

**VESSEL SUITABILITY STUDY
OF “SITKA-CLASS”
FAST VEHICLE FERRY OPERATION
IN PRINCE WILLIAM SOUND**

Prepared for

**Parsons Brinckerhoff
Seattle, Washington**

File No. 97077A
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Principal-in-Charge

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VESSEL SUITABILITY STUDY OF “SITKA-CLASS” FAST VEHICLE FERRY OPERATION IN PRINCE WILLIAM SOUND

SUMMARY

The suitability of the AMHS “Sitka-class” fast vehicle ferry (FVF) has been reviewed for year-round service in Prince William Sound in accordance with the recommendations of the Prince William Sound transportation master plan. The review focused on seakeeping and passenger comfort, cold weather impacts on on-board systems, and issues associated with floating ice. The principal findings and recommendations are as follows:

Seakeeping and Passenger Comfort

The statistics of significant wave heights in Prince William Sound are comparable to those for Southeast Alaska (e.g., Chatham Strait), but the wave periods are longer, reflecting the penetration of ocean swells through Hinchinbrook Entrance into central Prince William Sound. The suitability of the “Sitka-class” FVF for year-round service in Prince William Sound depends on exposure time. FVF transit times between Prince William Sound ports exceed two hours but the crossings of the central sound are on the order of one hour. At two-hour exposure, indications are that both active trim tabs and T-foils would be necessary to meet passenger comfort goals, but at one-hour exposure active trim tabs alone would suffice. The “Sitka-class” FVF is to be delivered with active trim tabs and foundations for a possible future installation of T-foils. It is recommended that the design-build contractor awarded the FVF be commissioned to prepare a supplemental seakeeping and passenger motion sickness incidence report for operations on Prince William Sound.

Snow Loads

Snow loads at Valdez are 242% greater than those at Juneau and snow loads at Cordova are 43% greater than those at Juneau. It is recommended that the design-build contractor awarded the FVF be commissioned to prepare a supplemental report describing any changes necessary for the “Sitka-class” FVF to operate in the presence of these higher snow loads.

Air and Seawater Temperatures

Air and seawater temperature distributions are comparable to those in Southeast Alaska and consistent with the AMHS Owner Requirements for the FVF. There is no indication that there are any design impacts on the FVF from air or seawater temperatures in Prince William Sound.

Floating Ice

Compared to AMHS operations in Southeast Alaska there is a greater presence of floating glacial ice in Prince William Sound. The “Sitka-class” FVF will be provided with a marine infrared imaging system capable of detecting floating ice as well as two pairs of night vision binoculars. During development of the AMHS FVF Owner Requirements, forward scanning sonars were investigated as a possible means to detect floating glacial ice and other debris. The conclusion at that time was that, while there were promising technologies under development, none was close to proven or close to production. In consideration of the greater hazard represented by floating ice in Prince William Sound, before any FVF is introduced into year-round service there, it is suggested that forward scanning sonar technologies again be reviewed to determine if useful products are available.

VESSEL SUITABILITY STUDY OF “SITKA-CLASS” FAST VEHICLE FERRY OPERATION IN PRINCE WILLIAM SOUND

1. INTRODUCTION

The Prince William Sound and Copper River area transportation master plan has identified improved ferry service in Prince William Sound as a recommended alternative. Specific recommendations are for improved ferry service based on the introduction of up to two high-speed roll-on/roll-off (Ro/Ro) passenger ferries, also known as fast vehicle ferries or FVFs. During the peak season one FVF would operate as a shuttle between Whittier and Valdez and the second FVF would operate on a loop route between Cordova, Valdez and Whittier. Service would also be provided periodically to Chenega and Tatitlek. During the off-season the Whittier-Valdez shuttle service would be discontinued and the FVF assigned to that service could act as a relief vessel as each FVF in the AMHS system is cycled through annual maintenance.

Amendment 10 (revised 26 October 2000) to the Scope of Services for the PWS/CR Transportation was for a Vessel Suitability Study (VSS) to assess the suitability of the “Sitka-class” FVF in Prince William Sound Service. Specific issues to be addressed included:

- Seakeeping and expected motion sickness incidence
- Cold weather impacts on on-board systems (e.g., space heating)
- Issues associated with floating ice

2. SITKA-CLASS FAST VEHICLE FERRY

The “Sitka-class” FVF is being acquired by Alaska Department of Transportation and Public Facilities, Alaska Marine Highway System, using a design-construct procurement process. AMHS issued a Request for Proposal (RFP) for the FVF using functional and performance based technical specifications. Technical proposals from five designer/shipyard teams have been received as outlined below.

TABLE 1

Proposal No.	Shipyard	Design Agent
1	Dakota Creek Industries, Inc.	Advanced Multihull Design (AMD)
2	Nichols Brothers Boatbuilding, Inc.	International Catamaran Design Pty., Ltd. (INCAT)
3	Austal U.S.A.	Austal Ships, Ltd.
4	Eastern Shipbuilding Group	Scheilde/Elliott Bay Design Group
5	R.E. Derecktor Shipyards, Inc.	Nigel Gee and Associates, Ltd.

Following an extensive review process, on 24 January 2001 Alaska DOT&PF announced that proposals submitted by Nichols Brothers Boatbuilding, Inc., of Whidbey Island, Washington, and R.E. Derecktor Shipyards, Inc., of Mamaroneck, New York, were in the “competitive range” according to the quantitative measures contained in the State’s Fast Vehicle Ferry (FVF) Request for Proposal solicitation and have been advanced to Step 2 in the procurement process. Following several months of additional design discussions necessary to address remaining DOT&PF comments on the submitted proposals, these two shipyard teams will submit cost proposals for their detailed design and construction of the first FVF, the Sitka shuttle. The RFP also contained options for construction of two follow-on FVFs, should DOT&PF and the winning design/build shipyard determine that exercise of these options is to the mutual benefit of both parties. The anticipated award of a contract for the first FVF will be not later than 1 May 2001. The target commencement of revenue service is the summer of 2003.

The principal characteristics required of the “Sitka-class” FVF are as follows:

TABLE 2

Hull Type	Catamaran
Passenger Capacity	250
Vehicle Capacity	30 Alaska Standard Vehicles and 3 small truck trailers (trailers @ 30,000 pounds each)
	30 Alaska Standard Vehicles and 2 small trailers (trailers @ 45,000 pounds each)
	35 Alaska Standard Vehicles
	30 Alaska Standard Vehicles and 1 large truck trailer
	20 Alaska Standard Vehicles, 2 small truck trailers and 6 recreational vehicles (RVs)
Speed	36.5 knots at 100% main engine ferry rating on sea trials
	35.0 knots at 90% main engine ferry rating on sea trials
	32.0 knots service speed in waves with 4.0 foot significant wave height and 21 knot head winds
Fuel capacity and range	Fuel capacity sufficient for a 270 n.m. round trip under service conditions with 37% residual fuel at the end of the day. (This is sufficient to make feasible the 312 n.m. round trip run between Sitka and Petersburg with at least 10% residual fuel at the end of the day.)

TABLE 2 Continued

Seakeeping	Safely operable through conditions characterized by a significant wave height of 2.0 meters (6.6 feet)
Passenger comfort (ride quality)	Motion sickness incidence (MSI) less than 10% for two hours exposure in head or following seas characterized by a significant wave height of 2.0 meters (6.6 feet) with peak (a.k.a. modal) periods anywhere between 4 and 6 seconds
Climatic data for HVAC design	Summer Season: Outside Air Dry Bulb 70° F (60% RH) Seawater 65° F
	Winter Season: Outside Air Dry Bulb -10° F (100% RH) Seawater 28° F

The environmental conditions for seakeeping and passenger comfort – significant wave heights of 2.0 m (6.6 feet) with peak (a.k.a. modal) periods anywhere between 4 and 6 seconds – were selected to correspond to 95% operability on an annual basis and/or 90% operability during the worst month, in Chatham Strait north of the juncture with Peril Strait.

3. PRINCE WILLIAM SOUND CLIMATOLOGY

As shown in Figure 1, National Data Buoy 46060 is centrally located in Prince William Sound and buoy 46061 is located just outside Hinchinbrook Entrance.

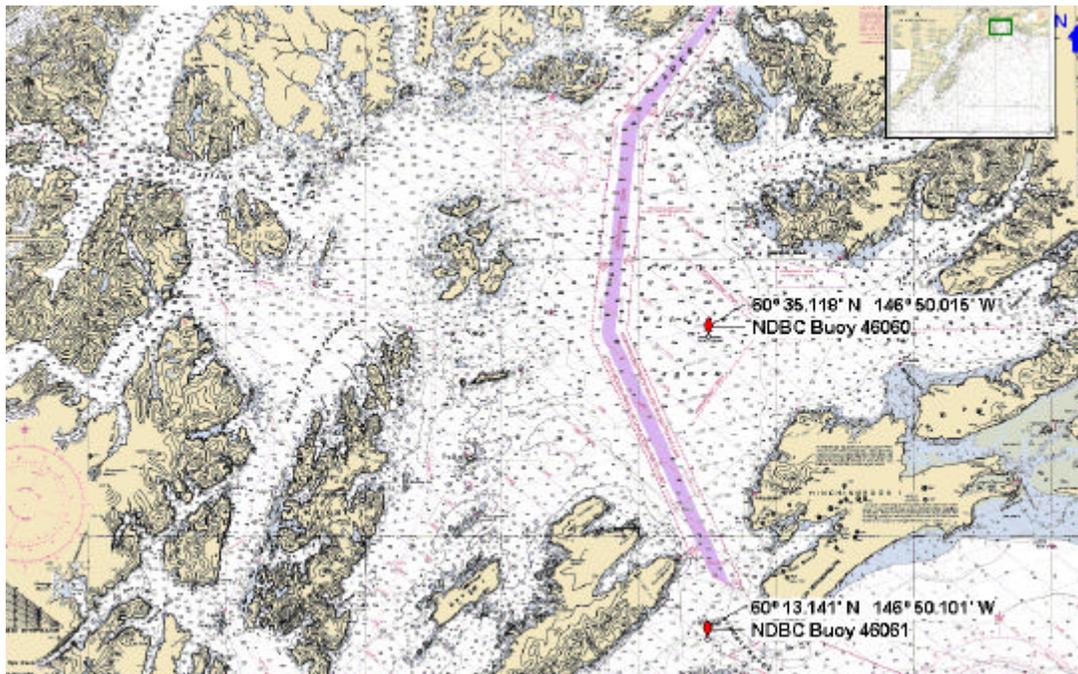


FIGURE 1 - Prince William Sound Data Buoys

Wind and wave climatology has been statistically summarized from hourly records by National Data Buoy 46060 located at 60.58 N 146.83 W (60°34'45"N 146°50'04" W) in the middle of Prince William Sound. Station 46060, shown in Figure 2, is a 3-meter discus buoy owned and maintained by National Data Buoy Center. The anemometer is located at a height of 5 meters above sea level. The buoy is moored in water with a depth of 1,500 feet.

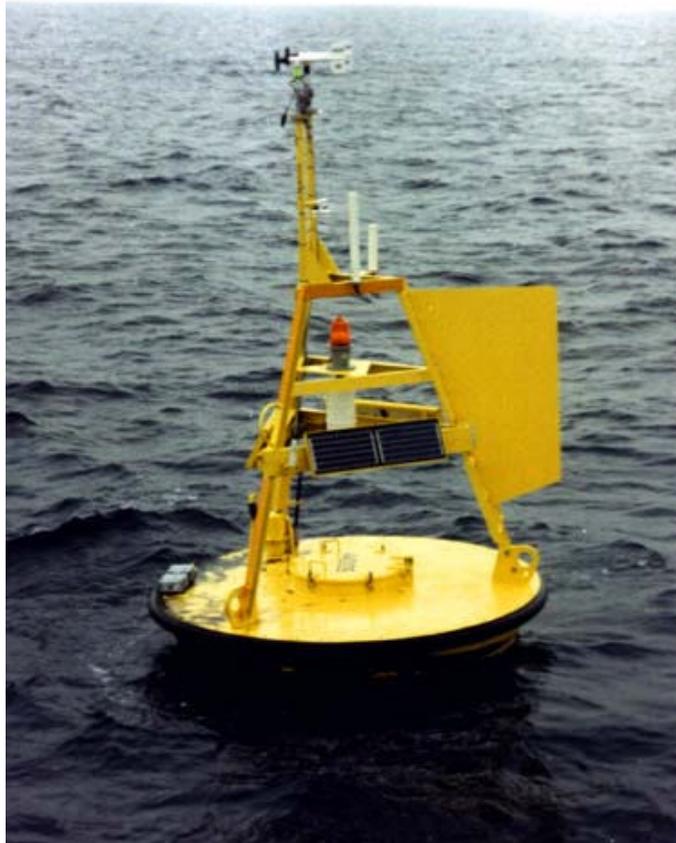


FIGURE 2 - Data Buoy 46060 in Prince William Sound

Complete data years for buoy 46060 were available for 1996, 1997, 1998 and 1999. In addition, a partial data year is available for 1995.

Wind Climatology

The joint annual distribution of wind speed and direction is given in Figure 3. For detailed breakdown by month, see Appendix 1.

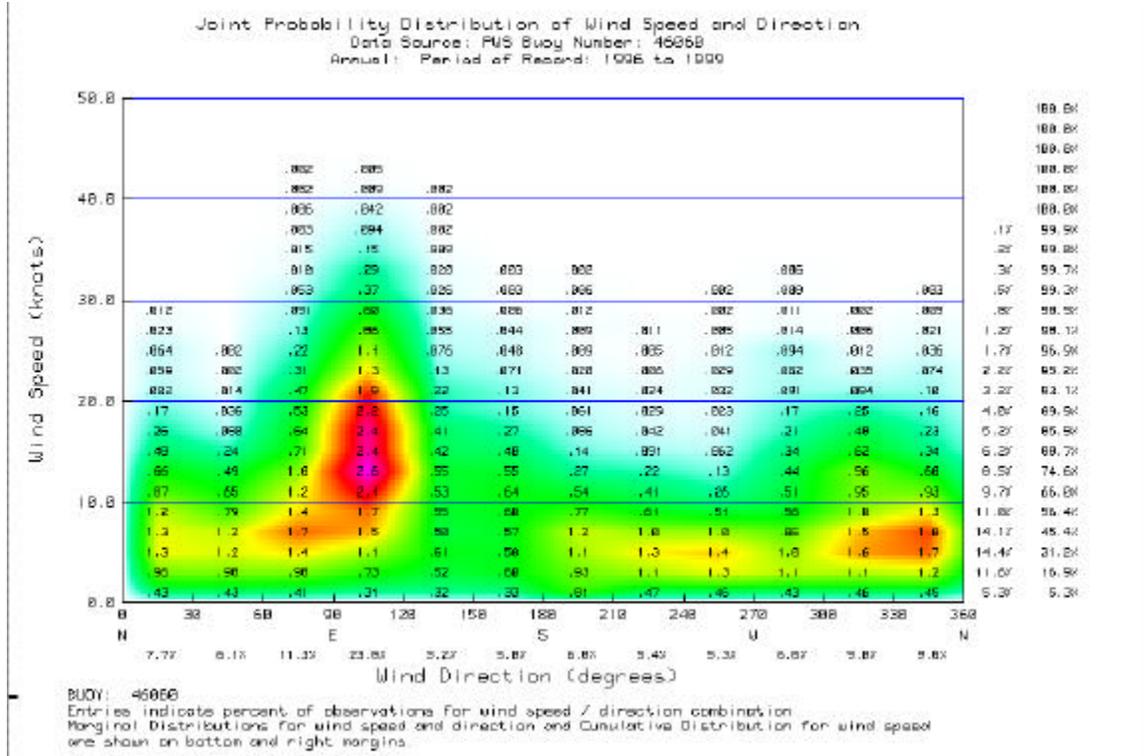


FIGURE 3
Annual - Joint Distribution of Wind Speed and Direction

This shows a dominant wind direction of about ESE (105 degrees) with a modal (most frequently occurring) wind speed of about 14 knots. A secondary mode for wind direction is located in the vicinity of NNW (approximately 345 degrees) but that peak is associated with reduced wind speeds.

