FAST VEHICLE FERRIES FOR THE ALASKA MARINE HIGHWAY SYSTEM

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ABSTRACT

For more than 40 years the Alaska Marine Highway System has maintained and operated a vehicle ferry service that provides critical transportation needs throughout coastal regions of Alaska. They are now implementing plans to markedly improve ferry service in Southeast Alaska and Price William Sound. High speed Ro-Ro ferries, or *fast vehicle ferries*, are an important part of these improvements. Such ferries have been used successfully in other regions of the world, but this is the first US application of fast ferries for year-round Ro-Ro service. This paper discusses why speed is important to economical improvements in Alaska transportation, outlines some of the critical features of the fast vehicle ferry design, and provides insight into the decision-making process to date.

WHY HIGH SPEED FOR THE ALASKA MARINE HIGHWAY SYSTEM?

The Alaska Marine Highway System (AMHS) is beginning a long-term improvement process as put forth by the Southeast Alaska Transportation Plan (*1*). The new system will utilize ferries that operate in daily runs from several homeports, forming a linked chain from Prince Rupert, British Columbia, to Skagway, Alaska. The new point-to-point routes will range from 292 to 578 kilometers (158 to 312 nautical miles) roundtrip. Existing long-haul vessels will still be used, but recent study indicates substantial savings in operation and acquisition costs can result from prudent use of high-speed day boats to meet the traffic demand in the next 20 years (*2*).

The key to the projected savings is reduction of crew costs, which total more than 70% of the operational costs of the current system. The average AMHS vessel has a crew of 40 and operates for 24 hours. If a vessel can operate and service its route in 12 hours or less, with a smaller crew, reductions in manning expenses will be significant. Study shows that savings in crew costs will clearly compensate for the increase in fuel and maintenance costs that speed will bring (*2*).

During development of plans for AMHS improvement, users of the AMHS fleet shared frustration with middle-of-the-night departures that unavoidably occur in a long-haul system. A fast ferry will provide more convenient schedules, and experience has shown that convenient schedules will increase ridership.

With this premise, AMHS has begun the acquisition of a fast vehicle ferry (abbreviated FVF) to carry 35 vehicles and 250 passengers on routes in Southeast Alaska and Prince William Sound at speeds in excess of 16.5 meters per second (32 knots). This paper will briefly describe the requirements of these new vessels, and relate the issues encountered when developing them.

THE EXISTING SYSTEM

It is not the intent of this paper to completely describe the state-run ferry system in Alaska, but for the reader who is not familiar with AMHS it will be helpful to understand the system as it now exists. For a more thorough description you may wish to refer to the AMHS web site (*3*).

AMHS consists of 1000 men and women, nine vessels, 35 community terminals, and routes that cover over 5635 kilometers (3500 miles). Within Southeast Alaska, AMHS uses seven vessels and calls at ports from Bellingham, Washington, to Skagway, Alaska, in year-round service. AMHS also crosses the Gulf of Alaska, and serves Prince William Sound, Kodiak and the Aleutian Islands. Figure 1 shows the vast extent of service. Omitted from this map is the cross-gulf service, from Juneau to Valdez with a stop at Yakutat, initiated by *M/V Kennicott* in 1998. The existing vessels range in capacity from 34 vehicles and 250 passengers up to 134 vehicles and 625 passengers. The system carries 100,000 vehicles and 350,000 people per year.

AMHS FAST FERRY ROUTES

AMHS initially plans for acquisition of four FVFs. The first will have a homeport in Sitka and make day runs to Juneau, for a roundtrip of 489 kilometers (264 nautical miles). This route, depicted in Figure 2, has been surveyed by a knowledgeable fast vehicle ferry master, AMHS vessel masters, and several local fast passenger boat operators. It is the same route used by existing AMHS vessels. The surveys point to areas between Sitka and Peril Strait where speed will need to be reduced to allow prudent navigation, to minimize impact of wake, and to take into account recreational traffic in these areas. There remain many miles along these routes where full operational speed can be responsibly maintained.

The second FVF will operate in Prince William Sound between the communities of Valdez, Whittier and Cordova as shown in Figure 3. The third and fourth vessels will serve routes from Ketchikan to Wrangell (roundtrip of 330 kilometers (178 nautical miles)) and Juneau to Petersburg (roundtrip of 456 kilometers (246 nautical miles)), where the navigational and speed constraints are less demanding than routes serving Sitka or Prince William Sound.

