	20.54	13.86	20.59	40.39	60.08	53.44	53.13	77.51	24.48	15.19	11.96	5.78
43	37.17	20.00	13.56	20.19	40.39	59.54	52.74	52.59	77.17	23.64	14.65	11.82	5.65
44	36.75	19.46	13.26	19.79	40.39	59.00	52.03	52.05	76.84	22.81	14.11	11.68	5.51
45	36.34	18.92	12.97	19.38	40.39	58.46	51.33	51.51	76.43	22.25	13.58	11.54	5.38
46	35.95	18.38	12.67	18.98	40.39	58.05	50.63	50.97	76.03	21.84	13.04	11.41	5.24
47	35.56	17.84	12.37	18.57	40.39	57.65	49.93	50.43	75.62	21.42	12.50	11.27	5.11
48	35.18	17.30	12.07	18.17	40.39	57.24	49.23	49.88	75.22	21.00	12.10	11.13	4.97

Table C 3. Probability (%) that the Significant Wave Height, $H_S \leq 3$ ft

Duration (hour)	Annual	January	February	March	April	May	June	July	August	September	October	November	December
1	10.47	4.60	0.15	4.98	3.93	20.84	10.52	16.29	22.76	11.82	6.45	2.36	2.96
2	8.97	3.92	0	3.50	2.67	17.46	8.28	14.75	20.40	10.29	5.11	1.67	2.55
3	8.04	3.51	0	2.83	2.10	15.43	6.87	13.67	18.59	9.46	4.44	1.39	2.29
4	7.32	3.11	0	2.29	1.82	14.07	6.03	12.82	17.10	8.62	3.90	1.11	2.02
5	6.68	2.84	0	1.88	1.54	12.86	5.19	11.97	15.69	8.07	3.63	0.83	1.75
6	6.08	2.57	0	1.48	1.26	11.64	4.35	11.20	14.41	7.51	3.36	0.56	1.48
7	5.52	2.30	0	1.08	0.98	10.56	3.65	10.43	13.13	6.95	3.23	0.42	1.34
8	5.02	2.03	0	0.67	0.70	9.74	2.95	9.73	12.05	6.40	3.09	0.28	1.21
9	4.63	1.89	0	0.40	0.56	9.20	2.38	9.11	11.25	5.84	2.96	0.14	1.08
10	4.29	1.76	0	0.27	0.42	8.66	1.96	8.57	10.51	5.42	2.82	0	0.94
11	3.99	1.62	0	0.14	0.28	8.12	1.68	8.11	9.83	5.01	2.69	0	0.81
12	3.71	1.49	0	0	0.14	7.58	1.54	7.72	9.16	4.59	2.55	0	0.67
13	3.45	1.35	0	0	0	7.04	1.40	7.41	8.49	4.17	2.42	0	0.54
14	3.21	1.22	0	0	0	6.50	1.26	7.10	7.88	3.76	2.29	0	0.40
15	2.98	1.08	0	0	0	5.95	1.12	6.80	7.27	3.48	2.15	0	0.27
16	2.76	0.95	0	0	0	5.41	0.98	6.49	6.73	3.20	2.02	0	0.13
17	2.55	0.81	0	0	0	4.87	0.84	6.26	6.20	2.92	1.88	0	0
18	2.36	0.68	0	0	0	4.33	0.70	6.02	5.72	2.64	1.75	0	0
19	2.20	0.54	0	0	0	3.92	0.56	5.79	5.32	2.36	1.61	0	0
20	2.04	0.41	0	0	0	3.65	0.42	5.56	4.92	2.09	1.48	0	0
21	1.88	0.27	0	0	0	3.38	0.28	5.33	4.51	1.81	1.34	0	0
22	1.72	0.14	0	0	0	3.11	0.14	5.10	4.11	1.53	1.21	0	0
23	1.56	0	0	0	0	2.84	0	4.87	3.70	1.25	1.08	0	0
24	**1.42**	**0**	**0**	**0**	**0**	**2.57**	**0**	**4.63**	**3.30**	**0.97**	**0.94**	**0**	**0**
25	1.29	0	0	0	0	2.30	0	4.40	2.96	0.70	0.81	0	0
26	1.18	0	0	0	0	2.03	0	4.17	2.76	0.42	0.67	0	0
27	1.09	0	0	0	0	1.76	0	3.94	2.63	0.28	0.54	0	0
28	1.00	0	0	0	0	1.49	0	3.71	2.49	0.14	0.40	0	0
29	0.91	0	0	0	0	1.22	0	3.48	2.36	0	0.27	0	0
30	0.83	0	0	0	0	0.95	0	3.24	2.22	0	0.13	0	0
31	0.75	0	0	0	0	0.68	0	3.01	2.09	0	0	0	0
32	0.69	0	0	0	0	0.54	0	2.78	1.95	0	0	0	0
33	0.63	0	0	0	0	0.41	0	2.55	1.82	0	0	0	0
34	0.58	0	0	0	0	0.27	0	2.39	1.68	0	0	0	0
35	0.53	0	0	0	0	0.14	0	2.24	1.55	0	0	0	0
36	0.48	0	0	0	0	0	0	2.09	1.41	0	0	0	0
37	0.44	0	0	0	0	0	0	1.93	1.28	0	0	0	0
38	0.40	0	0	0	0	0	0	1.78	1.15	0	0	0	0
39	0.36	0	0	0	0	0	0	1.62	1.01	0	0	0	0
40	0.32	0	0	0	0	0	0	1.47	0.88	0	0	0	0
41	0.28	0	0	0	0	0	0	1.31	0.74	0	0	0	0
42	0.24	0	0	0	0	0	0	1.16	0.61	0	0	0	0
43	0.20	0	0	0	0	0	0	1.00	0.47	0	0	0	0
44	0.17	0	0	0	0	0	0	0.85	0.40	0	0	0	0
45	0.14	0	0	0	0	0	0	0.70	0.34	0	0	0	0
46	0.11	0	0	0	0	0	0	0.54	0.27	0	0	0	0
47	0.09	0	0	0	0	0	0	0.46	0.20	0	0	0	0
48	0.07	0	0	0	0	0	0	0.39	0.14	0	0	0	0