Wave Climatology

The joint annual distribution of significant wave height and average wave period is given in Figure 4. For detailed breakdown by month, see Appendix 2.

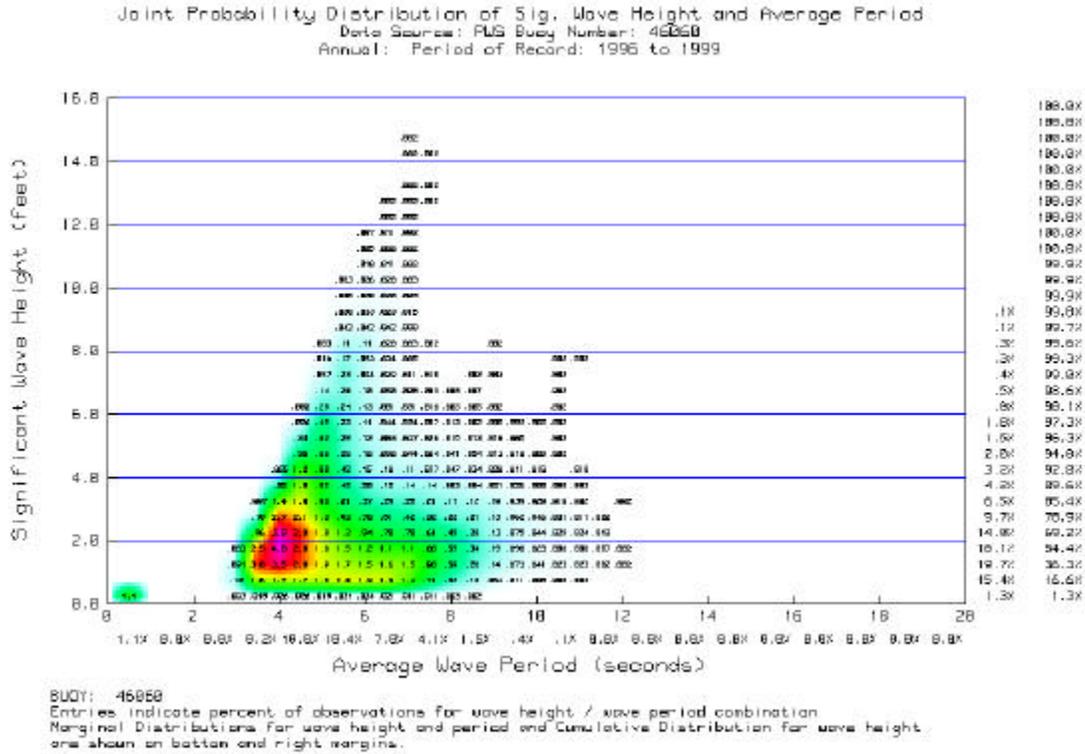


FIGURE 4
- Annual -
Joint Distribution of Significant Wave Height and Average Wave Period

This shows that the most frequently occurring average wave period is 4.0 seconds and the most frequently occurring significant wave height is about 2.0 feet. However, of considerable interest to the operability of a “Sitka-class” FVF is the fact that significant wave heights exceeding 6.5 feet occur less than two percent of the time annually.

“Sitka-class” FVFs have been shown to be sensitive to wave period. Motion sickness incidence (MSI) tends to increase as wave period increases. For theoretical wave spectra of the Bretschneider or JONSWAP forms, the standard relationship between average period and peak (a.k.a. modal) period is:

$$T_p = 1.408 T_z$$

where: T_p is the peak period and T_z is the average zero-crossing period

Preliminary indications are that the goal of 10% MSI is just achieved by “Sitka-class” FVFs when the significant wave height is 6.6 feet and the peak period is 6.0 seconds.

Furthermore, many of the FVFs proposed by shipyard/design teams for the “Sitka-class” procurement require active trim tab ride control to meet this requirement.

Based on the standard relationship between peak and average periods, a peak period of 6.0 seconds corresponds to an average period of 4.26 seconds. Average wave periods exceed 4.26 seconds 63% of the time on an annual basis at buoy 46060.

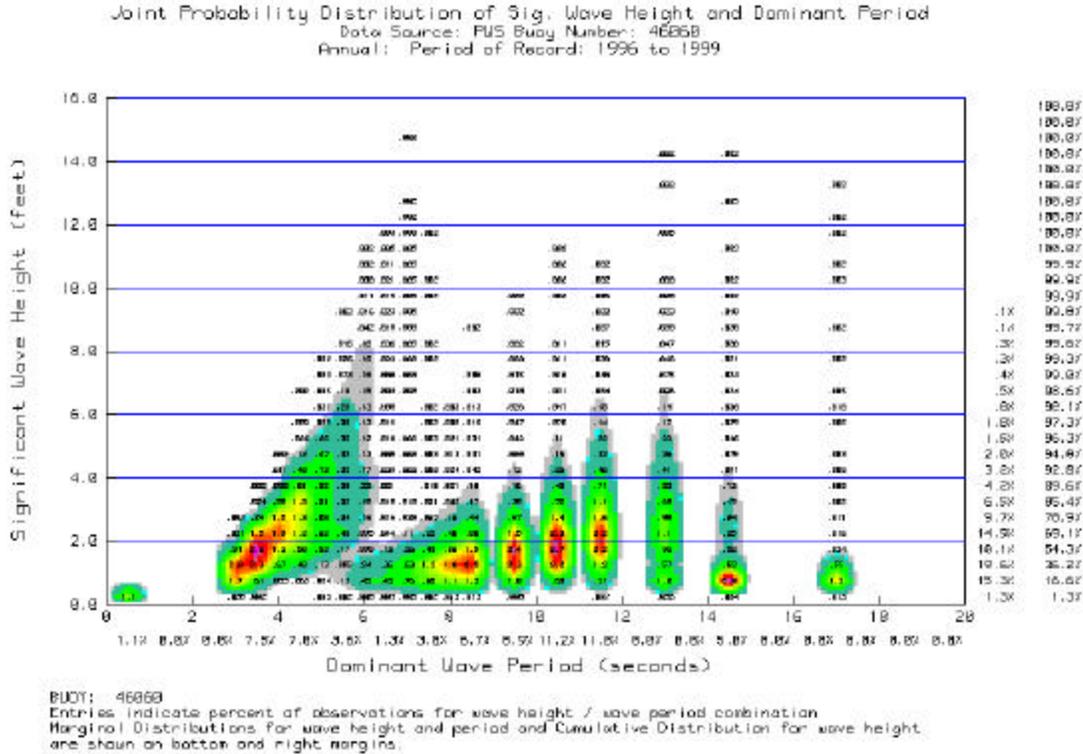


FIGURE 5
- Annual -
Joint Distribution of Significant Wave Height and Dominant Wave Period

Figure 5 shows the joint distribution of dominant wave period and significant wave height. Dominant wave period is the wave period associated with the peak of the measured wave spectral density, and hence shares a definition with the peak or modal period used as a parameter of theoretical spectra such as the Bretschneider and JONSWAP spectra. The vertical banding of the data shown in Figure 5 is an artifact resulting from the fact that the period bin widths used by the data buoy increase above nine seconds. What is of interest in Figure 5 is the prevalence of dominant wave periods in excess of six seconds. Annually the dominant wave period at buoy 46060 exceeds six seconds 63.1% of the time.

The large difference between average and dominant periods at buoy 46060 strongly indicates that theoretical spectra such as Bretschneider and JONSWAP are not sufficient models of the wave environment in central Prince William Sound. This premise may be further demonstrated by examining the wave spectra measured by buoy 46060.

In general, two measured wave spectra are available for each hour for the partial 1995 data year and the complete data years for 1996, 1997, 1998 and 1999. Shown below are some selected example spectra from 1996 illustrating typical departures of spectral form at buoy 46060 from standard theoretical spectra.

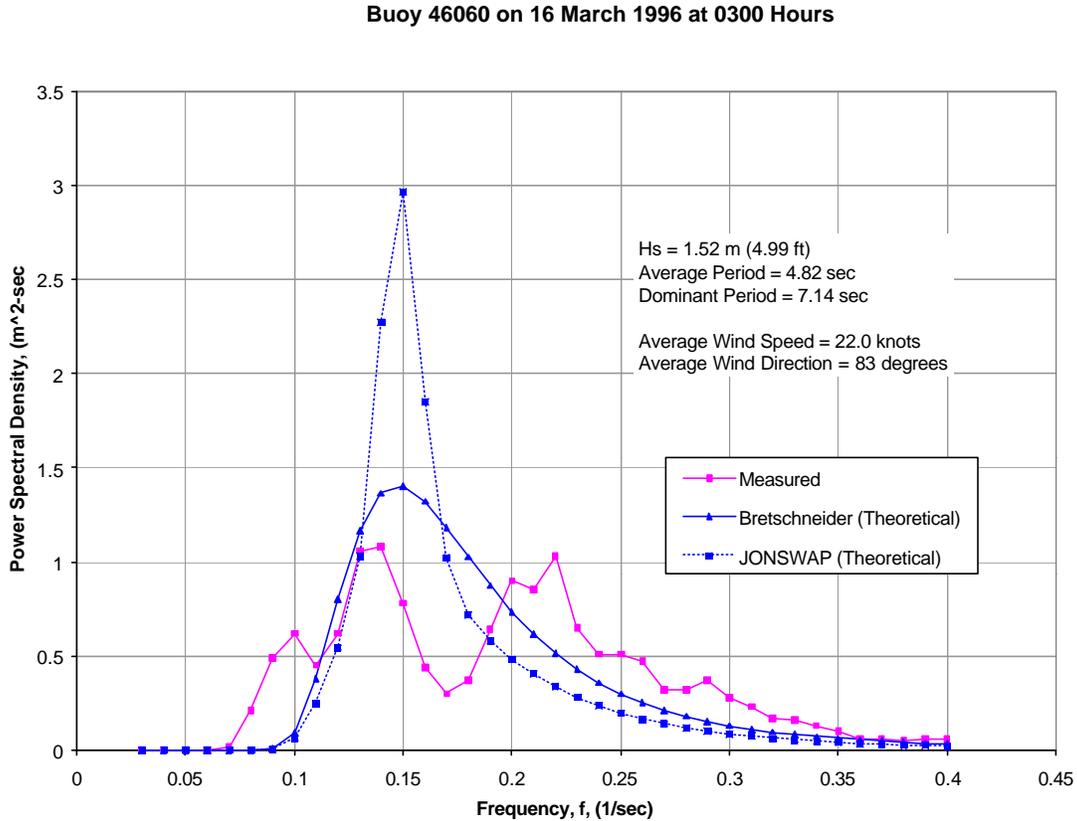


Figure 6 shows a measured spectrum with a significant wave height of 4.99 feet and an average period of 4.82 seconds, manifesting a wind driven sea with a peak at $f = 0.22$ ($T = 4.55$ seconds) and a low swell with a peak at $f = 0.14$ ($T = 7.14$ seconds). Also shown are theoretical Bretschneider and JONSWAP spectra with the same significant wave height and average period.

Buoy 46060 on 11 February 1996 at 0800 Hours

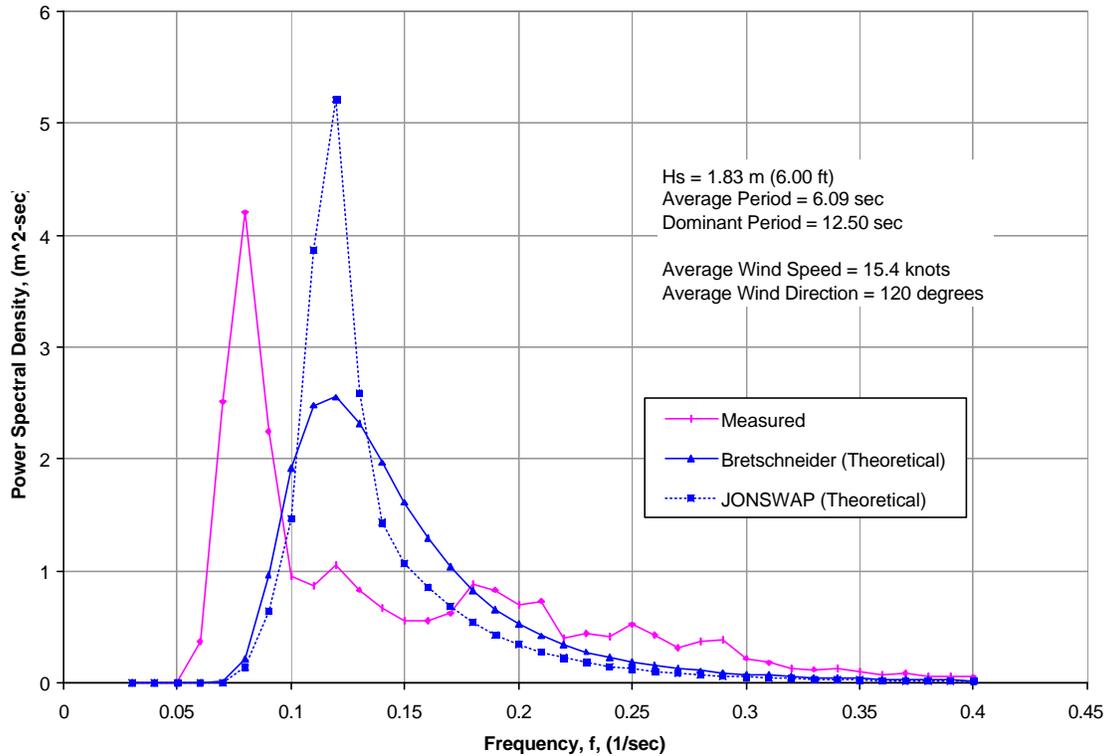


FIGURE 7
Sample Wave Spectrum Comparing Measured and Theoretical Spectra with Identical Average Periods and Significant Wave Heights

Figure 7 shows a measured spectrum with a significant wave height of 6.00 feet and an average period of 6.09 seconds. The measured spectrum has a peak at $f = 0.08$ ($T = 12.50$ seconds) that is lower than would be expected for a theoretical Bretschneider or JONSWAP spectra with the same average period. Thus the measured spectra are less steep and more swell-like than would be anticipated from the theoretical spectra.

Buoy 46060 on 9 Dec 1996 at 1300 Hours

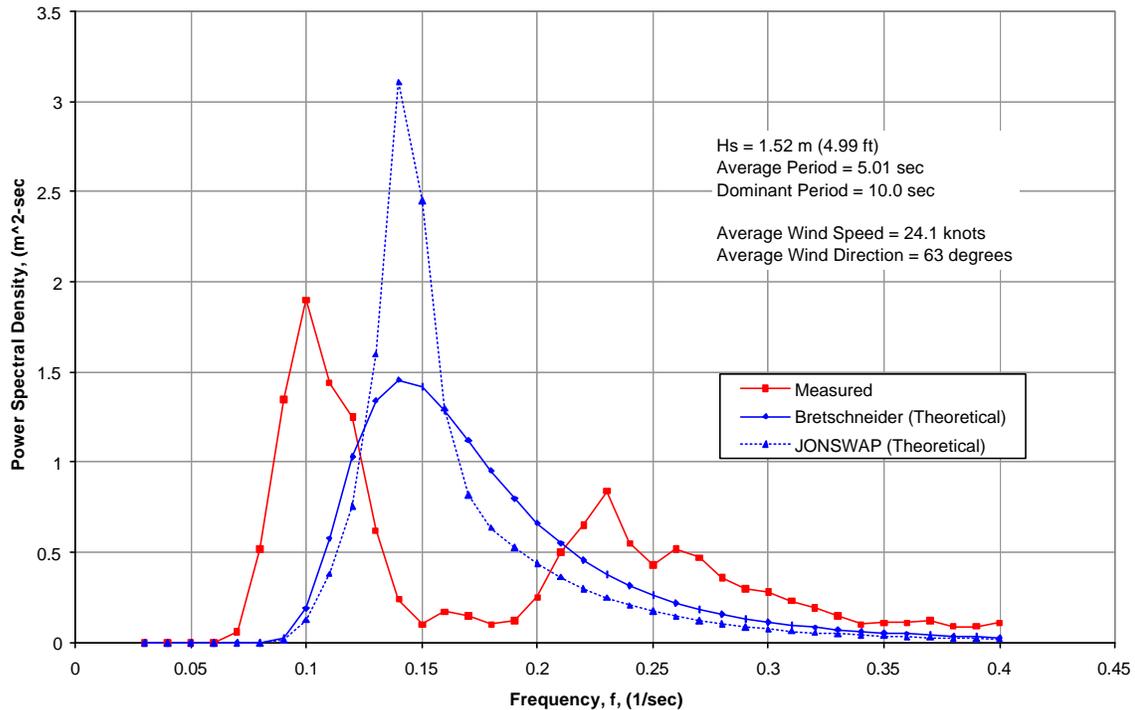


FIGURE 8
Sample Wave Spectrum Comparing Measured and Theoretical Spectra with Identical Average Periods and Significant Wave Heights

Figure 8 shows a measured spectrum with a significant wave height of 4.99 feet and an average period of 5.01 seconds, manifesting a wind driven sea with a peak at $f = 0.23$ ($T = 4.35$ seconds) and a high swell with a peak at $f = 0.10$ ($T = 10.00$ seconds). Also shown are theoretical Bretschneider and JONSWAP spectra with the same significant wave height and average period.