OPERATIONAL CHALLENGES

Climatology

Wind and wave climatology of Southeast Alaska was studied in depth by The Glosten Associates and AMHS (*2*). Joint probability wind speed and direction tables (monthly, seasonal and annual) and joint probability significant wave height and period tables for selected locations along the routes of the proposed ferries were developed using hindcast methodologies.

Wind speed distributions generated for locations in Southeast Alaska pertinent to planned fast ferry operations are illustrated in Figure 4 for the winter season. The significant wave height and period were estimated from synthesized hourly wind speed and direction data using a program developed by The Glosten Associates together with the US Army Corps of Engineers NARFET Program. Selected wave height statistics from this analysis are illustrated in Figure 5.

Wind and wave climatology for Prince William Sound was investigated in a similar yet abbreviated manner as documented in a Glosten Associates study (*4*). Results indicated that wave heights are similar to Southeast Alaska, but that in Prince William Sound wave periods can be higher over portions of the planned routes.

The relationship to the climatology studies and the owner requirements for FVF seakeeping qualities is discussed below under *Motion Sickness*.

Glacial Ice and Wood Debris

Alaska is famous worldwide for glaciers, and although the average winter water temperatures are above freezing for Southeast Alaska and Prince William Sound, multi-year glacial ice in the form of icebergs and “bergy bits” can occur in these waters. Figure 6, a photo taken by Captain Larry Sackett, master on board the AMHS *M/V Aurora*, illustrates bergy bits floating in the area of the Sukoi Islands near Petersburg on 9 March 2000.

In addition to bergy bits, icebergs can occur in regions of Prince William Sound routes (*4*) and these will require operational slowdowns based on reported sightings and known areas of concentration. Existing AMHS vessels have operated in these areas for many years, and monitoring knowledge of large concentrations of ice is standard procedure. Infrared sensors, discussed below under *Navigation Equipment*, will provide the FVF with additional warning.

Logs and other floating wood debris are also common. The impact on structural design of ice and wood debris is discussed below under *Structure*.

Ice Accretion

The International Maritime Organization’s (IMO) *International Code of Safety for High-Speed Craft: HSC Code* (*5*), establishes zones where ice accretion (on the exterior of the vessel) must be taken into account in the vessel design. The Prince William Sound and Southeast Alaska routes are outside the zones identified in the HSC Code; however, freezing rain and spray conditions are known to occur in these areas. In order to reduce the possibility of weather delay, AMHS is requiring that the vessel be designed in accordance with the requirements of Annex 5 of the HSC Code.

Snow

The American Society of Civil Engineers Standard ANSI/ASCE 7-95, *Minimum Design Loads for Buildings and Other Structures* (*6*) identifies snow loads for various types of structures. When subjected to snow loads from this standard, the vessel structures must be undamaged, and the vessel must remain afloat and stable without having to take any special precautions or measures (assuming no vehicles or passengers on board). The FVF design will incorporate snow loads for Cordova, Alaska, which corresponds to a ground snow load of 4788 Pascal (100 pounds per square foot).

OWNER'S REQUIREMENTS

Principal Dimensions

The principal dimensions required to meet the capacity, range, endurance, seakeeping shoreside limitation and other requirements are as follows:

- Full load navigational draft — Less than 3.65 meters (12 feet)
- Height above light load line — Less than 30.18 meters (99 feet)
- Beam — Approximately 19.82 meters (65 feet)
- Length overall — Less than 74.70 meters (245 feet)
- Freeboard at vehicle doors — Less than 3.65 meters (12 feet)

Payload

The vessel payload at full load will include the following:

- Passengers — 250 @ 75.0 kilograms (165 pounds) each
- Luggage — 9.1 kilograms (20 pounds) passenger
- Bicycles — 12 @ 13.6 kilograms (30 pounds) each
- Kayaks — 6 @ 34.1 kilograms (75 pounds) each
- Vehicles — total weight up to 122,727 kilograms (270,000 pounds)

Pickup trucks, campers, and sport utility vehicles dominate the Alaska vehicle population. The automobile equivalent unit (AEQ) definition for this project is noticeably larger and heavier than notional vehicles used in design of ferries for urban commuter traffic or European vehicles. Each AEQ is defined as 6.1 meters (20 feet) long and 3 meters (10 feet) wide with a weight of 2727 kilograms (6000) pounds. In contrast, a typical lower-48 or European AEQ is less than 5.5 meters (18 feet) long, 2.6 meters (8.5 feet) wide and only 1500 kilograms (3300 pounds).