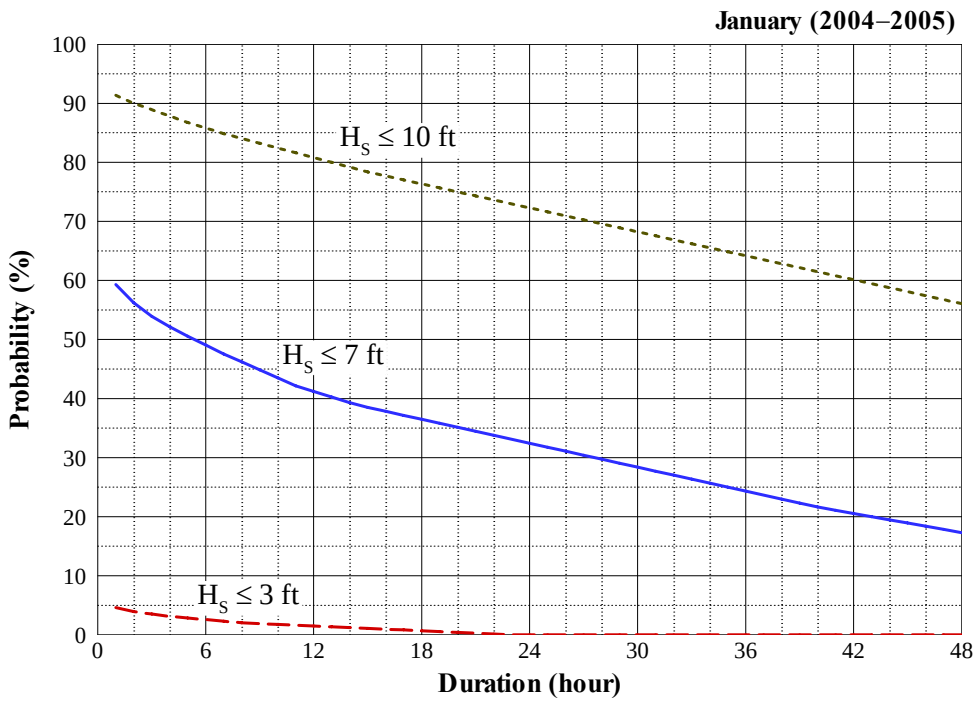

Figure C 1. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

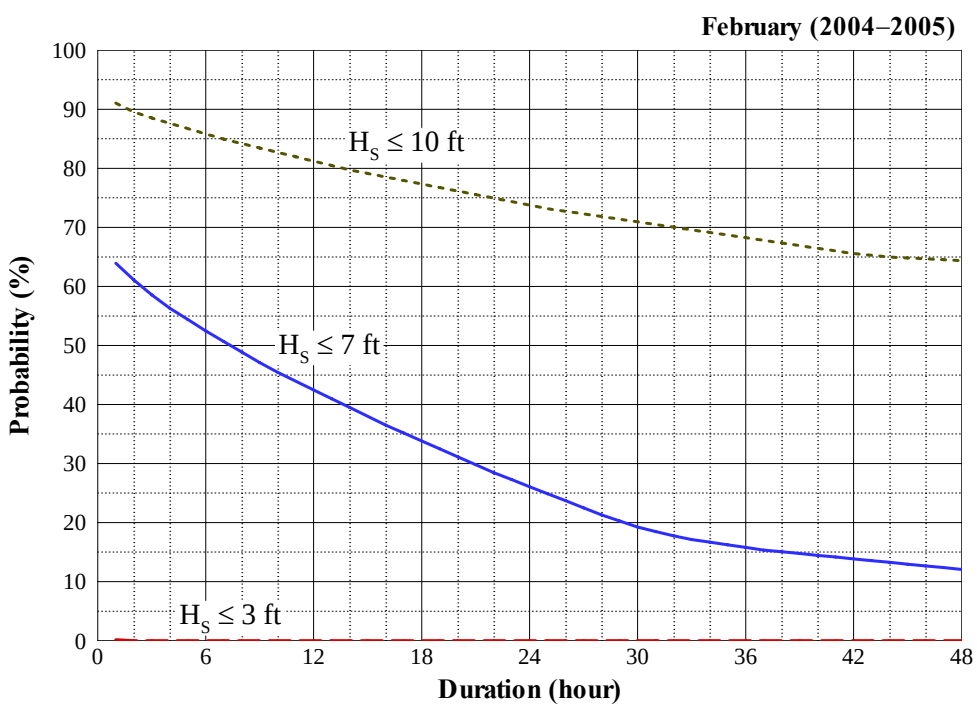

Figure C 2. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

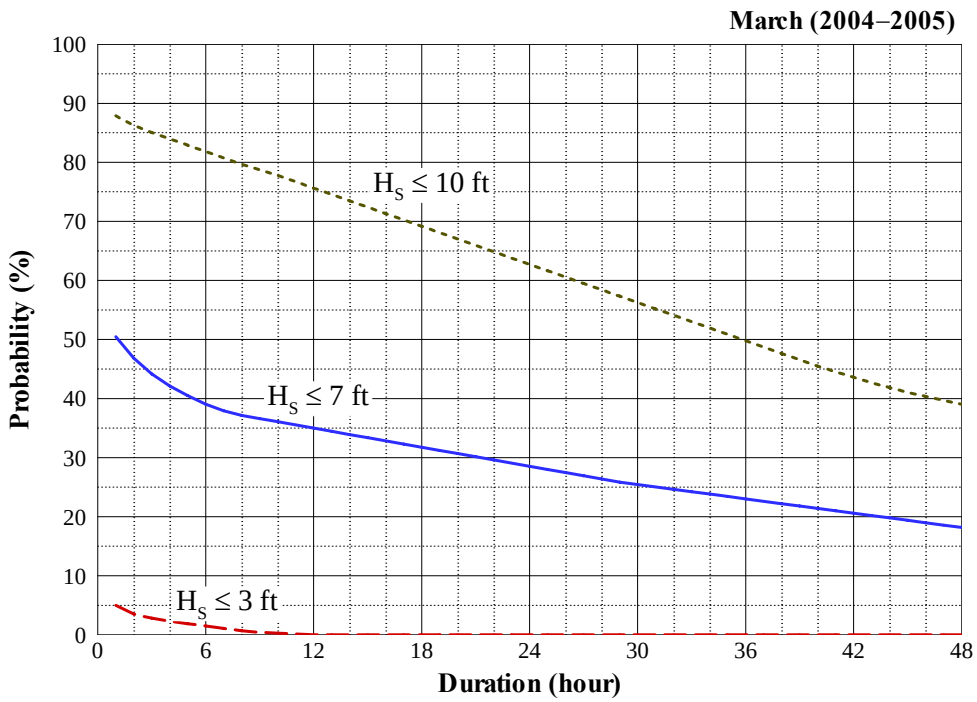

Figure C 3. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

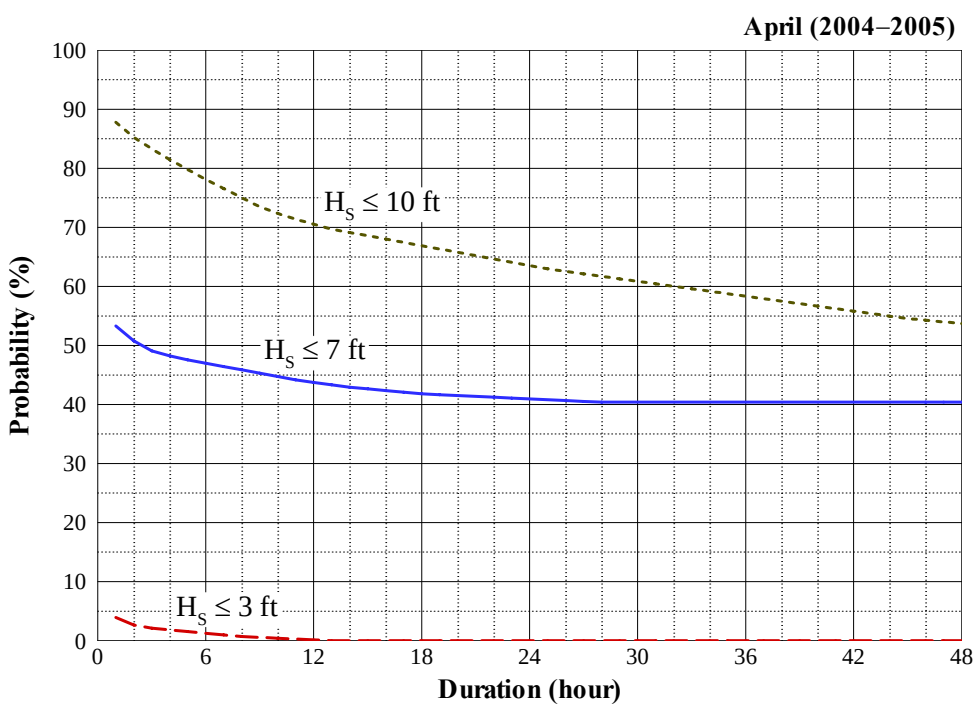

Figure C 4. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

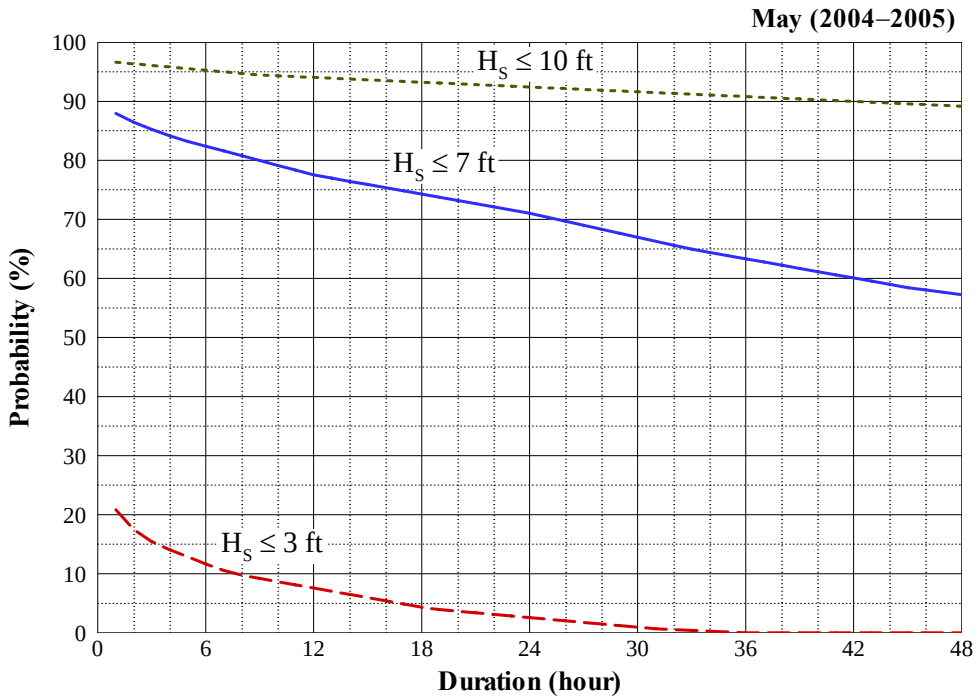

Figure C 5. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

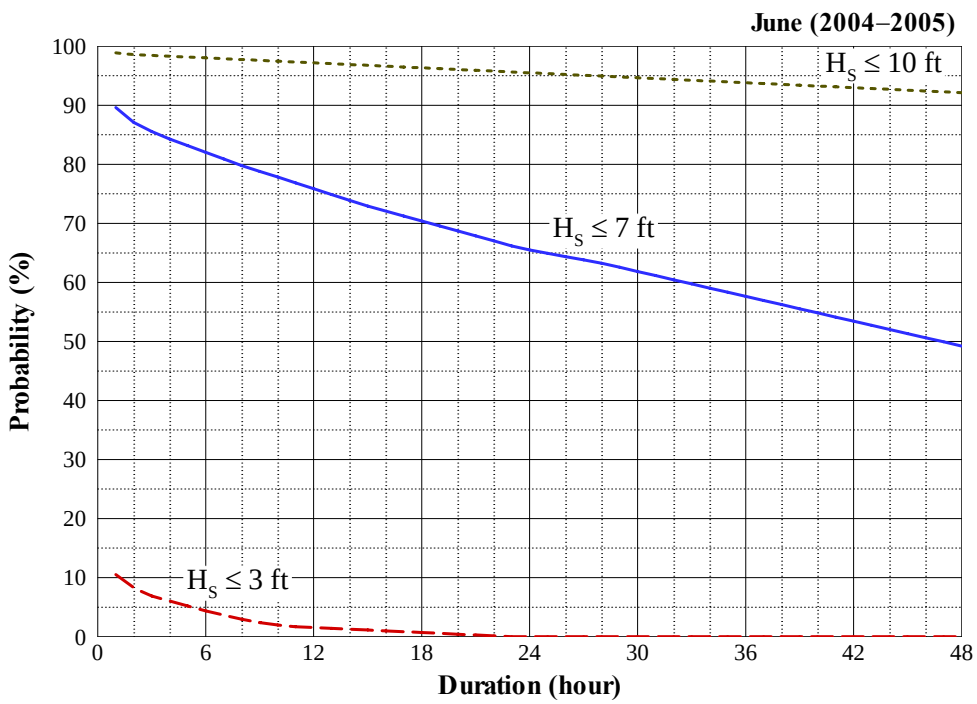

Figure C 6. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

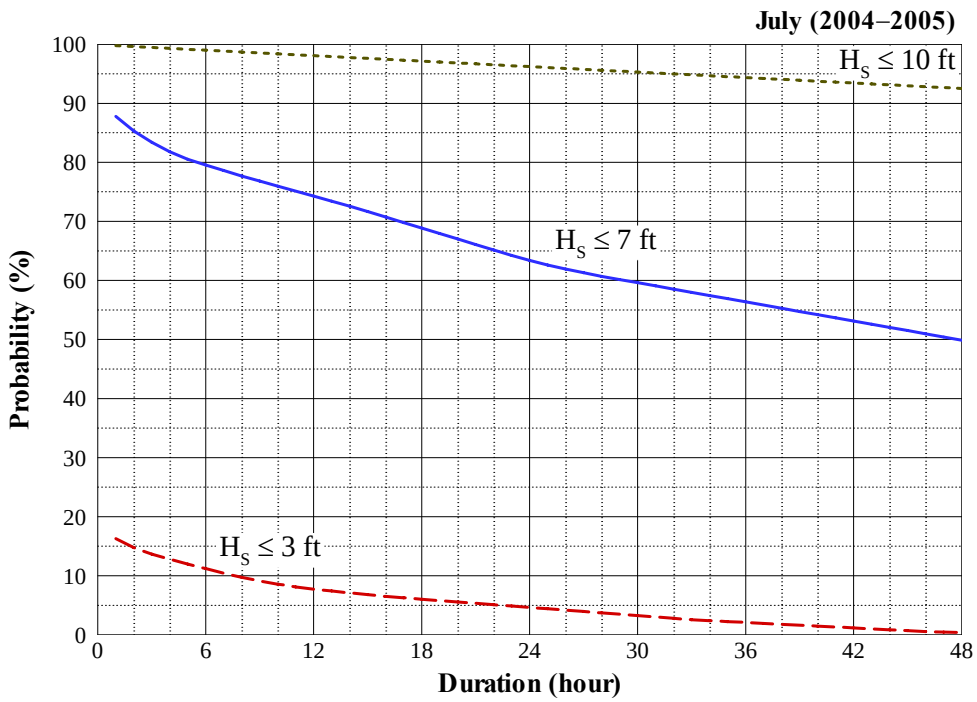

Figure C 7. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

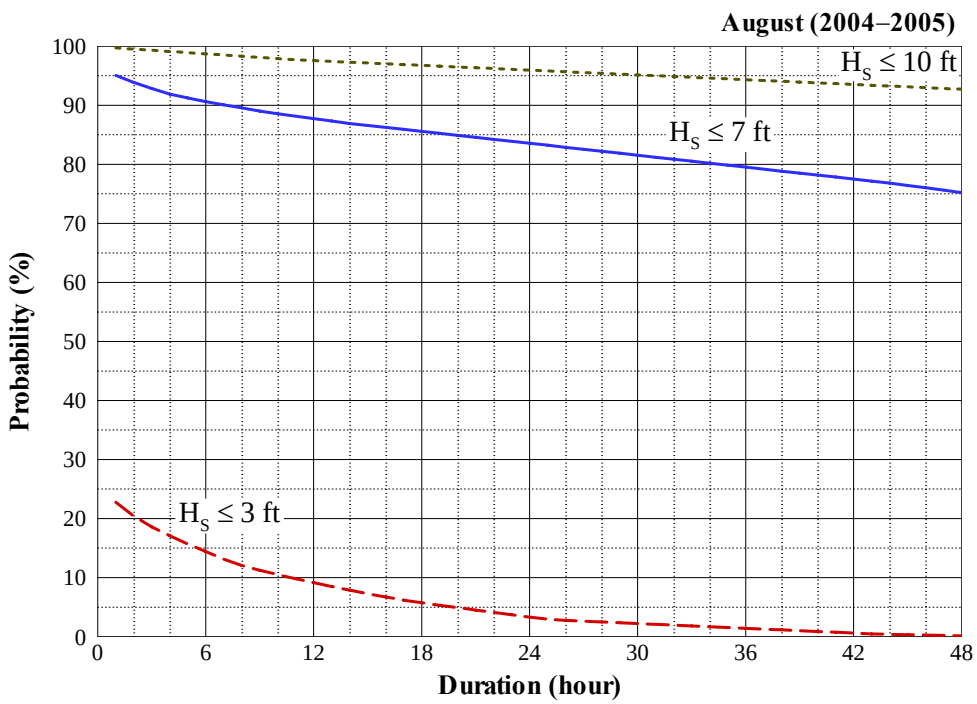

Figure C 8. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

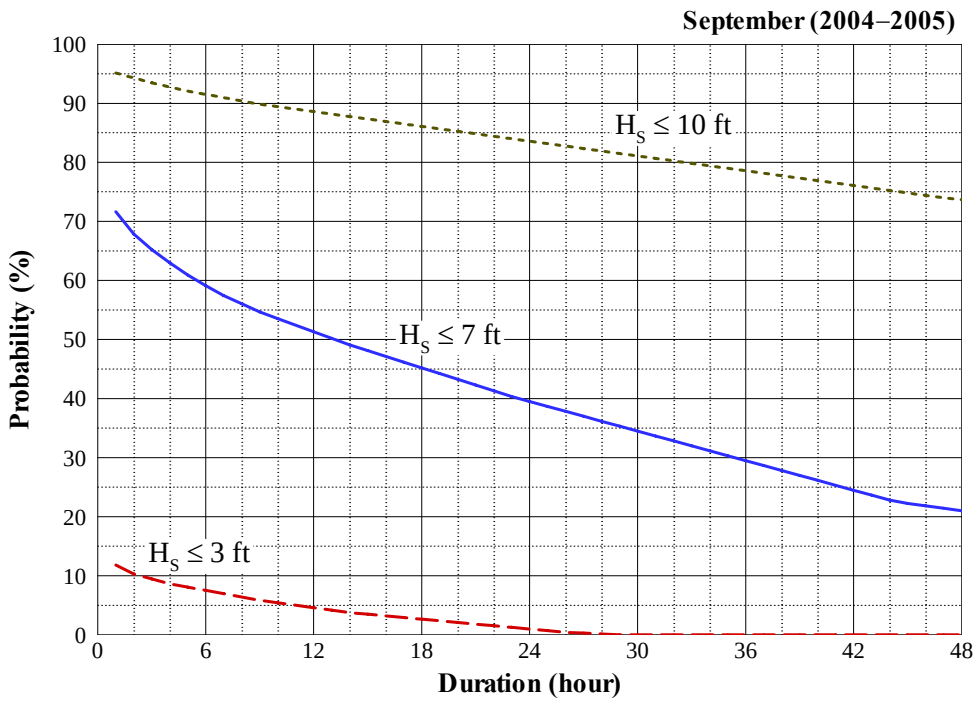

Figure C 9. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

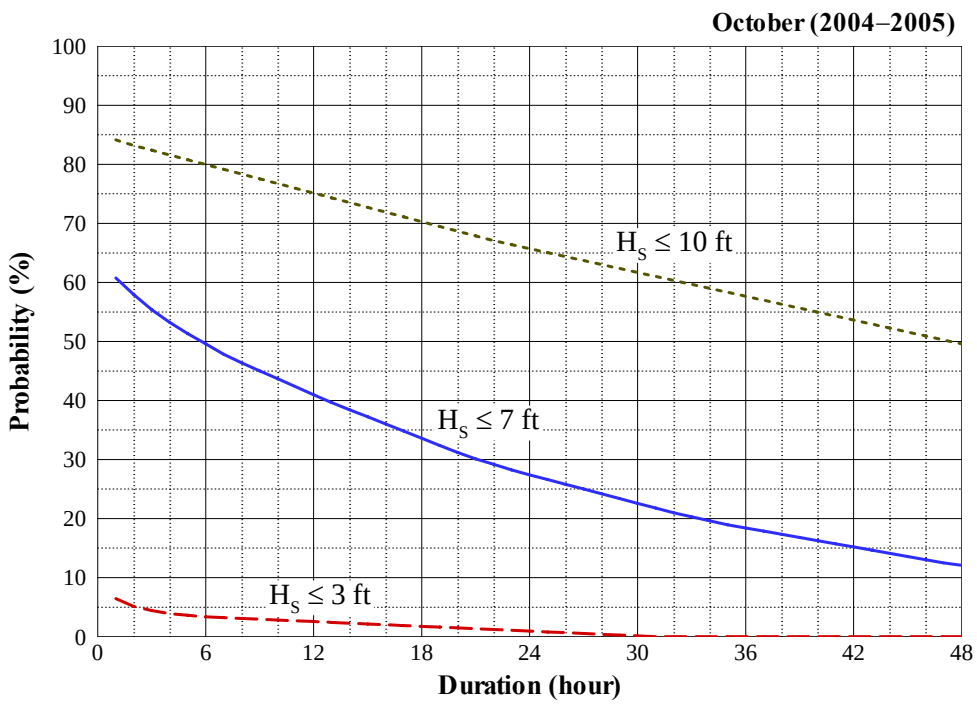