Figures 6 and 8 both manifest swell and winds from an eastern quadrant. Since buoy 46060 does not measure directional wave spectra, one can only speculate as to the origins and directions of the swell, but it seems likely that the swell originates from ocean waves diffracting through Hinchbrook Entrance while the local wind driven sea would likely be more closely aligned with the wind (presumably with something akin to cosine squared directional spreading). This hypothesis is supported by recent discussions with the ship's officers of the *Tustumena* while operating in Prince William Sound.

The distribution of ocean waves diffracting as swell throughout Prince William Sound could be modeled using a wave refraction/diffraction program such as MIKE-21 or

SWAN. Ocean waves outside Hinchbrook Entrance that drive the process would be well defined by spectra measured at buoy 46061 (refer to Figure 1). However, such efforts are outside the scope of this vessel suitability study.

Air and Seawater Temperatures

The AMHS Owner Requirements for the “Sitka-class” FVF specify air and seawater temperatures for design as follows:

Summer Season (Ventilation/Air Condition Design Criteria)

Outside Air Dry Bulb	70° F	(60% RH)
Seawater	65° F	

Winter Season (Heating Design Criteria)

Outside Air Dry Bulb	-10° F	(100% RH)
Seawater	28° F	

Air and sea temperatures for five data years at buoy 46060 are given in the following tables.

TABLE 3
Air Temperatures at Buoy 46060, degrees Fahrenheit

	1995	1996	1997	1998	1999	5-yr Extreme
Maximum	62.6	62.06	68.36	63.5	68.54	68.54
Minimum	15.8	18.86	18.32	22.82	11.84	11.84

Note: Air temperature at a height of 4.0 m (13.12 feet) above sea level

TABLE 4
Seawater Temperatures at Buoy 46060, degrees Fahrenheit

	1995	1996	1997	1998	1999	5-yr Extreme
Maximum	59.9	61.88	65.84	62.96	64.58	65.84
Minimum	42.26	37.94	37.4	40.1	38.48	37.4

Note: Seawater temperature at a depth of 0.6 m (1.97 feet) below sea level

Summer maximum air temperatures at buoy 46060 are seen to be less than that specified for the FVF design, while summer maximum sea water temperatures exceeded the FVF design criteria once in five years. Winter minimum air and seawater temperatures at buoy 46060 are less extreme than the design criteria for the FVF.

A comparison of extreme annual winter low temperatures at Juneau, Cordova and Valdez is given in the following table.

TABLE 5
Extreme Minimum Temperatures

	97½ th Percentile	99 th percentile
Juneau (Note 1)	1° F	-4° F
Cordova (Note 2)	3° F	-1° F
Valdez (Note 2)	-6° F	-10° F

Notes: 1) Source: 1993 ASHRAE handbook, Section 24.4, Table 1, Juneau Airport
2) NCDC winter daily temperature extremes data for years 1950 through 1999

In general, temperatures up to and including the 99th percentile are less severe than the -10°F design criterion for the “Sitka-class” FVF. The 99th percentile extreme minimum for Valdez equals that design criterion.

Snow Loads

The AMHS Owner Requirements for the “Sitka-class” FVF specify that: *“Structure and fittings shall be designed so that the vessel can structurally sustain, without damage, snow loads for Juneau, Alaska, as specified in ASCE Standard ANSI/ASCE 7-95 (Minimum Design Loads for Buildings and other Structures).”* The Owner Requirements go on to further specify that: *“For calculating the snow load the Contractor shall assume that the vessel is unheated, is partially exposed, terrain Category A and is a Category II building classification.”* And...*“When subjected to the snow loads specified above, the vessel shall be capable of remaining afloat and stable without having to take any special precautions or measures.”* The Contractor is instructed to consider full and partial snow loads.

The following table indicates the snow loads for Juneau, Cordova and Valdez determined from ASCE Standard/ASCE 7-95 as described in the preceding paragraph.

TABLE 6
ASCE Snow Loads

Location	Snow Load (lbs/sq.ft.)
Juneau	49.9
Cordova	71.3
Valdez	121.2

The snow load in Valdez is 242% that at Juneau, which represents the minimum basis for FVF structural design and stability. This obviously requires further examination before a “Sitka-class” FVF is placed in Prince William Sound winter service. At this point in the design/build process it is not possible to state whether there is a problem or not. It could be that other design considerations impose more demanding requirements and that therefore it is not a problem.

Floating Ice

According to the *Alaska Marine Ice Atlas*, eighteen tidewater glaciers calve into the waters of Prince William Sound as shown in Figure 9. It is well known that there are concentrations of floating glacial ice (icebergs and “bergy bits”) in Prince William Sound from these tidewater glaciers, primarily from the Columbia Glacier (refer to Figure 10). These concentrations move around the Sound in response to wind and tidal currents. Also posing a hazard and requiring vigilance are lone icebergs and bergy bits, removed from the main ice concentrations. The volume of floating glacial ice encountered along ferry routes in Prince William Sound is, in general, greater than that typically encountered along Southeast Alaska ferry routes, such as found in Frederick Sound (from the Le Conte Glacier) and in Stephens Passage (from the Sawyer Glaciers and Dawes Glacier).

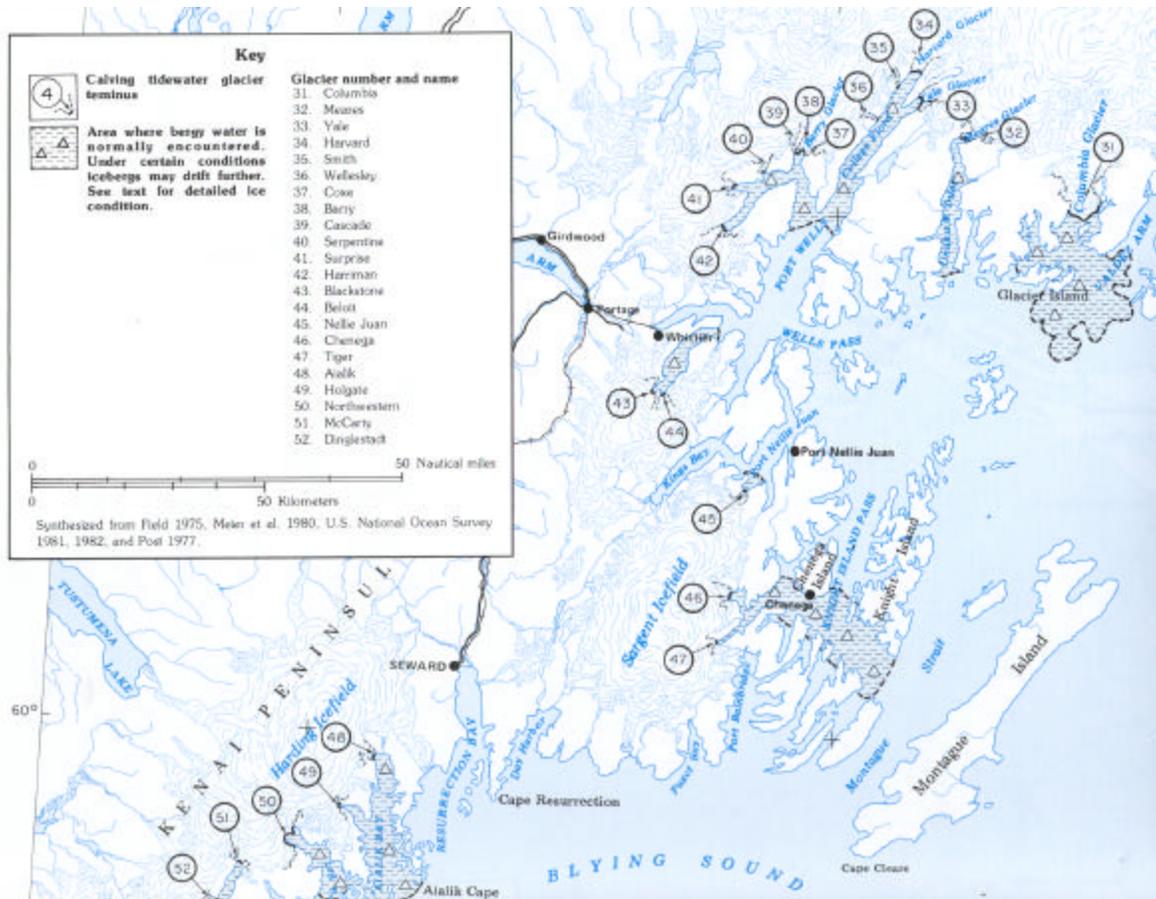


FIGURE 9
Tidewater Glaciers Calving into Prince William Sound from the *Alaska Marine Ice Atlas* (1983)

As shown in Figure 9, floating ice fields from Columbia Glacier typically may impede access at the mouth of Valdez Arm. Also, icebergs from glaciers in the College Fiords may flow out of Port Wells and impede passage to and from Whittier in Wells Pass. And, according to Figure 9 the possibility also exists for icebergs from Blackstone Bay to similarly migrate into Wells Pass. Iceberg concentrations from Chenega and Tiger Glaciers are also shown in Figure 9 around Chenega.

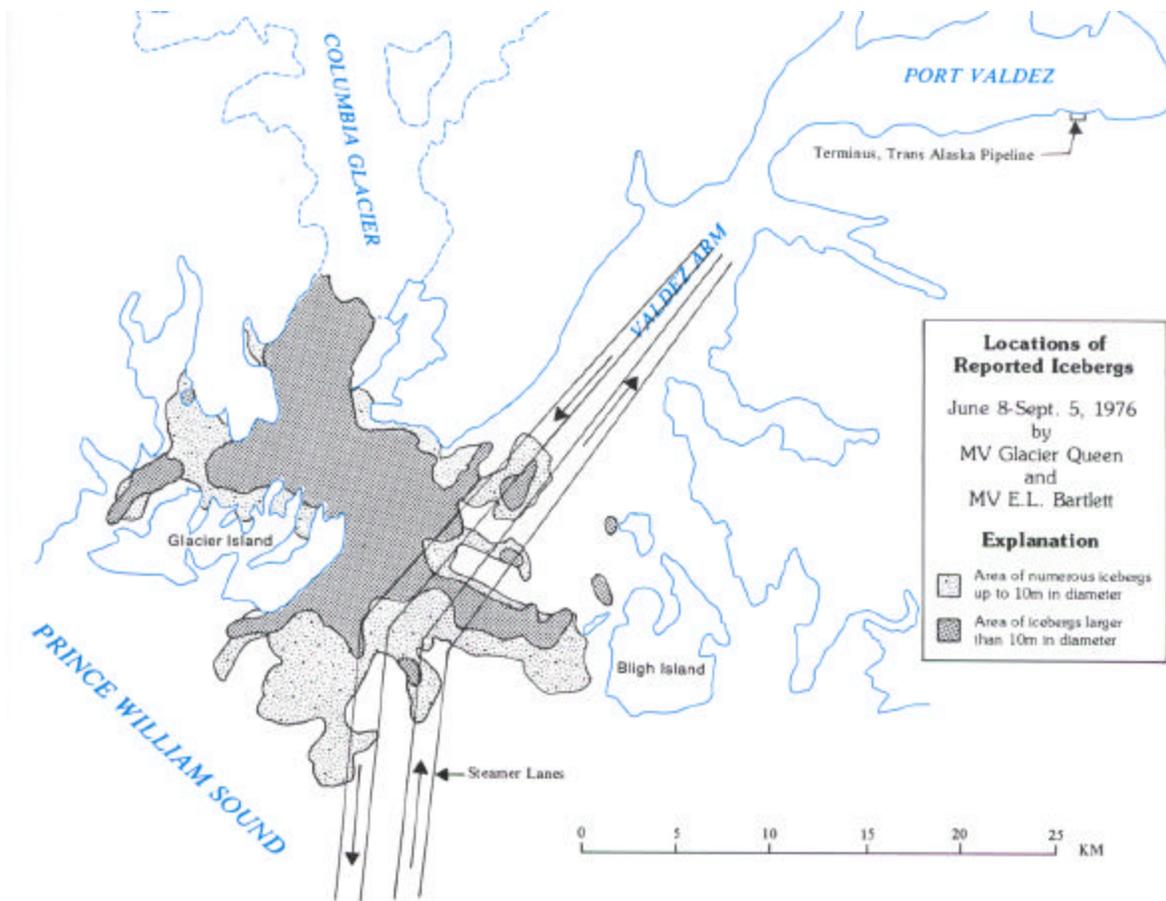


FIGURE 10
Columbia Glacier Iceberg Drift Patterns
from the Alaska Marine Ice Atlas (1983)

While the drift pattern shown in Figure 10 for Columbia Glacier icebergs are typical, other patterns can develop, especially under conditions of north winds, resulting in fields of floating glacial ice extending south across central Prince William Sound.

The “Sitka-class” FVF is to be fitted with a marine infrared imaging system located at the main conning station, capable of detecting small pieces of glacial ice such as “bergy bits,” floating logs, small boats, etc. at the vessel’s rated speed, in sufficient time to avoid collision (distances of not less than one mile). The system will be provided with the capability to determine distance and time-to-intercept of detected objects. In addition, the FVF will be outfitted with two pairs of the latest generation of night vision binoculars. The binoculars will have 70 mm infrared panoramic lenses and a magnification of not less than 7x, with an effective range of approximately 1100 meters.

During development of the AMHS FVF Owner Requirements, forward scanning sonars were also investigated as a possible means to detect floating glacial ice and

debris. The conclusion at that time was that, while there were promising technologies under development, none was close to proven or close to production. In consideration of the greater hazard represented by floating ice in Prince William Sound, before any FVF is introduced into year-round AMHS service there, it is suggested that forward scanning sonar technologies be reviewed again to determine if useful products are available.

4. SEAKEEPING AND PASSENGER COMFORT

The “Sitka-class” FVF is safe and operable from a seakeeping perspective (i.e., slamming, shipping of “green” water, dangerous motions, etc.) in conditions considerably more severe than the 6.6 feet significant wave height established as a certificate limit in the AMHS Owner Requirements. The limit on operability primarily reflects passenger comfort. The passenger comfort criterion established for operation of the “Sitka-class” FVF in Southeast Alaska was 10% motion sickness incidence (MSI) for two-hours of exposure. The associated operability goal was 95% operable on an annual basis and/or 90% operable in the worst month, whichever controlled.

As observed earlier in the section on wave climatology, significant wave heights exceeding 6.5 feet occur less than two percent of the time annually at buoy 46060 in central Prince William Sound. Figure 11 shows the average monthly probability of significant wave heights equal to or less than 6.6 feet at buoy 46060. Excepting for the month of December significant wave heights exceed 6.6 feet less than 5% of the time.