The FVF will be capable of transporting tractor/trailer units and most heavy vehicles meeting the State of Alaska highway standards within the current maximum load capacity. Normally, the trailers are driven onto the ferry by the tractor, and the tractor is decoupled and removed from the vessel. At the discharge port, another tractor is driven aboard to unload the trailers after the passenger vehicles are unloaded.

Classification and Regulation

AMHS has chosen to have the ships built in accordance with the HSC Code (*5*), and to have the vessel classified by Det Norske Veritas. These vessels are expected to be the first fast *vehicle* ferries to be built in the US, and some special challenges with regulatory compliance are anticipated. All applicable IMO regulations, as well as national and state regulations must be satisfied. This includes the Americans with Disabilities Act which, for example, will require wheelchair access to all passenger areas, and sets standards for stairways and aisle widths.

Manning

Manning reduction is a critical aspect of this project, and the project team has identified a maximum manning level of ten crew, with five on duty at any time during a normal 12-hour day of operation. The number of persons required for a vessel evacuation in case of an emergency, not the number of persons on watch, determines the required manning levels. Watch stations are as follows:

- Deck officers on the bridge 2
- Engineer on the bridge 1
- Craft rating making rounds 1
- Passenger services 1

Terminal Interface

The FVF home ports will be equipped with new stern loading facilities such that vehicles will load via the stern at the home port and offloaded using the forward side door at the destination port, reversing the procedure for the return trip. A typical side load terminal is shown in Figure 7. To maximize the use of the FVF within the existing system, the new vessels must be able to operate effectively using the existing terminals, particularly at the destination ports. The key interface issue is the freeboard of the FVF as compared with the freeboards that can be accommodated by existing terminals. Further complicating the issue is a tidal range that can exceed 6.1 meters (20 feet).

Originally AMHS limited the FVF freeboard to 3 meters (10 feet). However, initial analysis indicated that this limitation would likely detract from the seakeeping quality of the vessel or force designers to install a ballast system to match shoreside ramp heights. Such a system, and associated weight and complexity, are unacceptable to AMHS. Accordingly, AMHS has elected to adjust the "float" height of the shore-side ramps, allowing FVF freeboard of 3.65 meters (12 feet).

Other important terminal interface considerations include shore power hook-up, sewage pump-out, fueling connections, phone connections, fender placement, and line handling interference. All these issues have had influence on the overall requirements for the FVF.

Vehicle Deck

A single vehicle deck without mezzanine decks is essential to achieve the operational flexibility required. The deck strengths must accommodate the heaviest highway truck rolling axle and tire loads throughout, for loading and unloading operations, but dedicated parking spaces for recreational vehicles and trailers will be used while underway. Another requirement, which is not usually seen on fast ferries, is electric power hook-up stations for vans with refrigeration units. In all weather conditions it is AMHS policy to lash down trailers. Other vehicles may be lashed down as weather conditions dictate. Parking and maneuvering space will be provided for all of the following notional vehicle configurations:

- 30 AEQs and two 20,454 kilogram (45,000 pound) truck trailers or
- 35 AEQs, or
- 30 AEQs and one 31,818 kilograms (70,000 pounds) truck trailer, or
- 24 AEQs, one 20,454 kilogram (45,000 pound) truck trailer, and four 9090 kilogram (20,000 pound) recreational vehicles

Hull Form

The design team studied existing designs of candidate vessels for this operation and found that the catamaran hull form is best suited to these vehicle deck capacities and offers the minimum capital and operating costs. The design team found that the seakeeping characteristics of conventional catamaran hull forms would satisfy the required motion sickness index criteria. AMHS is looking for an adaptation of a design proven in service, and is not considering experimental concepts or hull forms that have no demonstrated successful operating experience as a high-speed vehicle ferry.

Availability

The routes in Southeast Alaska and Prince William Sound transit truly remote regions, and the ferries are the only link for getting vehicles to many of these communities. Delays and downtime have a serious impact on the communities served by AMHS. The ferries must be self-sufficient, as there are limited rescue and support resources in the service areas. It is essential that the FVF have the highest possible availability of all systems in order to remain in service with the minimum of downtime. Therefore, redundancy has been specified for all major systems, particularly the main propulsion and electrical systems. A minimum of four independent main propulsion systems, with four waterjets, each with independent steering controls, is required. The electric power generation is to be provided by four independent diesel generator sets with two generator sets per hull and separate switchboards in each hull, with emergency battery backup power.