Figure C 10. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

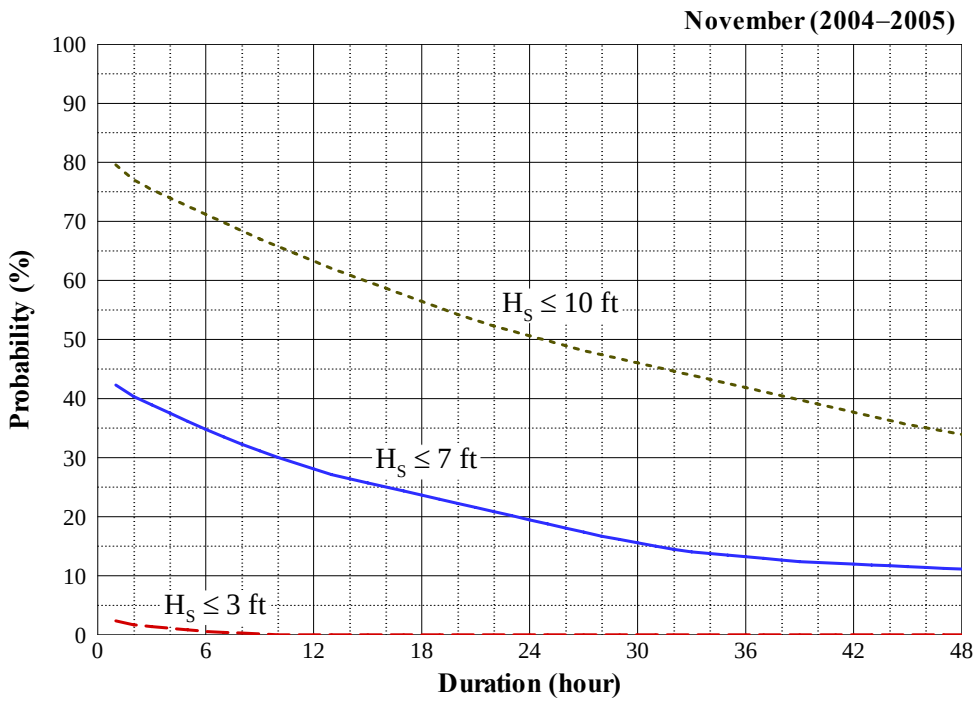

Figure C 11. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

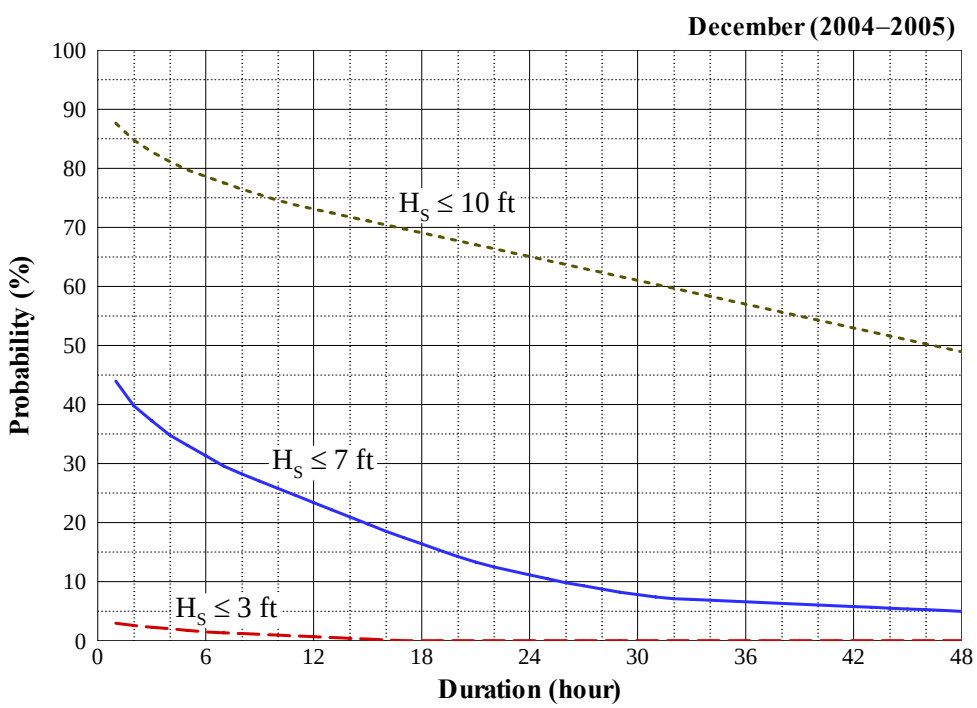

Figure C 12. Weather Operability for Fishing Vessels in the Vicinity of Neah Bay (From NDBC Buoy 46087)

SECTION 1

Historical Review of Spills in Washington State Waters and Elsewhere

A statistical analysis of spills greater than 1000 gallons revealed two trends: 1) Spill frequency and total volume both show a downward trend since 2000, and 2) there is a slight trend toward higher frequencies and volumes in the winter months.

A literature search produced several articles discussing how vessels of opportunity had been used in actual spill responses.

1.1 Summary Statistics and Overview of Databases Used

1986 to 2004 Spills

Historical data were obtained from Dr. Dagmar Schmidt Etkin on oil spills in Washington state waters from 1986 to 2004 in which vessels of opportunity may have been of assistance. For verification, these