Also mentioned in the wave climatology section, the “Sitka-class” FVF is sensitive to wave period, and buoy 46060 include longer periods than the wave periods typically found on Southeast Alaska routes such as upper Chatham Strait. Figure 11 also shows the probability of significant wave heights less than 6.6 feet and average wave periods equal to or less than 4.5 seconds (corresponding to theoretical peak periods of 6.34 seconds). Such benign conditions occur between 25% and 60% of the time depending on month, with an annual average of 45.2%.

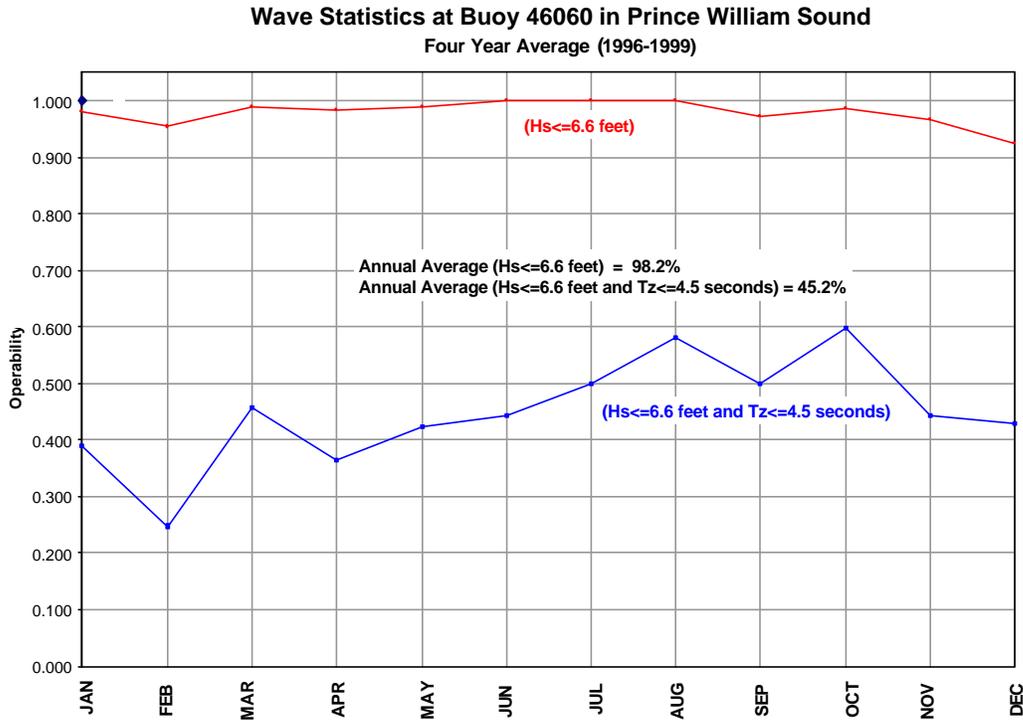


FIGURE 11
Monthly Average Wave Statistics at Buoy 46060

These wave statistics, particularly the frequent occurrence of waves with longer periods, suggest that the operability based on passenger comfort should be carefully studied for “Sitka-class” FVF operations in Prince William Sound. Figure 12 provides monthly average operability of the “Sitka-class” FVF in Prince William Sound for three different levels of active ride control. The lowest level, “Bare Hull” (shown in red), is the total absence of any active ride control features. The intermediate level, shown in blue and labeled “Trim Tabs,” corresponds to the ride active ride control to be delivered with the “Sitka-class” FVF. And the highest level, shown in green and labeled “Trim Tabs & T-Foils,” includes both the trim tabs that will be delivered with the FVF and the active T-foils that may be added at a later date. The “Sitka-class” FVF is to be delivered with trim tabs, and foundations for possible future installation of T-foils, but not the actual T-foils.

The operability shown in Figure 12 is for 10% MSI and two-hours of exposure, the same exposure as in Southeast Alaska. The port-to-port transit times for FVF service in Prince William Sound are in excess of two hours, but include route segments more protected than central Prince William Sound represented by buoy 46060 (more on this later).

AMHS Sitka-Class FVF Operability in Prince William Sound
Four-Year Average (1996-1999)

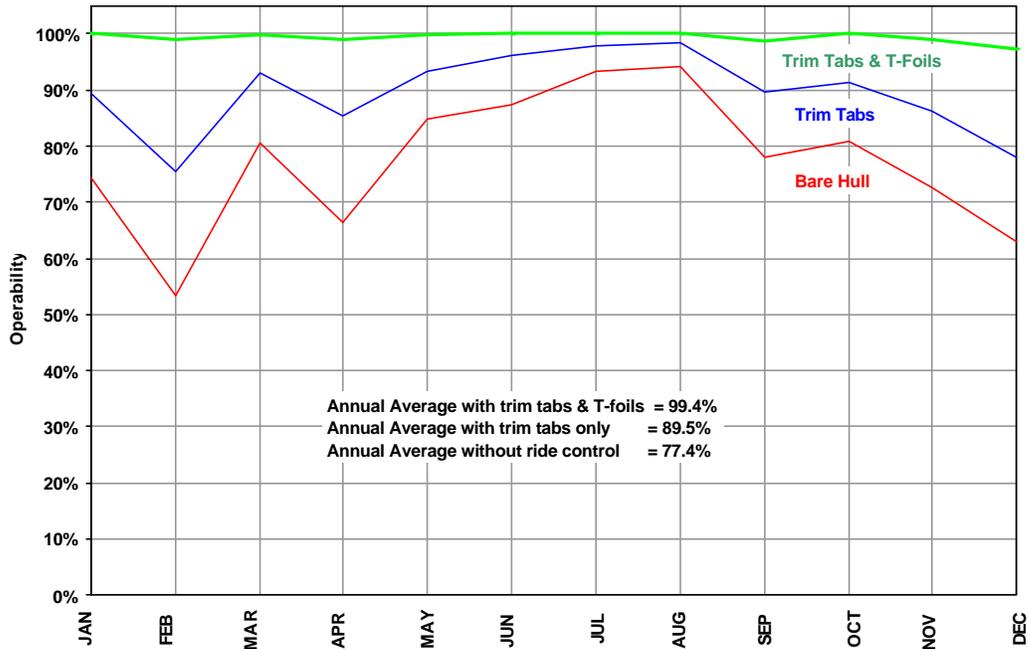


FIGURE 12
Monthly Average Operability
Corresponding to 10% MSI Limit and Two-Hour Exposure

Based on two-hour exposure, the operability goals of 95% annual and 90% worst month, are met with both trim tabs and T-Foils but not by active trim tabs alone and certainly not without any active ride control features (“bare hull”).

The “Sitka-class” FVF is to be delivered with active trim tabs but without T-foils. In that configuration the operability associated with a two-hour 10% MSI limit would be 75% in the worst month (February) and averages 89.5% over the year. Furthermore, these are four-year averages. The lowest monthly operability over the four-year period would have been 68% in December 1997.

Much of the operability problem is associated with the ocean swell that penetrates into central Prince William Sound through Hinchinbrook Entrance. Figure 13 depicts the approximate extent of that swell Prince William Sound. And Figure 14 indicates that the route distances across the swell-affected region is on the order of 29 nautical miles or approximately one-hour transit time for an FVF. This suggests that passenger exposure time for motion sickness may be more on the order of one rather than two hours.

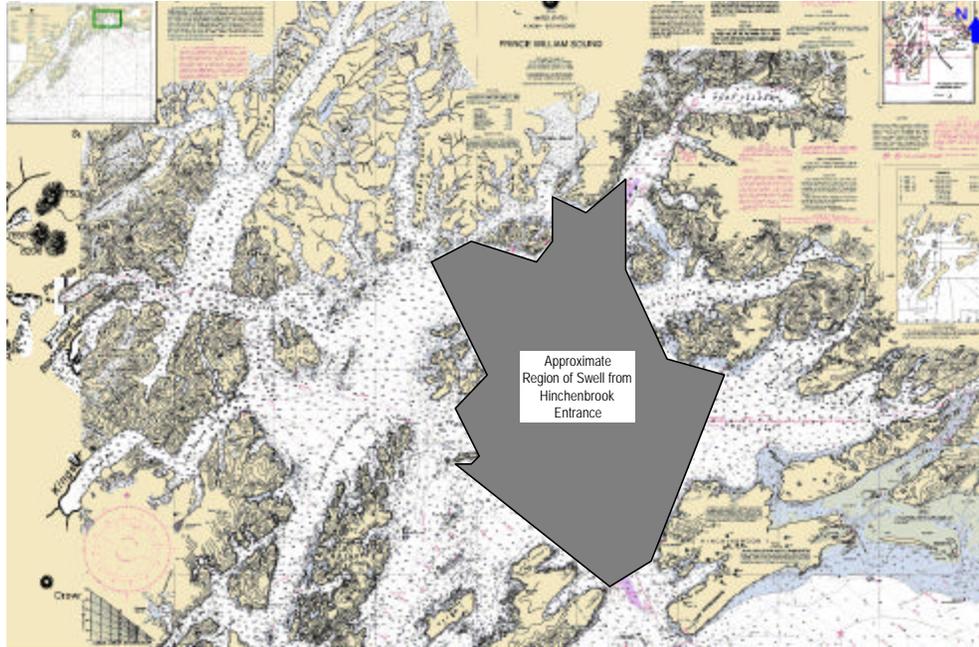


FIGURE 13
Approximate Extent of Ocean Swell
Penetrating Central Prince William Sound through Hinchbrook Entrance

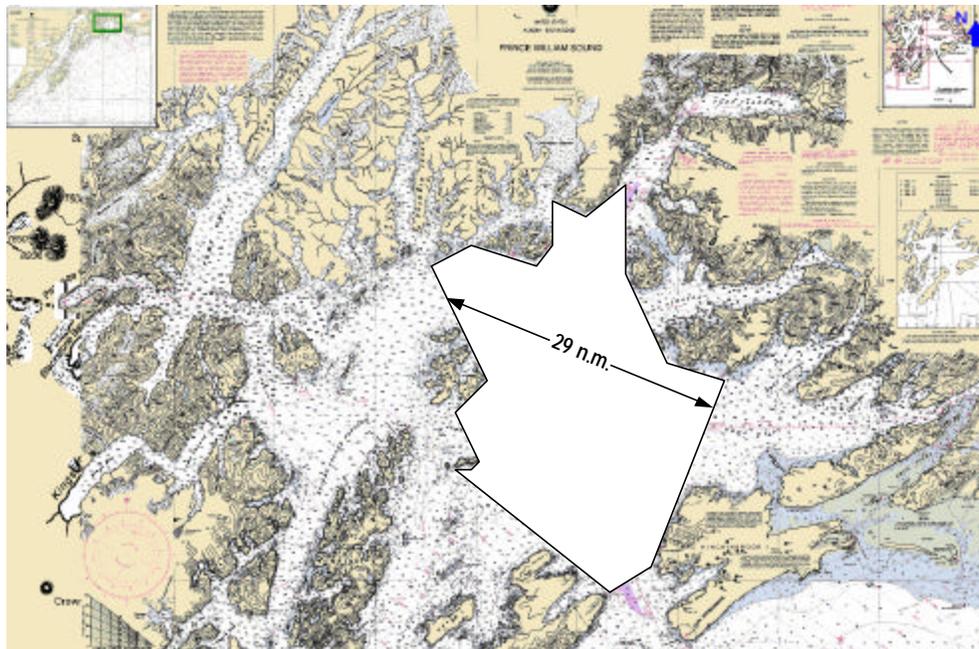


FIGURE 14
Approximate Route Distance across Ocean Swell-Affected Region

Incidence of motion sickness reduces as the square root of the exposure duration. If the exposure were reduced to one hour, the operability associated with a 10% MSI limit will increase to the values shown by the solid lines in Figure 15 (the dashed lines for two-hour exposure are shown for reference). Note that only the upper half of the scale is shown in order to focus on these higher operabilities.

Based on a criterion of one-hour exposure, 10% MSI, active trim tabs alone would provide 90% operability in the worst month (December) and 96.7% operability on an annual basis, thus meeting the goals established for service in Southeast Alaska. Again, these are four-year averages. The lowest monthly operability over the four-year period would have been 84% in December 1997.

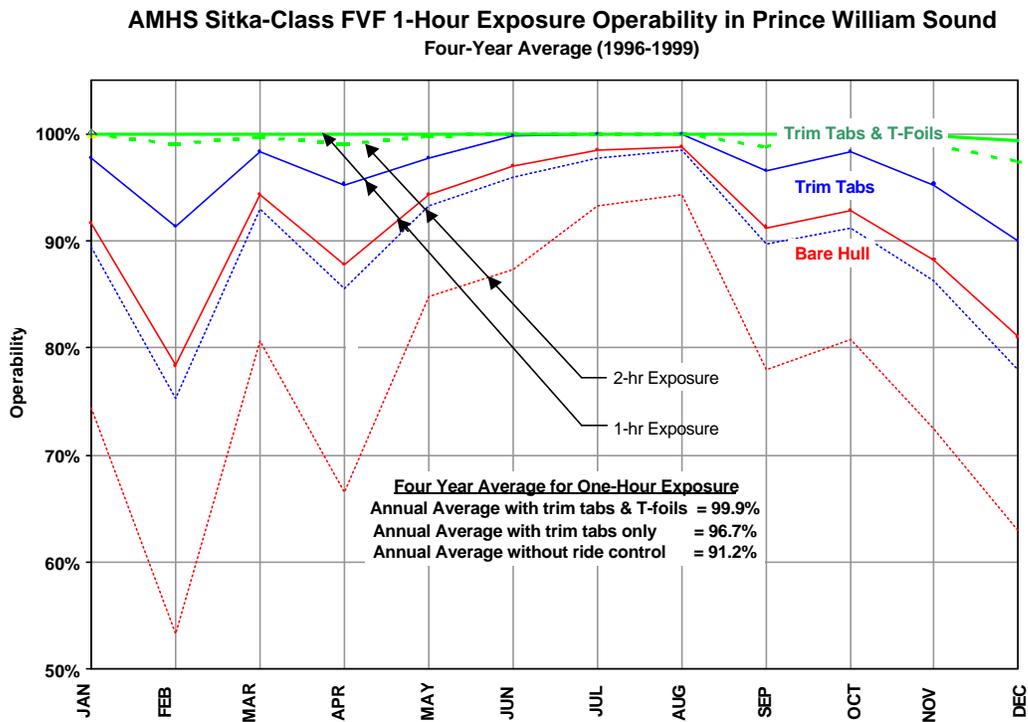


FIGURE 15
Monthly Average Operability
Corresponding to 10% MSI Limit and One-Hour Exposure

The preceding analysis does not provide altogether clear, unequivocal, guidance regarding the recommended suite of active ride control features for a “Sitka-class” FVF engaged in year-around Prince William Sound service. If the passenger exposures are closer to two hours, then it would appear that trim tabs and T-foils would be indicated. If the passenger exposures are closer to one hour, then it would

appear that trim tabs alone will suffice. Given that the "Sitka-class" vessels will be delivered with trim tabs but without T-foils, and in consideration of the potential problem of operating T-foils around floating glacial ice ("bergy bits"), it is suggested that "Sitka-class" vessels fitted with trim tabs alone could be introduced into Prince William Sound service and the T-foils could be added at a later date if experience indicated that they were desirable. It is recommended that the design-build contractor awarded the FVF be commissioned to prepare a supplemental seakeeping and passenger motion sickness incidence report for operations on Prince William Sound.

APPENDIX 1

JOINT DISTRIBUTIONS OF WIND SPEED AND DIRECTION BY MONTH AND ANNUALLY

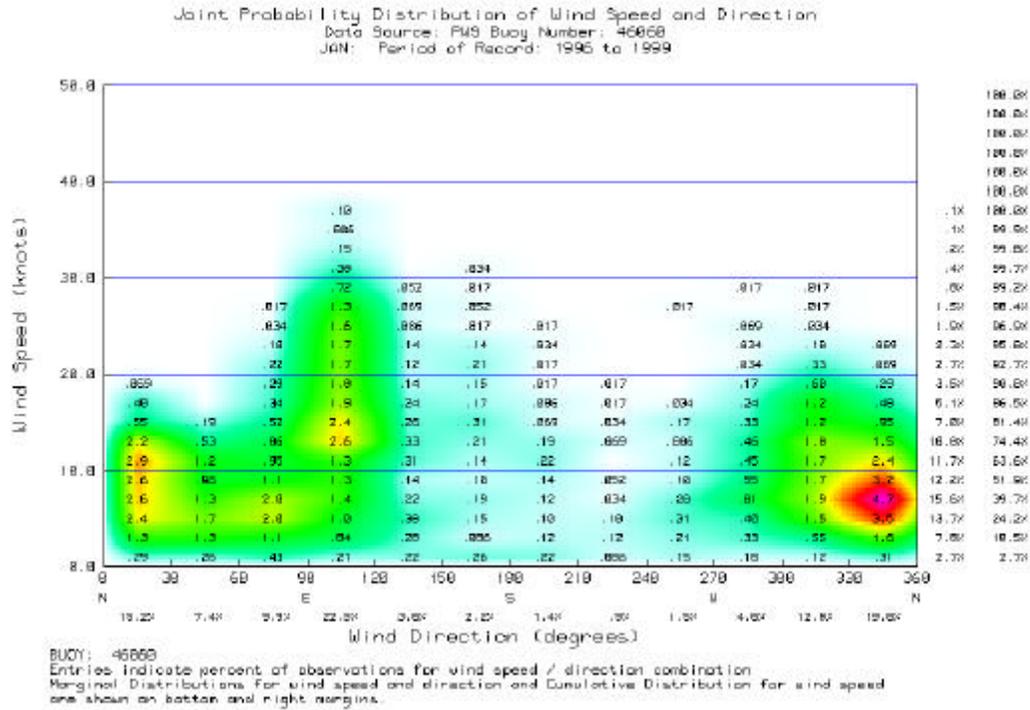


FIGURE 1
January - Joint Distribution of Wind Speed and Direction

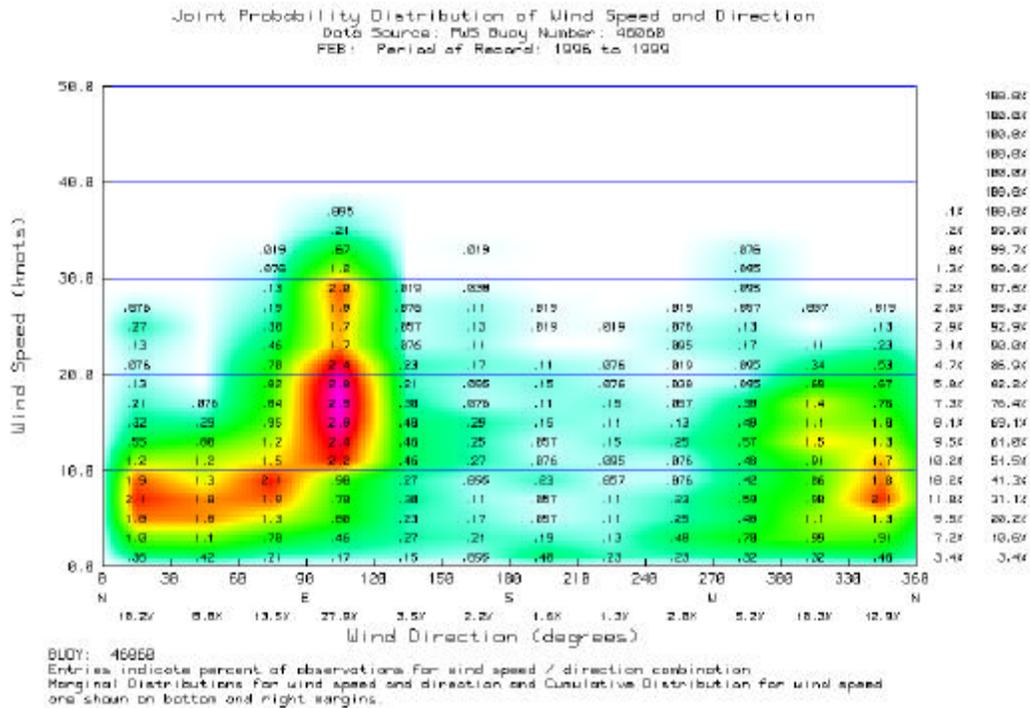


FIGURE 2
February - Joint Distribution of Wind Speed and Direction

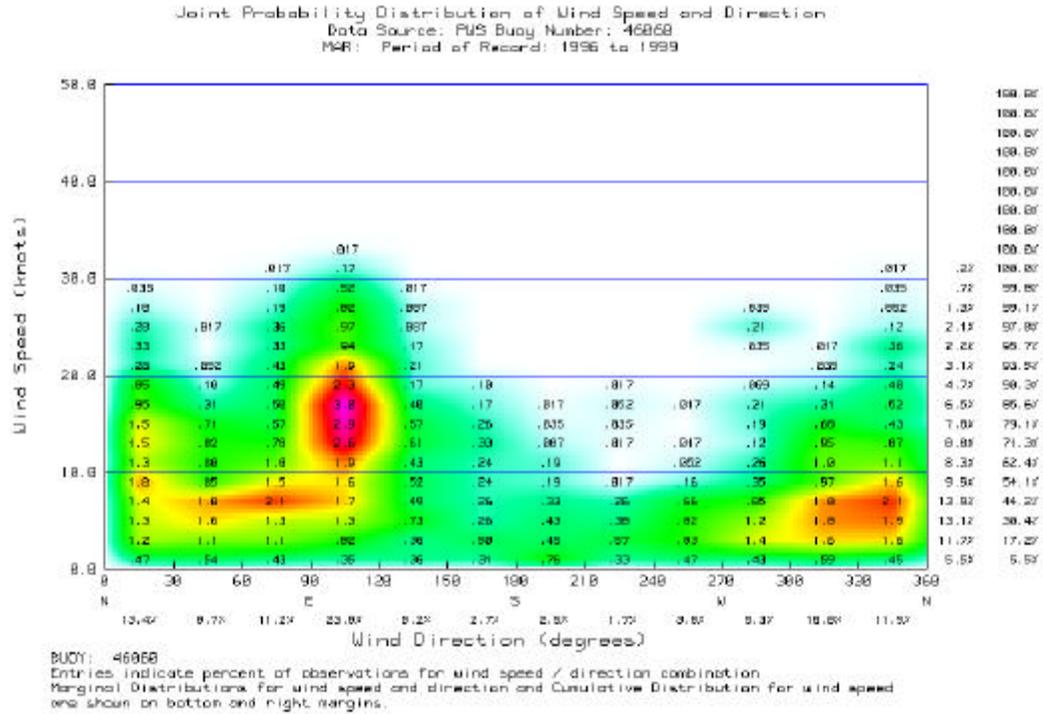


FIGURE 3
March - Joint Distribution of Wind Speed and Direction

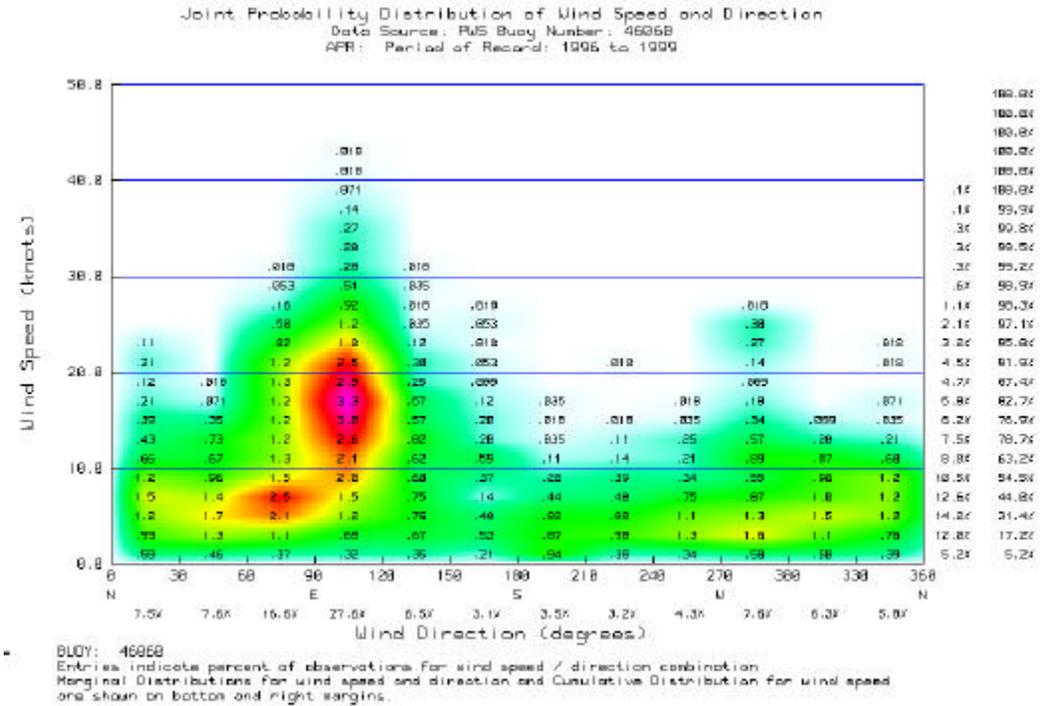


FIGURE 4
April - Joint Distribution of Wind Speed and Direction

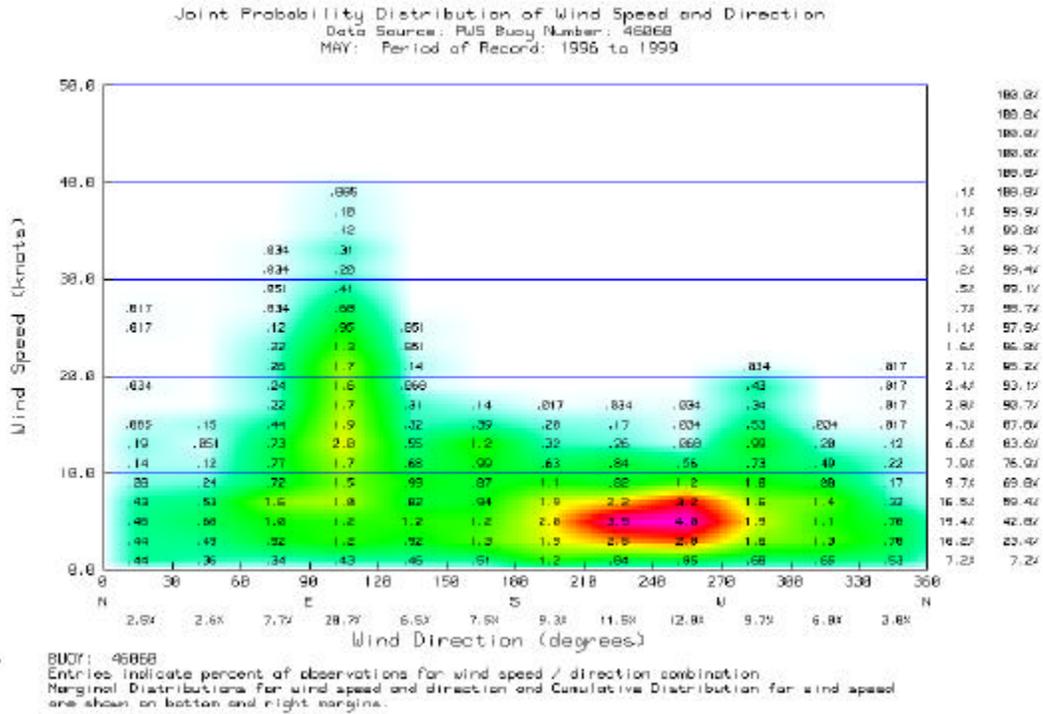


FIGURE 5
May - Joint Distribution of Wind Speed and Direction

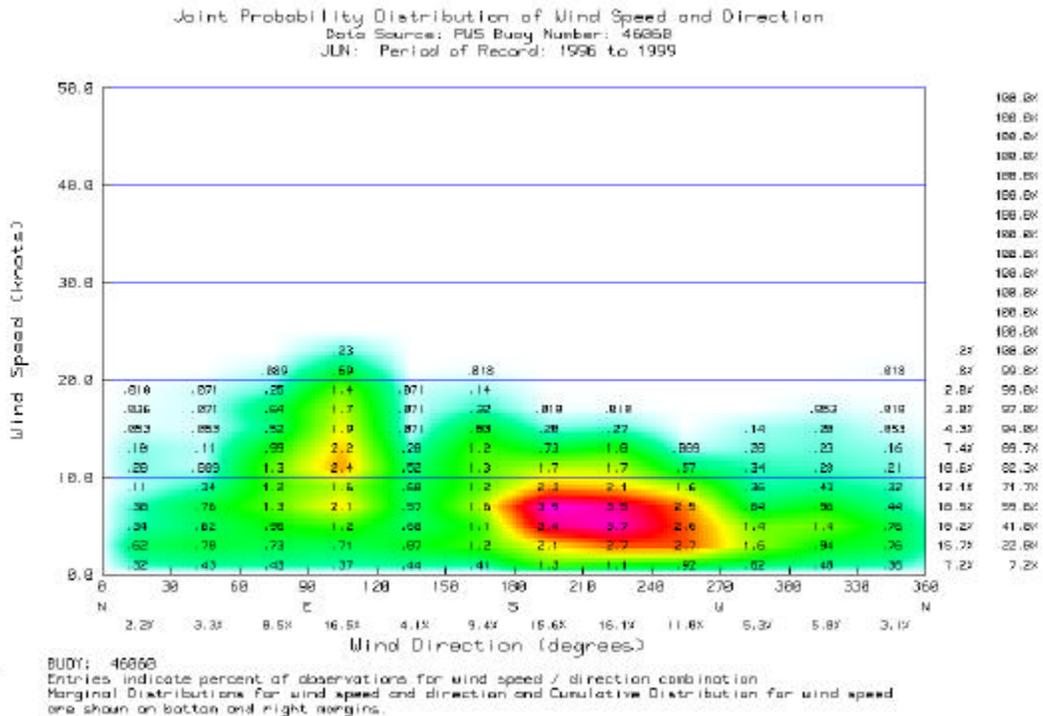


FIGURE 6
June - Joint Distribution of Wind Speed and Direction

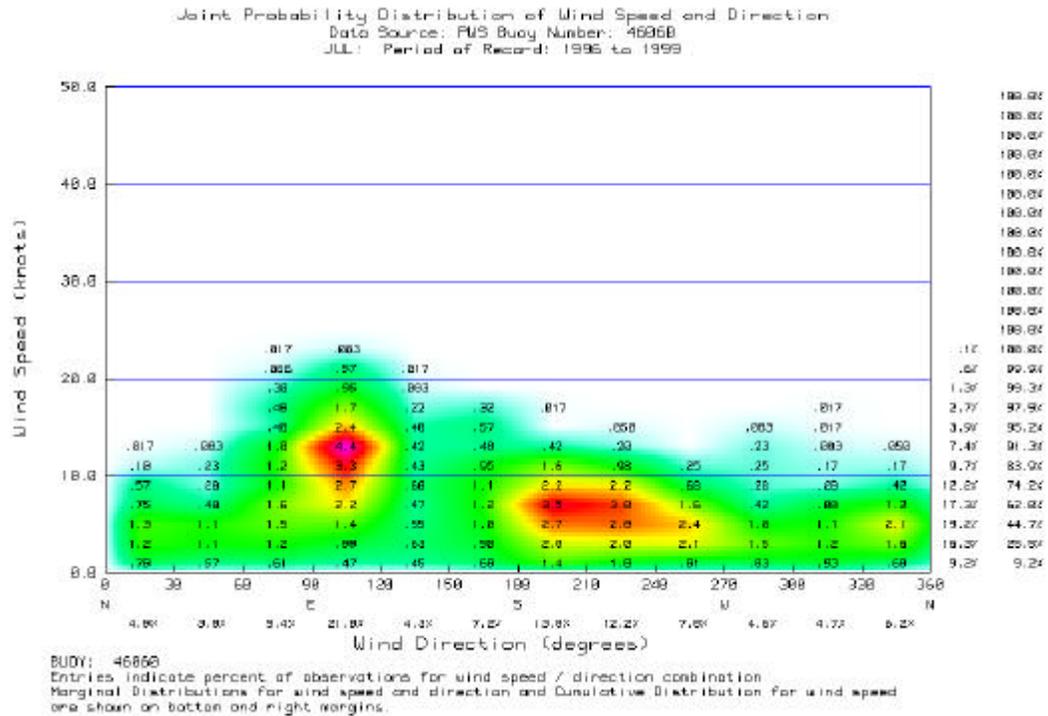


FIGURE 7
July - Joint Distribution of Wind Speed and Direction

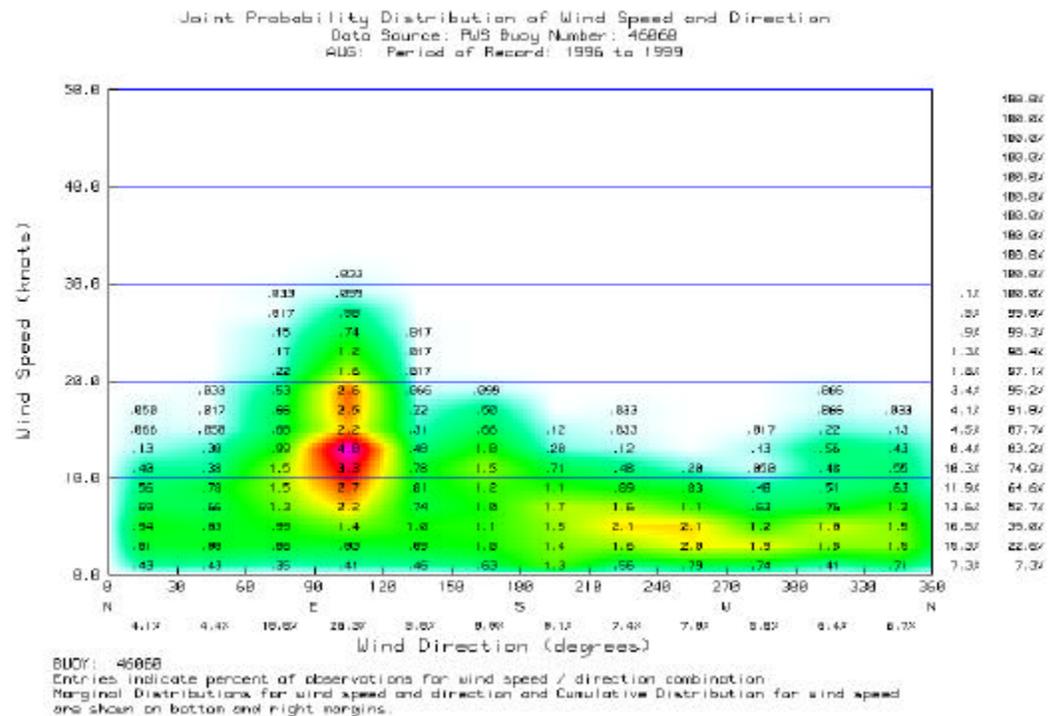


FIGURE 8