data were compared with data recorded by the United States Coast Guard (USCG) in its nationwide Marine Casualty and Pollution Database and with the list of selected spills from the Department of Ecology 1997 report "Oil Spills in Washington State: *A Historical Analysis.*" There were four records that were excluded from the dataset, two of which were spills outside Washington waters, and two of which contained clearly erroneous information concerning the spill size.

One event: Nestucca *spilled 227,000 gallons*

Spills that released less than 1,000 gallons of petroleum product into the water were excluded from this analysis. The 1,000-gallon lower limit for "significant" spills was selected to represent spills where multiple vessels would likely be engaged in a response operation. There were more than 80 significant spills in Washington waters from 1986 to 2004. These data are shown on Figure 1-1 as red dots, sized proportionally to the spill volume. Only spills for which latitude and longitude were known are shown on the map. These spills represent 58% of the total number of selected spills over 1,000 gallons, and 70% of the total volume spilled.

The largest single spill event in Washington State during the time period was 227,304 gallons. In December of 1988, the tank barge *Nestucca* spilled No. 6 fuel oil offshore at the entrance to Grays Harbor as a result of an allision.

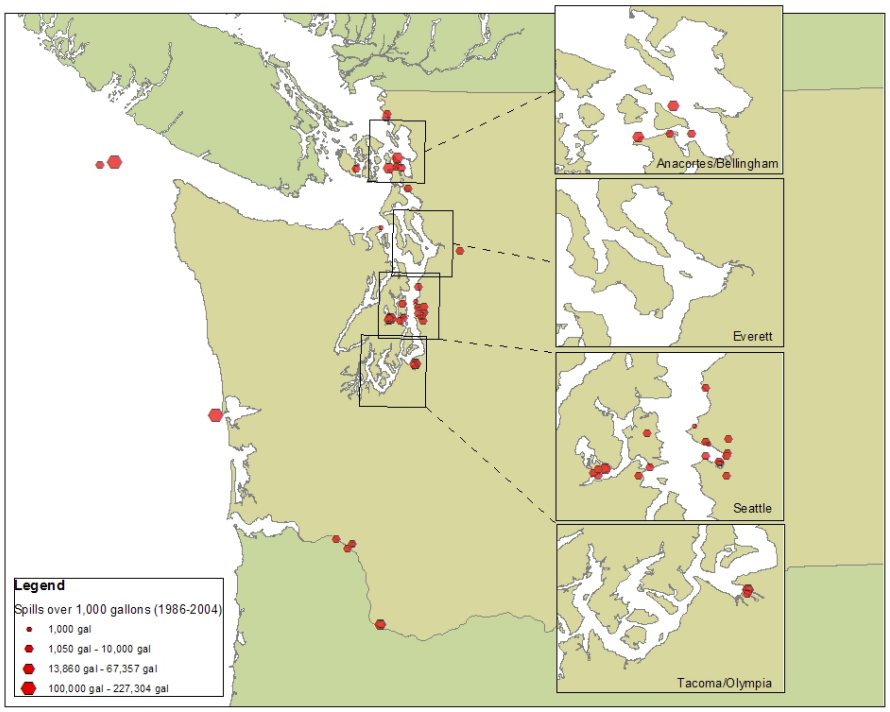

Figure 1-1: Distribution of historical spills 1986 to 2004 (> 1,000 gal)

1.2 Trends

Evidence of worst activity in winter

The plots below (Figure 1-2 and Figure 1-3) show the monthly and yearly spill event and spill volume distributions for the selected spills over 1,000 gallons. These plots show spills as a function of time of year. There appears to be a slight increase in number of spills and total quantity spilled in the winter months (December, January and February); however the correlation is not strong. June also exhibits relatively high spill activity measured both by number of events and total quantity spilled.