August - Joint Distribution of Wind Speed and Direction

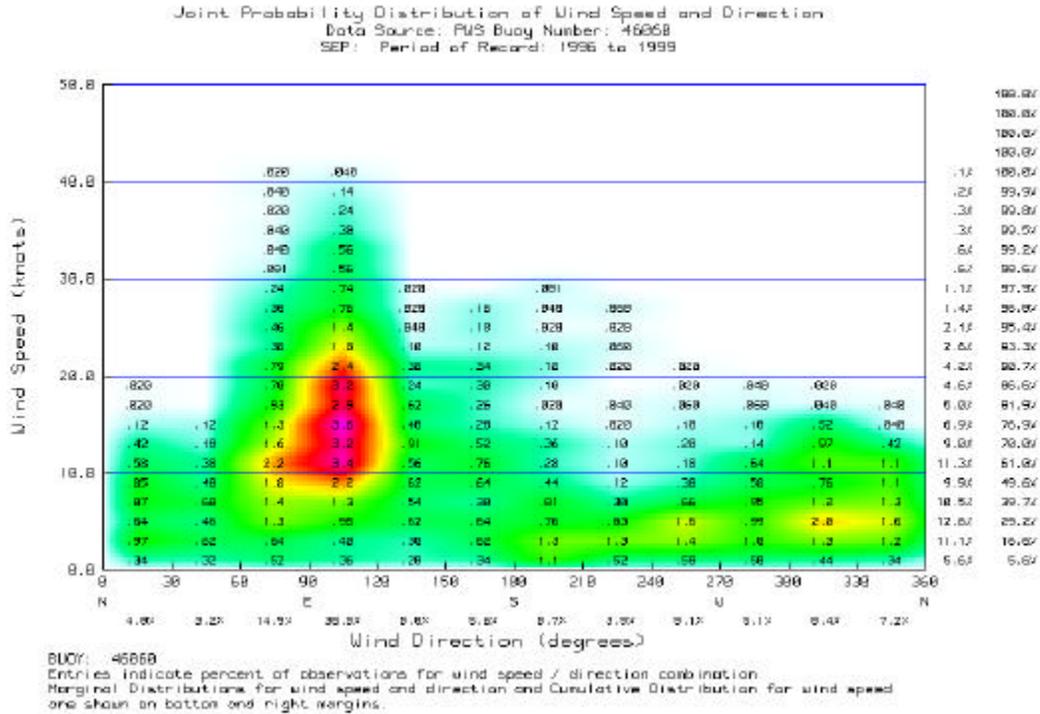


FIGURE 9
September - Joint Distribution of Wind Speed and Direction

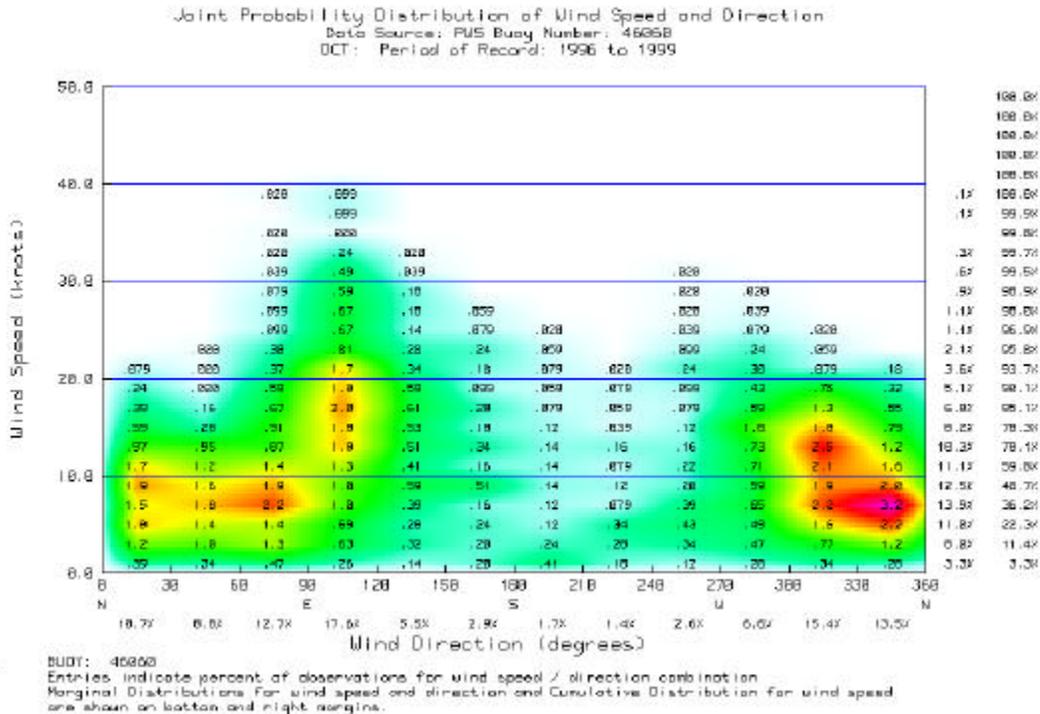


FIGURE 10
October - Joint Distribution of Wind Speed and Direction

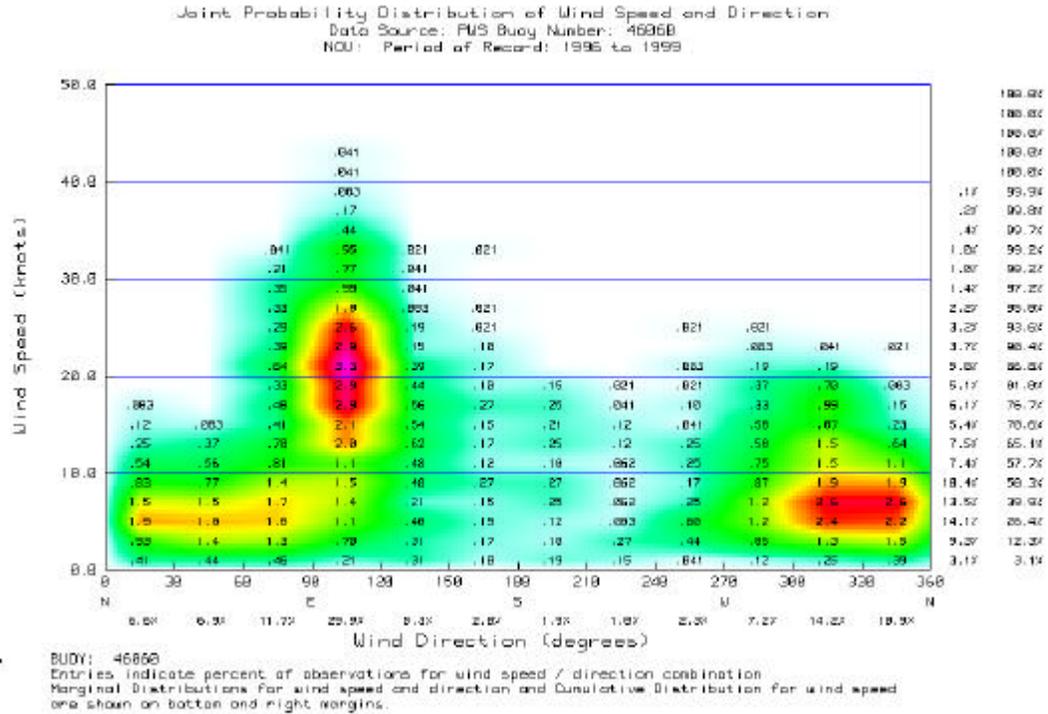


FIGURE 11
November - Joint Distribution of Wind Speed and Direction

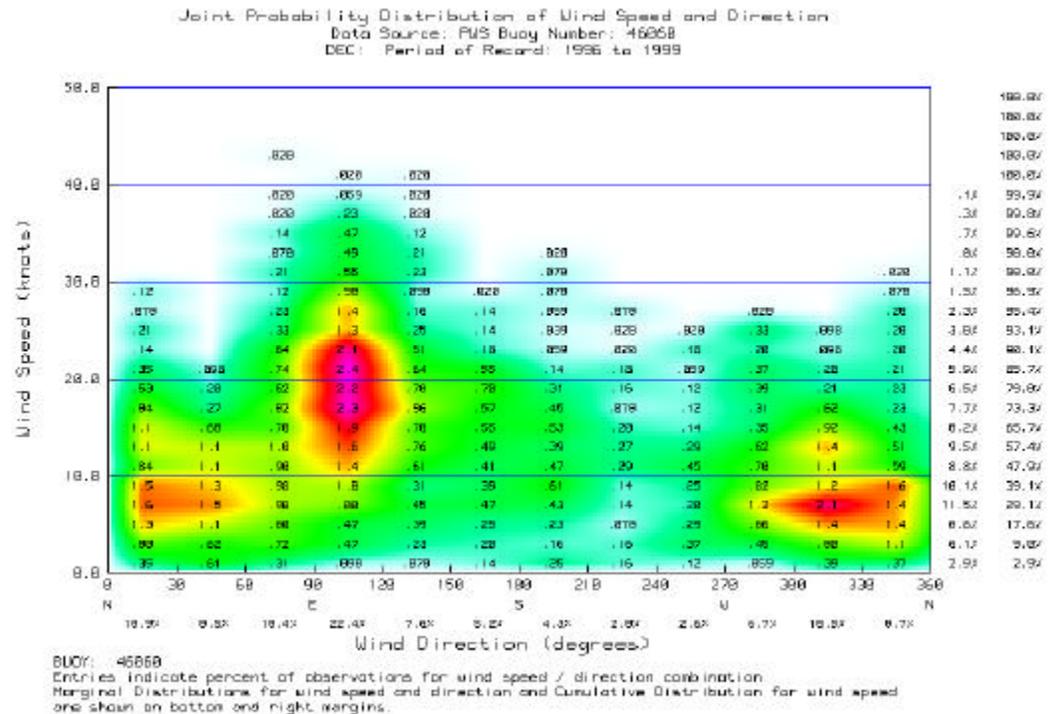


FIGURE 12
December - Joint Distribution of Wind Speed and Direction

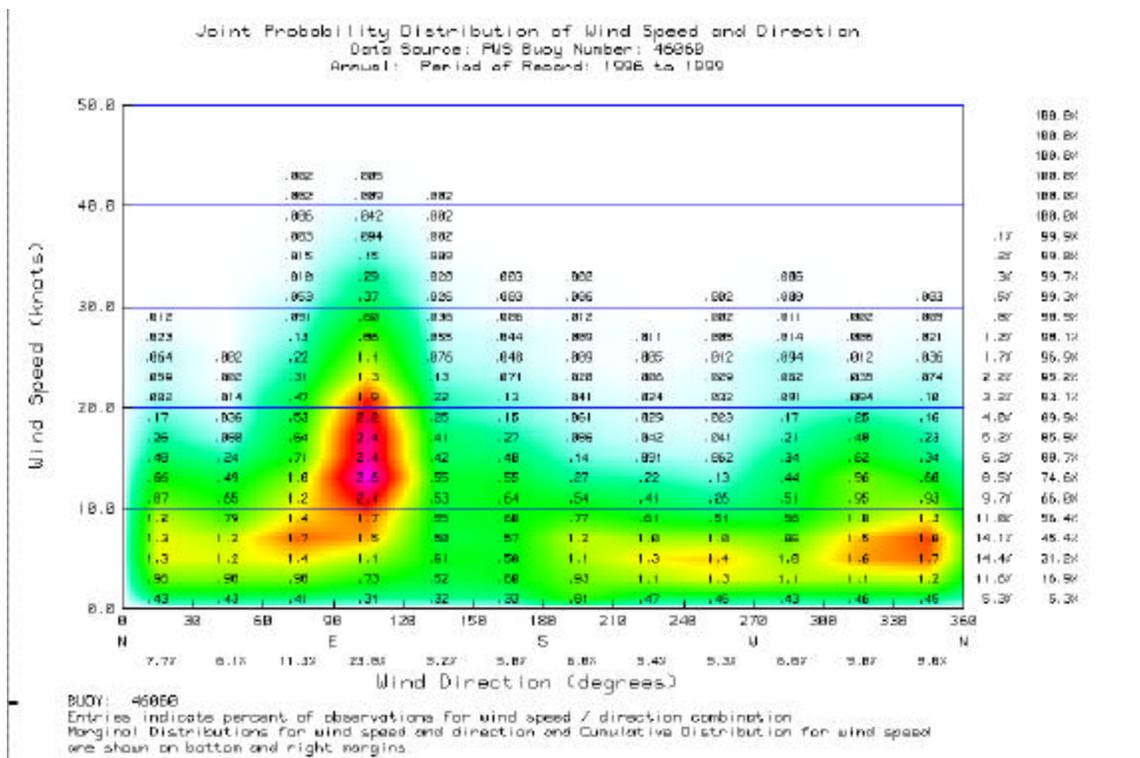


FIGURE 13
Annual - Joint Distribution of Wind Speed and Direction

APPENDIX 2

JOINT DISTRIBUTIONS OF SIGNIFICANT WAVE HEIGHT VERSUS AVERAGE WAVE PERIOD BY MONTH AND ANNUALLY

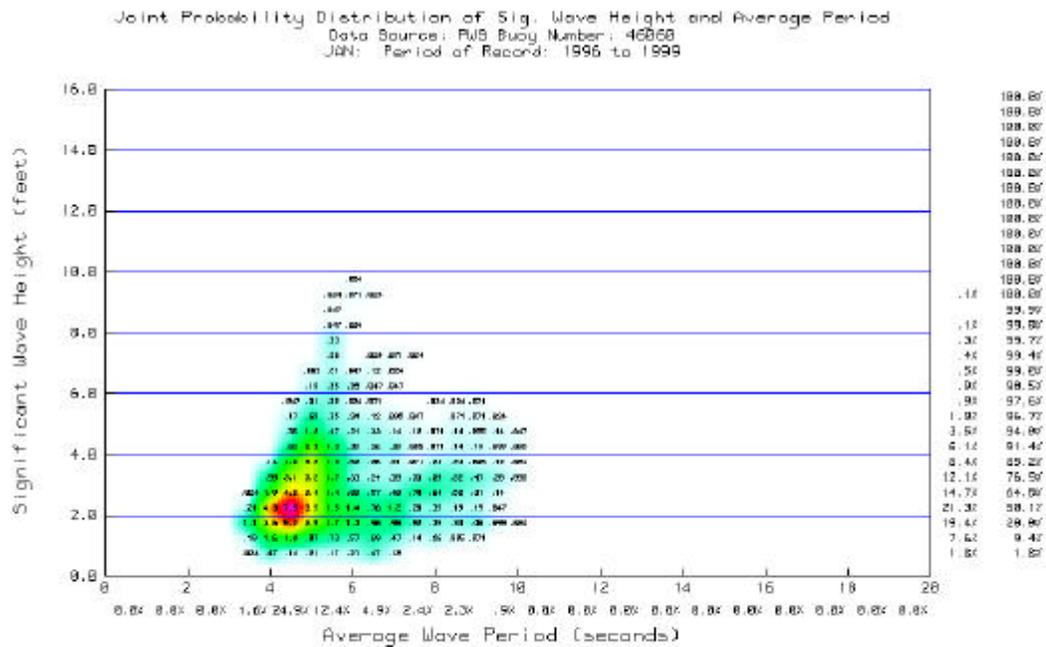


FIGURE 1
- January -
Joint Distribution of Significant Wave Height and Average Wave Period

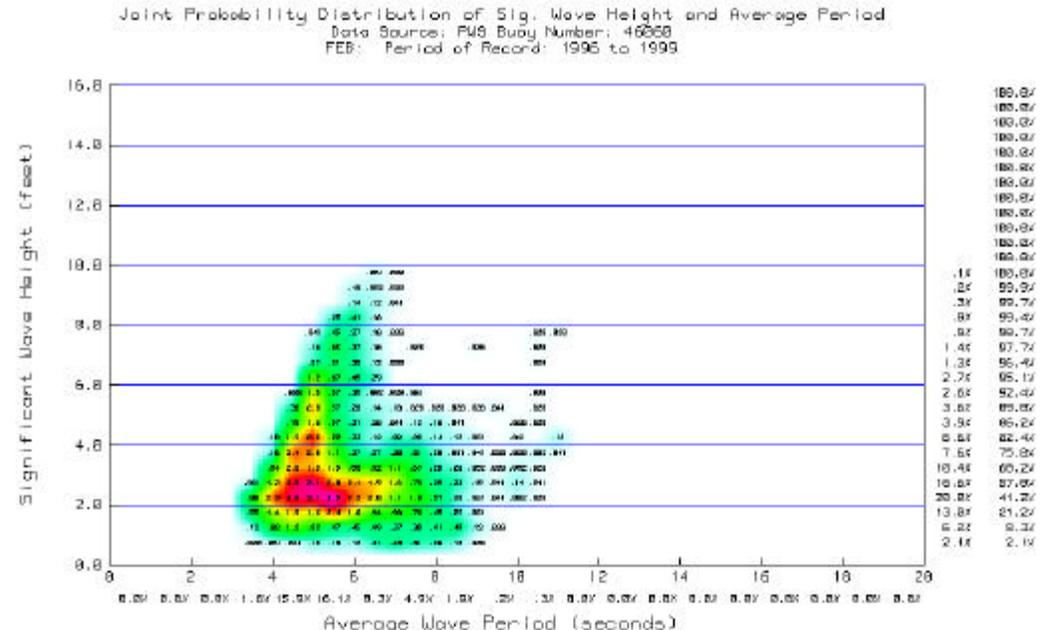


FIGURE 2
- February -
Joint Distribution of Significant Wave Height and Average Wave Period

Joint Probability Distribution of Sig. Wave Height and Average Period
 Data Source: PWS Buoy Number: 46868
 MAR: Period of Record: 1996 to 1999

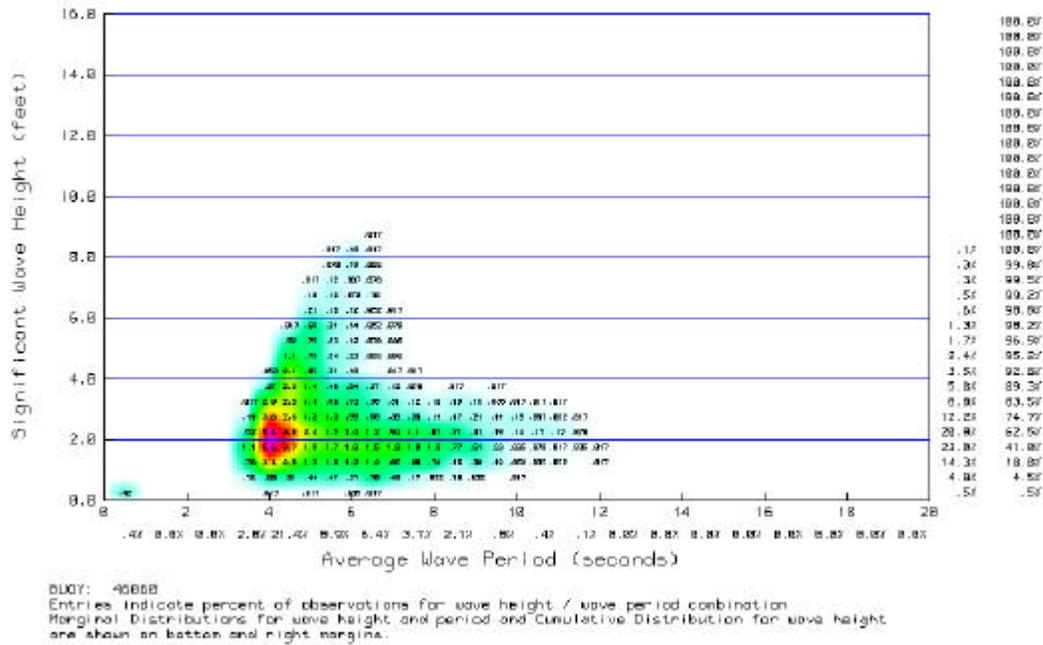


FIGURE 2
- February -
Joint Distribution of Significant Wave Height and Average Wave Period

Joint Probability Distribution of Sig. Wave Height and Average Period
 Data Source: PWS Buoy Number: 46868
 APR: Period of Record: 1996 to 1999

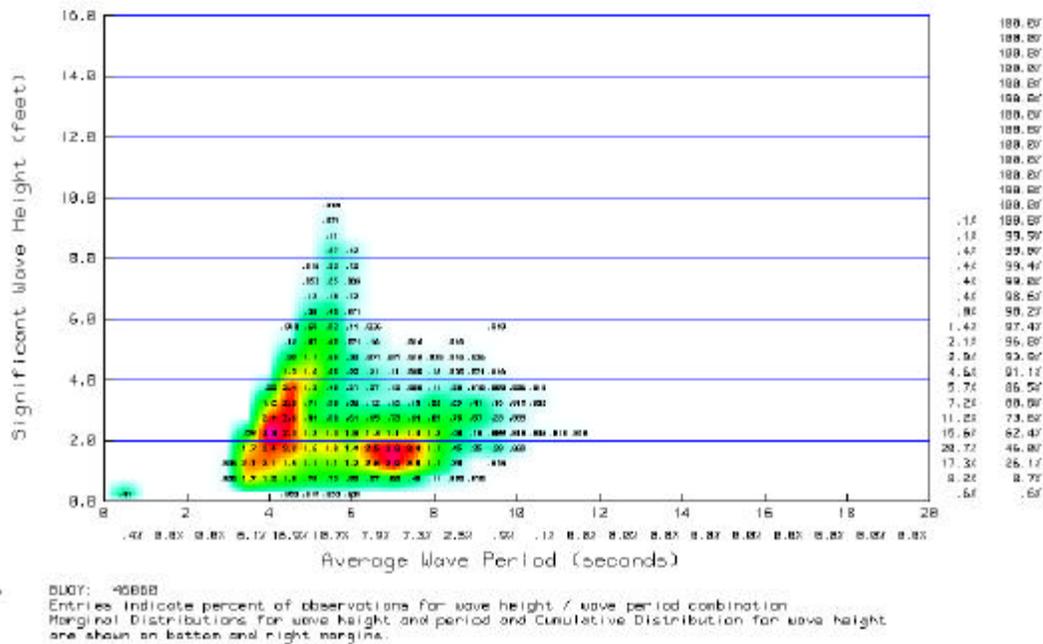


FIGURE 4
- April -
Joint Distribution of Significant Wave Height and Average Wave Period

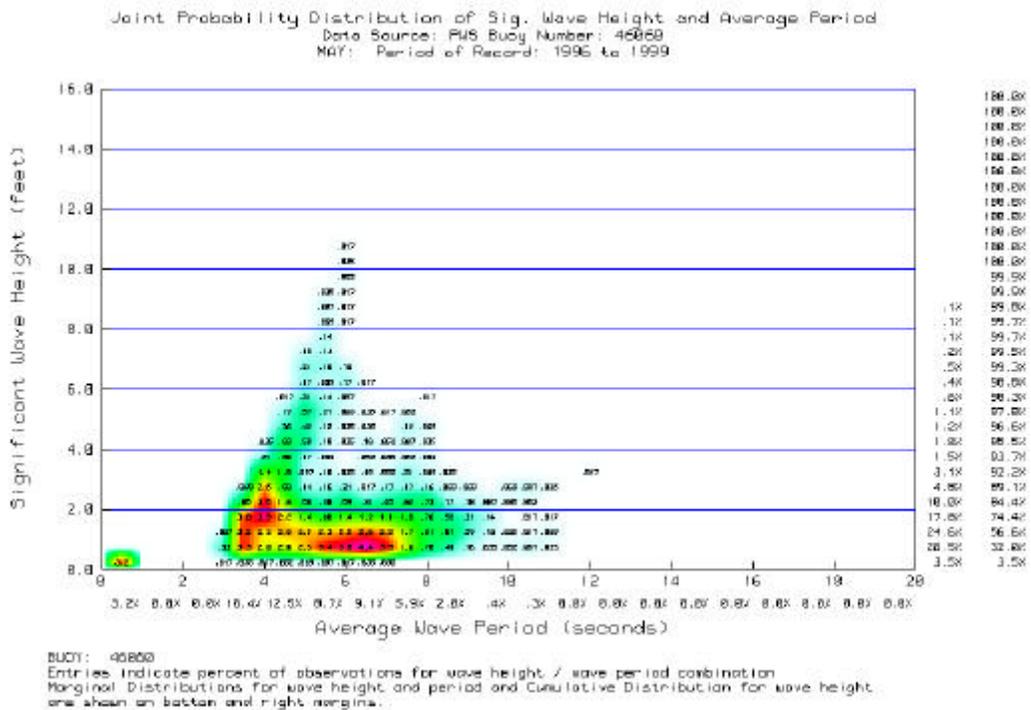


FIGURE 5
- May -
Joint Distribution of Significant Wave Height and Average Wave Period

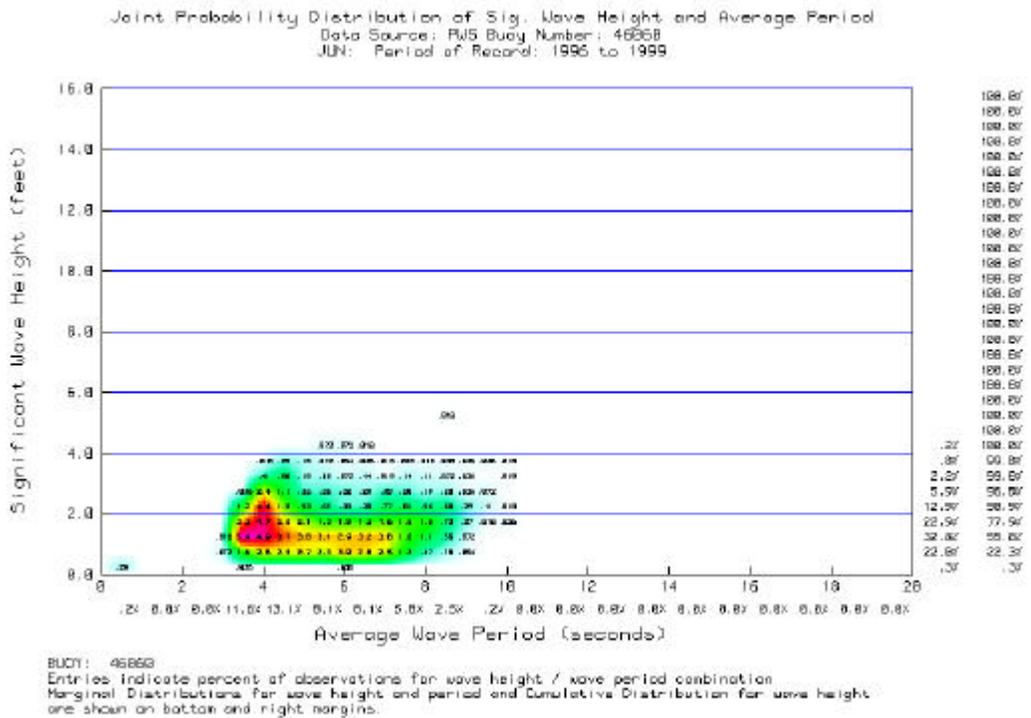


FIGURE 6
- June -
Joint Distribution of Significant Wave Height and Average Wave Period