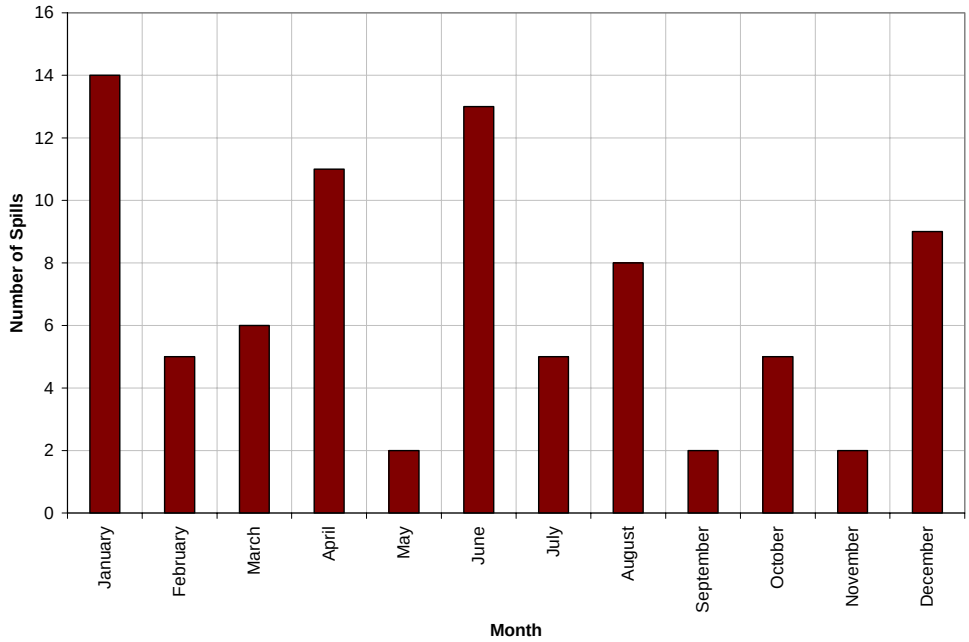

Figure 1-2: Number of spills by month 1986 to 2004 (> 1,000 gal)

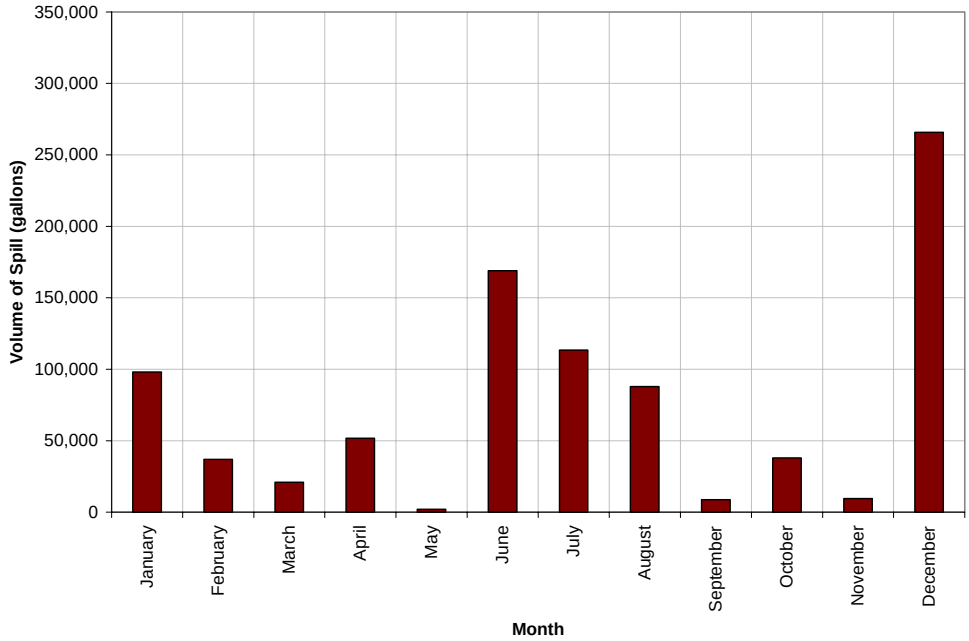

Figure 1-3: Volume of spills by month 1986 to 2004 (> 1,000 gal)

High variability year-to-year but declining since '2000

Figure 1-4 and Figure 1-5 show that the annual number of spills has, on average, been declining since 2000. A trend with respect to the annual volume of oil spilled is not apparent. It changes statistically from year to year. There is little correlation between the number of annual (or monthly) spill events and the annual (or monthly) volume of oil spilled.

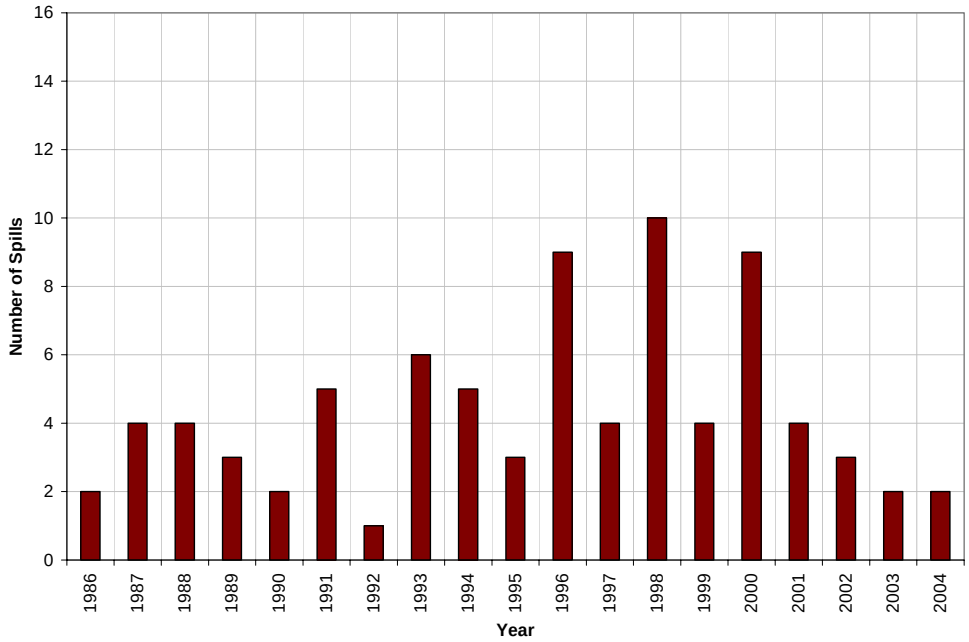

Figure 1-4: Number of spills by year (> 1,000 gal)