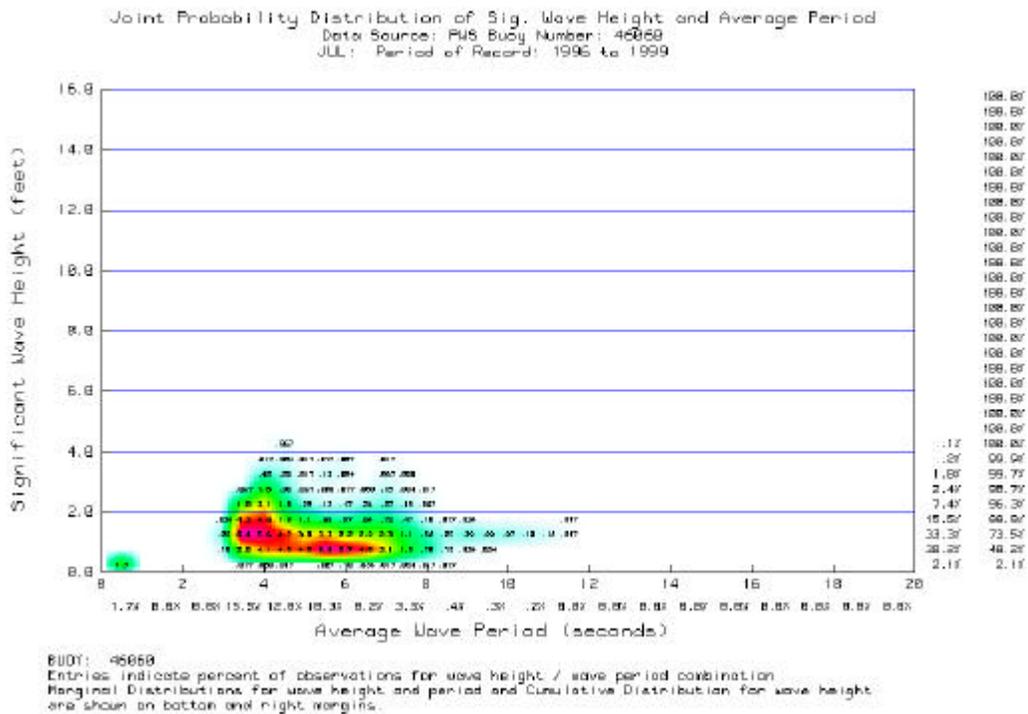


FIGURE 7
- July -
Joint Distribution of Significant Wave Height and Average Wave Period

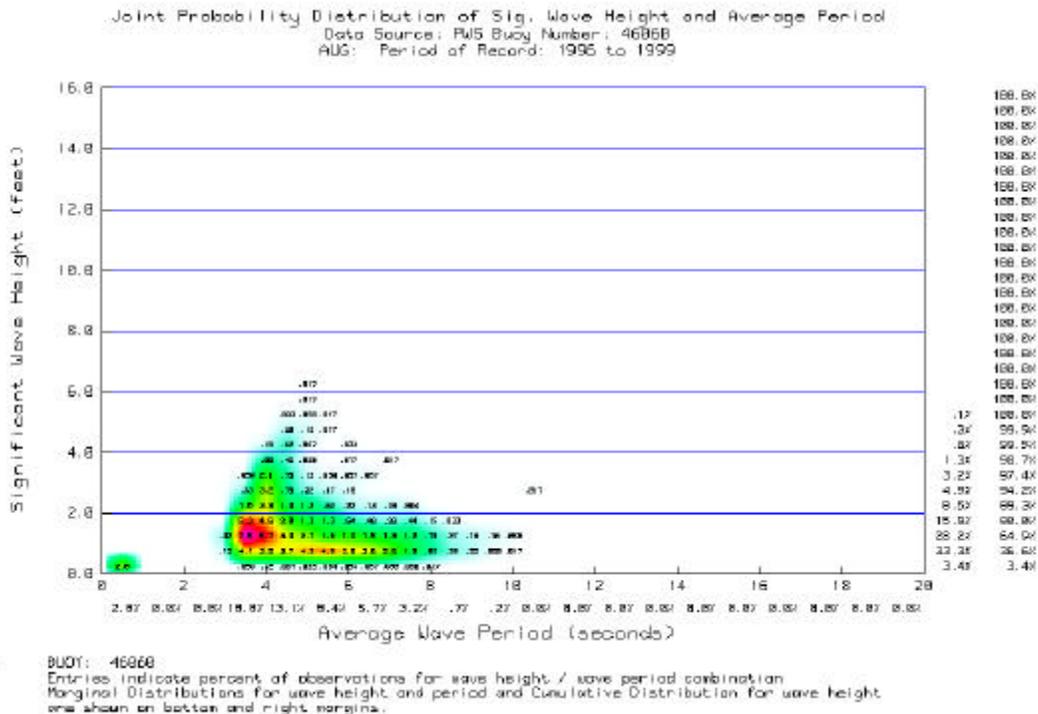


FIGURE 8
- August -
Joint Distribution of Significant Wave Height and Average Wave Period

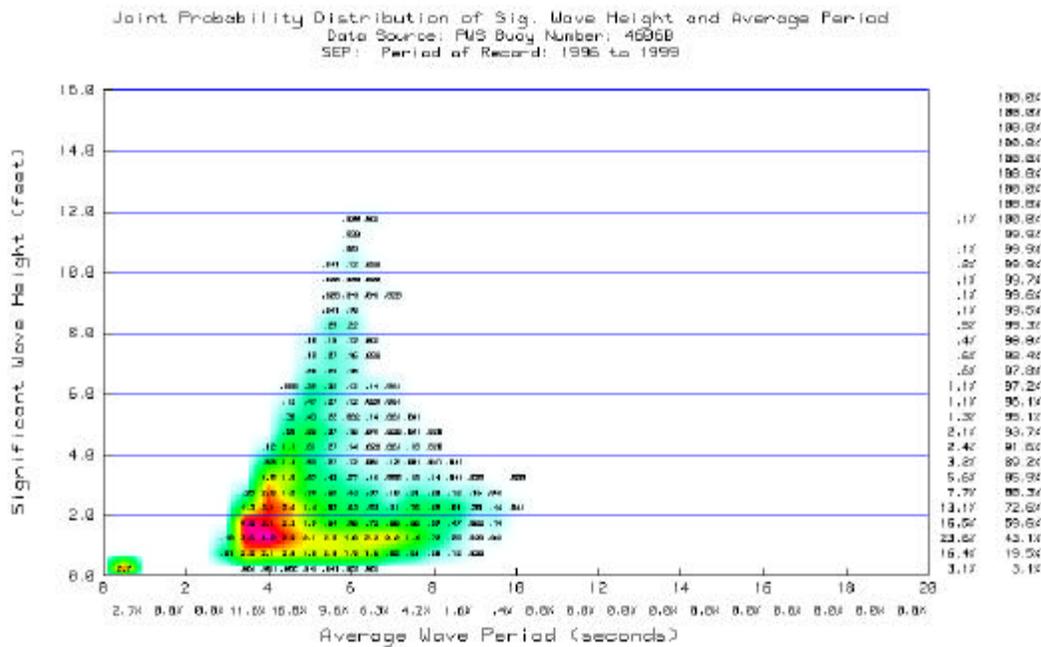


FIGURE 9
- September -
Joint Distribution of Significant Wave Height and Average Wave Period

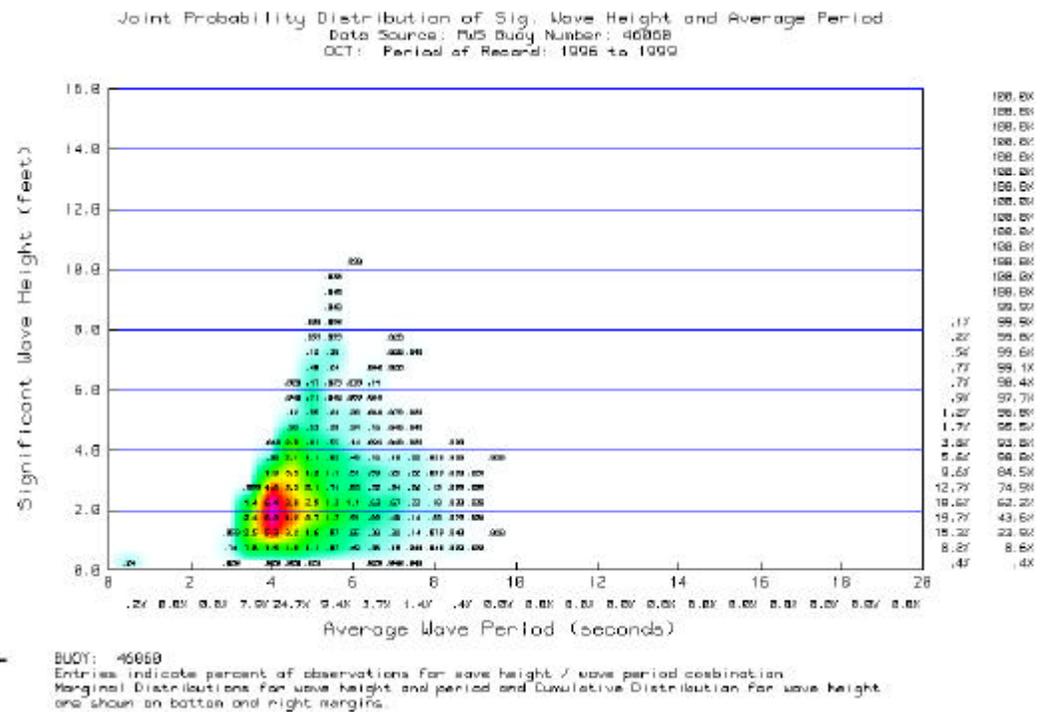
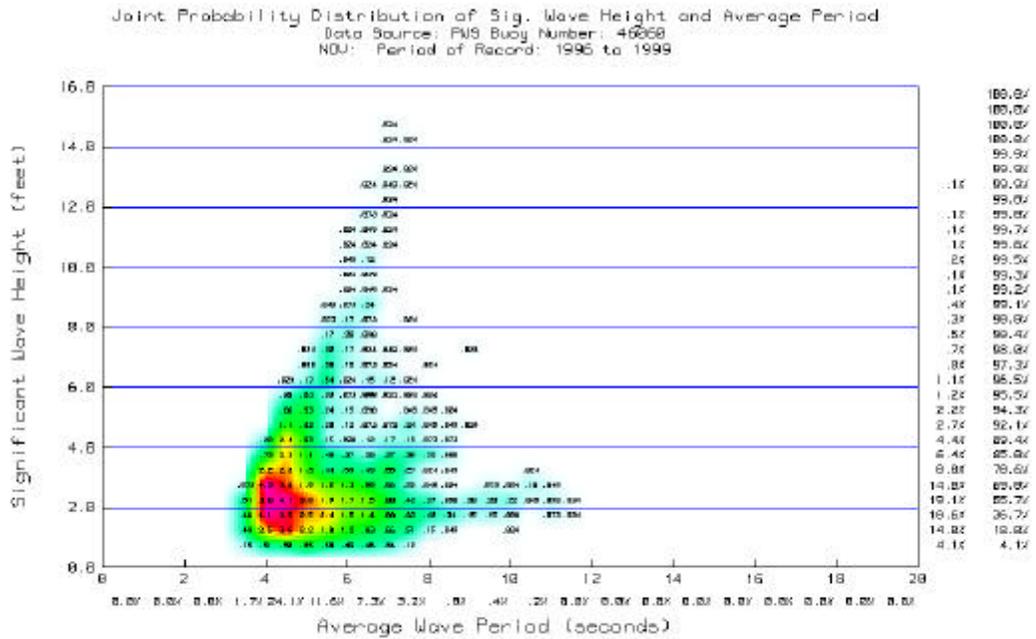
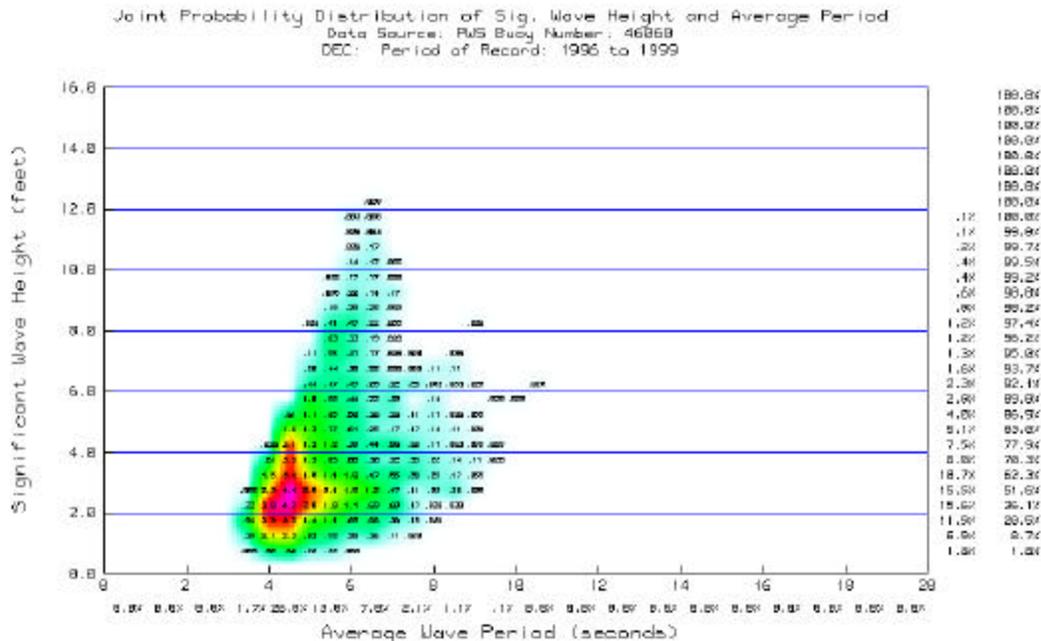


FIGURE 10
- October -
Joint Distribution of Significant Wave Height and Average Wave Period



BUOY: 46859
 Entries indicate percent of observations for wave height / wave period combination
 Marginal Distributions for wave height and period and Cumulative Distribution for wave height
 are shown on bottom and right margins.

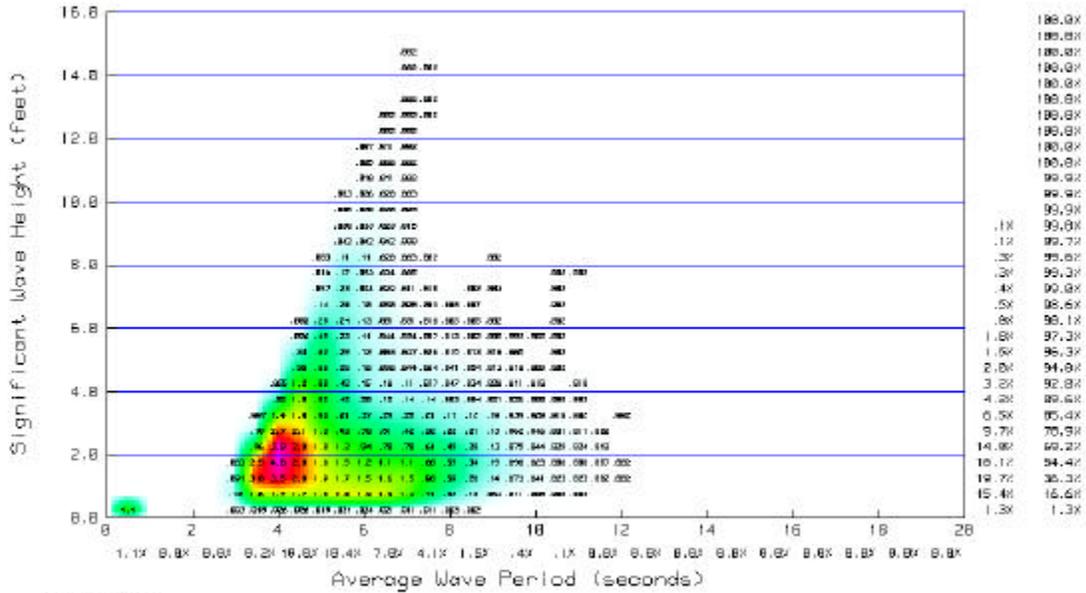
FIGURE 11
- November -
Joint Distribution of Significant Wave Height and Average Wave Period



BUOY: 46859
 Entries indicate percent of observations for wave height / wave period combination
 Marginal Distributions for wave height and period and Cumulative Distribution for wave height
 are shown on bottom and right margins.

FIGURE 12
- December -
Joint Distribution of Significant Wave Height and Average Wave Period

Joint Probability Distribution of Sig. Wave Height and Average Period
 Data Source: PWS Buoy Number: 46068
 Annual: Period of Record: 1996 to 1999



BUOY: 46068
 Entries indicate percent of observations for wave height / wave period combination.
 Marginal Distributions for wave height and period and Cumulative Distribution for wave height are shown on bottom and right margins.

FIGURE 13
- Annual -
Joint Distribution of Significant Wave Height and Average Wave Period