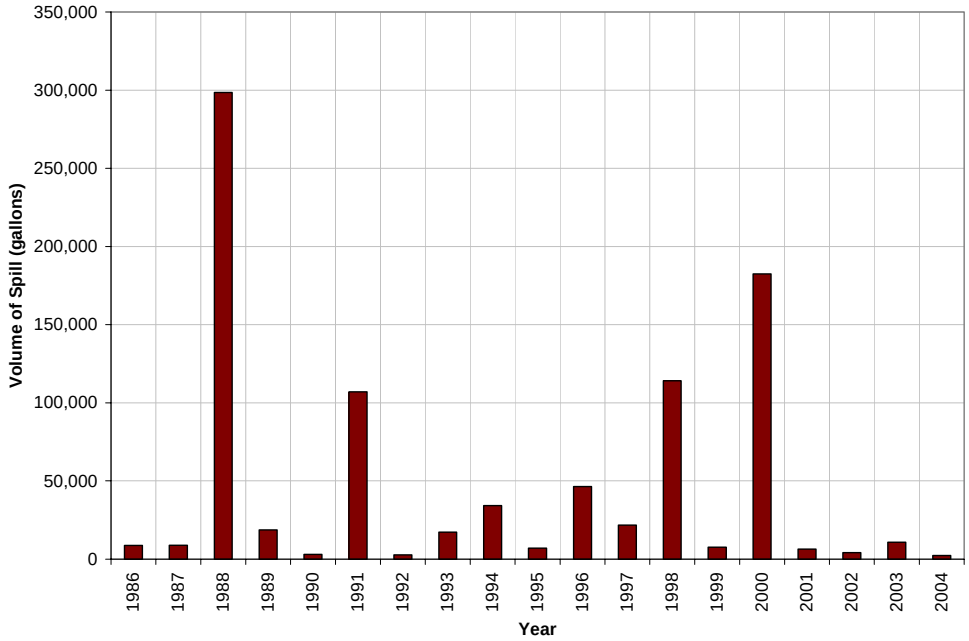

Figure 1-5: Volume of oil spilled by year (> 1,000 gal)

Figure 1-6 shows the volumetric distribution of the selected spills by product type. The plot shows that a significant portion of the spilled oil has been persistent, black oil (as opposed to gasoline and other light products), and requires aggressive spill response. Black oil is defined as crude oil, waste oil, fuel oil (not otherwise classified), and No. 5 or No. 6 Fuel Oil.

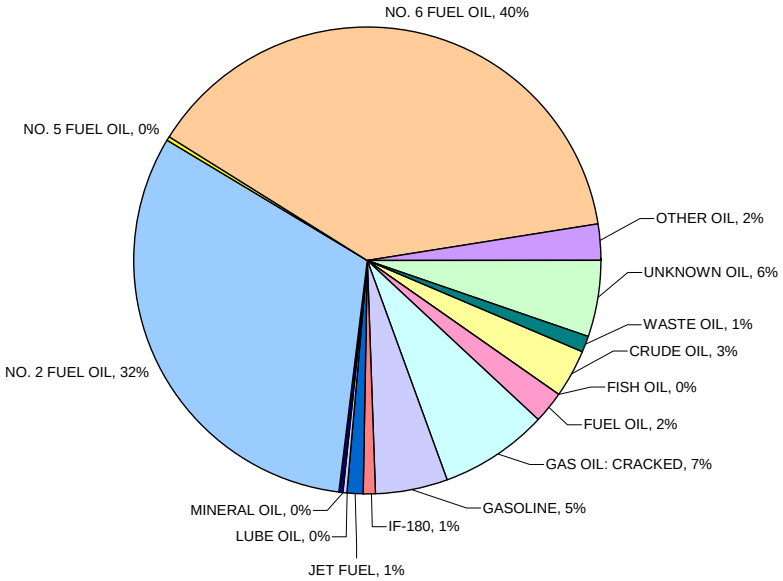

Figure 1-6: Spilled Oil by Category 1986 to 2004 (> 1,000 gal)

1.3 Lessons Learned from Spills beyond Washington State Waters

Few references to vessels of opportunity in literature

A broad-based literature search scanned more than a thousand papers and published articles worldwide. The search yielded few sources that discussed lessons learned in the use of vessels of opportunity. Those sources seem to indicate that fishing vessels (and other vessels of opportunity) can be used effectively in a response operation, but more for logistical duties than for recovery operations.

The one exception to this generalization is the response to the spill off Spain from *Prestige*. In that instance fishermen were actively engaged in on-water recovery, with remarkable success. No record was found documenting any difficulties the spill management team may have encountered in managing this resource.

Below are pertinent passages from this literature search.

1.3.1 Use of vessels of opportunity in actual spill response events

In the following cases, emphasis has been added in bold type.

- Brodie, Donald. "The *Kirki* Incident." Proceedings International Oil Spill Conference. Tampa, Florida. March/April 1993.

- "The offshore supply vessel *Lady Kathleen*, standing by an oil exploration venture off Freemantle, responded to the SOS and headed for the casualty, together with two other Freemantle-based vessels…. **United Salvage chartered *Lady Kathleen*** which reached *Kirki* when it was only eight miles from the coast and drifting towards the coastal reefs at 1.5 knots… Before abandoning the vessel, the crew of *Kirki* had not made suitable arrangements for boarding or taking the tanker in tow. This made connection extremely difficult in the weather conditions at the time, and *Lady Kathleen*'s master and crew displayed exceptional seamanship and courage in boarding and securing a tow line to the casualty" (p.202).

- "**Fishing vessels were chartered** to rig breaker boards of the Warren Spring type and to run through the thickest patches of oil closest offshore" (p.202).

- Cabioc'h, Fanch, Commander Nedellec, and Commissaire Lambert. "*Erika* vs. *Prestige*: Two similar accidents, two different responses. The French case." Proceedings International Oil Spill Conference. Miami Beach, Florida. May 2005.

Prestige – *Local fishermen had time to organize*

- Re: PRESTIGE, 2002: "Local authorities and fishermen had time to organize themselves and choose the best manual techniques to deal with the drifting oil. Their performance matched those of the specialized vessels. Basque fishermen took the lead in this party and some days, more than **200 Basque fishing vessels recovered up to 2,000 tons of emulsion and spoiled debris**… The organization of the recovery at sea guided by AZTI helicopters together with the waste management in harbours was impressing" (p.5).

Erika – *Fishing vessels were not used because of "no prior preparation"*

- Re: ERIKA, 1999: "**Fishing vessels or vessels of opportunity were not much used** during the ERIKA spill, mainly because there was no prior preparation to be on site in such a short period of time" (p.5).

- "**Vessels of opportunities and fishermen clearly have a role to play**, specially using nets, although these are only suitable for sticky and agglomerated pollutants" (p.6).

Table 1-1: Spill recovery amounts for Prestige and Erika spills

(all amounts in tons)	**PRESTIGE Wastes & emulsion**	**PRESTIGE Fuel**	**ERIKA Wastes & emulsion**	**ERIKA Fuel**
Specialized vessels unloading in Spain	14,946	5,381	-	-
Specialized vessels unloading in France	1,081	350	1,100	600
Specialized vessels unloading in Portugal	160	60	-	-
TOTAL Specialized vessels	**16,187**	**5,791**	**1,100**	**600**
Fishing boats unloading in Spain	34,924	15,737	-	-
Fishing boats unloading in France	1,363	500	-	-
TOTAL fishing vessels	**36,287**	**22,031**	**-**	**-**

Table 1-2: Assessment of clean-up for *Erika* and *Prestige* spills

	PRESTIGE	**ERIKA**
DRIFTING PROVISION (time before oil reached shore)	During 6 months	During 2 weeks
DRIFTING MANAGEMENT	Drifting committee Drifting buoys	Cedre and Meteo France
SHORE CLEANING	Efficient, slight tendency to beach over cleaning	Particularly efficient
WASTE MANAGEMENT	Fair Well organized	Poor 25,000 tons of waste
AT SEA RECOVERY	Excellent Good manage-ment of fishermen	Poor, but significant in terms of possibilities
COMMUNICATION	Daily situation charts on Cedre website	Poor at the beginning, no website

Shrimpers and fishing gear used for recovery

- Clark, Tricia, Beatrice Strong and Ben Benson. "Recovery of tarmats using commercial shrimping boats during the *Buffalo 292* spill." Proceedings International Oil Spill Conference. Ft. Lauderdale, Florida. April 1997.
    - "…a plan was developed to use vessels of opportunity in an attempt to utilize nets to snare and recover the tar mats… Basic operations consisted of towing a shrimp net between two shrimping vessels in a V-configuration, "trapping" the tar mats and patties in the mesh of the net, and then using dip nets to scoop the snared product into plastic bags. After a day of successful experimental operations, it was decided that **shrimp boats could be used as platforms to continue offshore recovery operations**, once a few modifications could be made according to the experience gained during the first day's operations. A night crew further developed a net system that was specifically geared toward recovery of the tar mats and patties. A section of a bale of fish net made of #12 nylon twine in a 1.75-inch mesh size in a length of 75 to 100 feet long by 22 feet wide was folded over three times, giving crews a net approximately 75 to 100 feet long by 7 feet wide with a very tight (less than 1 inch) mesh. A 0.25-inch galvanized chain was run through the bottom to serve as ballast to keep the net stretched down into the water, with a 0.50-inch poly rope woven through the top with fish floats for flotation of the top portion" (pp. 44, 49).
    - "Responders also found that tying pompom snare to the net helped with recovery. The tar mats and patties became entangled in the pompom snare and were less likely to be broken up by the net as it encountered them. Crews were also able to cut the soiled pompoms off the net, thus allowing the net to be used again" (p.49).
    - "After day 1 of the…operation , it was decided that support platforms would be necessary to make the response more efficient. **Two work boats were employed: one to serve as a command center for the operations and the other to act as the central staging area**" (p.49).
    - Central staging area vessel:
        - "eventually supplied with all necessary equipment needed to sustain the recovery operation: food, personal protective equipment, dip nets, roll-off boxes, plastic bags, and so on" (p.49).

- "A lined roll-off box…served as temporary storage for the recovered product and soiled pompom snare, which was unloaded at night while the staging vessel was being prepared for the next day's operation" (p.49).

Jon boats deployed from staging vessel

- "Crews in jon boats were deployed (weather permitting) from the staging vessel to assist the shrimp boats in maneuvering the recovery nets, in addition to using dip nets to pick up smaller patties and tar balls" (p.49).

- Command center vessel:

Cell phones found useful

  - "For maximum recovery potential, a helicopter was used to spot the concentrations of tar mats and to relay the GPS location to the command center vessel…via radio…[The command center vessel] would then direct the shrimp vessel captain to the latitude and longitude given by GPS via cellular phone,…" (p.49).

- "Recovery operations [on the vessels] were manned by contractor cleanup crews. Each vessel carried a crew of six to eight response technicians. These response personnel were not used to performing manual cleanup operations on small vessels under the sea conditions encountered during this response. As a result, seasickness was a continual problem" (p.49).

- "Heath and safety personnel (certified paramedics) were permanently assigned to the…fleet during the entire operation and were based on the command vessel…These personnel carefully monitored the seasickness problems of the crew and ceased operations if conditions warranted. In addition to the monitoring program, crew work shifts were modified to accommodate each individual's ability to work in a given sea state" (p.49).

- "To further maximize crew safety, the deck had to be continually maintained with fresh sorbent materials to prevent slips, trips, and falls" (p.49).

- "In using the **shrimp boats**, no extraordinary problems were encountered during the decontamination process. Both work crews and **decontamination personnel had to give careful attention to wooden surfaces**. In addition, the specially rigged **nets were deemed** suitable only for recovery of the tar mats and patties; obviously, after being used to recover

hydrocarbons, they were **unsuitable for further use** in the commercial shrimping industry and were disposed of" (p.49).

- "**Another issue that had to be dealt with was payment of the crew…Traditionally boat crews receive payment at the time the catch is sold, usually daily, and in this case they were caught unaware when the contracts specified payment otherwise**" (p.49).
- "Although it was not anticipated that large volumes of tar mats would be recovered, any oil kept off the shoreline was considered a success" (p.49).

- Smith, Joseph BH, Capt. Richard J Asaro, and Cdr. Harlan Henderson. "Oil, rats and salvage: The grounding of the *Hyundai #12*." Proceedings International Oil Spill Conference. Tampa, Florida. March/April 1993.
  - "Because fishing season had just ended, vessels were readily available locally" (p.214).
  - "…a **chartered fishing vessel was moored alongside the ship to serve as a platform for divers** conducting a hull survey" (p.214).
  - "**Pollution contractor crews were transported to the fishing vessels**, and deployment of containment boom was begun in the sensitive areas" (p.216).
  - "The successful mitigation of the grounding of the *Hyundai #12* can be attributed in large part to cooperation among the dozens of public and private entities involved in the response" (p.216).

1.3.2 Use of fishing nets for heavy oil recovery

Additional experience using fishing nets for recovery

- Brown, HM and RH Goodman. "The recovery of spilled heavy oil with fish netting." Proceedings International Oil Spill Conference. San Antonio, Texas. February 1989.
  - "Three nets, each 10 m long by 0.5 m wide and of different mesh sizes, were used in the tests. Fifty elliptical Styrofoam floats sewn into the upper hem provided a buoyancy of 2.5 kg/m and resulted in a freeboard of about 5 cm and a draft of 50 cm. The mesh sizes and construction details were as follows:

- Net No. 1 (fine net): two layers of ¼ inch braided nylon (type 210/9) with 1 mm twine and effective hole size of 1 mm by 1 mm.
- Net No. 2 (medium net): one layer of ¼ inch braided nylon with 1 mm twine and 1.9 mm by 1.9 mm hole size.
- Net No. 3 (coarse net): one layer of ½ inch braided nylon (type 210/10) with 1.2 mm twine and 5.5 mm by 5.5 mm hole size" (p.123).

- "Although this study of net capabilities was a preliminary one, some useful observations can be made.

  1. Sprayed Cold Lake bitumen, which will float initially, may be collected easily with any net.
  2. Spilled liquid oil was neutrally buoyant and floated as large semi-submerged globules. This oil could be corralled by the nets, and when fresh, adhered to them readily.
  3. There was no oil leakage with the fine net at speeds of up to 0.3 m/s and small but possibly acceptable leakage with the medium mesh net.
  4. Slightly weathered globules of oil appeared to have a viscous skin that retarded extrusion through the net.
  5. The empirical equation of Delvigne appears to overestimate the leak rate for Cold Lake bitumen.
  6. The nets were easily deployed and towed well through the water.
  7. Up to about 30 kg/m^2 of oil adhered to the net without seriously affecting its towing characteristics.
  8. Measured towing stresses are lower for the nets than for similarly sized booms.
  9. Heavily oiled nets were difficult to remove from the water, and showed some loss of oil.
  10. Without a special cleaning apparatus and the use of solvents, it does not appear that the nets can be successfully cleaned" (p.125-6).

1.3.3 Vessel shortages identified in spills

Landing craft, tank vessels and general logistics vessels in short supply

The most frequently reported shortages in spill response vessels were tank vessels (for temporary storage of recovered oil) and landing craft style vessels (supporting beach cleanups). Unfortunately, neither of these shortages would be alleviated with a formal fishing vessel program. Other common shortages were a lack of transportation vessels for equipment, consumables and personnel. In particular, larger spills frequently required the movement of people to disparate locations: reinforcement responders, regulators (shoreline cleanup assessment teams), wildlife recovery specialists and other observers.

These logistical shortages could benefit from a formal fishing vessel program.