Maintainability

Ready access for regular maintenance on all equipment is a necessity, and it is highly desirable that machinery and equipment have sources of service and support in Alaska. Clearly defined removal routes for all equipment (including main engines, generator sets and waterjets) are required to facilitate shore based repair and overhaul.

Weight and Weight Margins

Weight control is the most important aspect of fast ferry design and construction, and weight changes must be anticipated and wisely managed. During construction, everything that goes on and off the vessel is weighed, and the differences between design weights and actual weight are carefully tracked. Acknowledging that some difference will occur, a *design and build margin* is provided by the Contractor as part of the construction contract.

Also, recognizing that all the requirements may not be fully reflected in the Owner's Requirements as initially issued, a *contract modification margin* of 5090 kilograms (5 long tons) is to be included in the design weight budget.

These vessels will remain in service for 25 or more years, and it is likely that weights will increase over time due to changes in service, modifications, or regulatory changes. Accordingly, a *service life margin* of 10,180 kilograms (10 long tons) is allocated.

Structure

There is a structural design limit of 22,727 kilograms (50,000 pounds) in excess of the full load displacement plus all margins. Additionally, the hull will be strengthened as shown below, for possible impacts with logs and similar floating debris as well as occasional pans of floe ice.

- The stem bar is two times the section modulus required by the regulatory bodies.
- The thickness of the side shell plate at forepeak is 1.5 times the regulatory body requirement from 0.3 meters (1 foot) above the deepest waterline to the keel.
- For the balance of side shell plate to 0.2L (ship length) aft of the stem, the plate thickness is 1.5 times the regulatory body requirement from 0.3 meters (1 foot) above the deepest waterline to 0.6 meters (2 feet) below the lightest load waterline.
- The side frames are a minimum of 1.25 times the section modulus required by the regulatory bodies.

Propulsion Machinery

The FVF is intended to operate with periodically unattended machinery spaces in order to minimize manning. Propulsion machinery will consist of four independent propulsion systems, two in each hull, each driven by a turbocharged marine diesel engine. The bidders will determine the particular machinery required to achieve the vessel performance requirements. The entire propulsion system will be designed to withstand impacts with fragments of glacial ice and wood debris, and machinery will be resiliently mounted to the extent required to achieve the noise criteria for the vessel. A bow thruster system will be fitted to provide suitable pier-side and stationary maneuvering capability.

The waterjets will be capable of operating at the maximum engine speed (within the capabilities of the engine) when the vessel is at zero ship speed and the waterjet buckets are in neutral, ahead or reverse position, without catastrophic damage to the waterjets or waterjet seals. Emergency crash stop maneuvers must be possible by immediately deploying the reverse buckets at full engine speed without any delay for the engines to reduce speed. The result is a stopping distance in the order of one or two ship lengths.

PERFORMANCE

Speed/Power

The required maximum service speed is 16.5 meters per second (32 knots) in seas of up to 1.2 meters (4 feet) significant wave height and head winds of 10.8 meters per second (21 knots). During these weather conditions, the engines may reach 90% of their rating. In more severe weather, or to make up time for delays, the engines may be called on to operate at 100% rated power for short periods. However, for the majority of the year, in the normally moderate weather conditions, the engines are expected to operate at less than 85% of the rated power when traveling at 16.5 meters per second (32 knots) with a full load.

The equivalent calm water speed is 18.8 meters per second (36.5 knots) at 100% of the main engine fast ferry rating, or 18.0 meters per second (35 knots) at 90% of the rated power. These calm water speeds will be used for acceptance trials.

Motion Sickness

The vessel must have good seakeeping characteristics. As normal for fast ferry design, the design goal is to induce motion sickness in less than 10% of the passenger population in the worst expected conditions. The motion sickness index will be computed by the method given in ISO 2631-1 (*7*), for expected exposure times and vertical accelerations. Based on the planned Southeast Alaska routes, motion sickness is be computed with an exposure duration of two hours in a significant wave height of 2.0 meters (6.6 feet) with a peak period ranging from 4 to 6 seconds. The vertical accelerations required in this method will be obtained from theoretical seakeeping computer programs and/or physical model tests for the following conditions:

- Head and following seas
- Forward speed of 15.4 meters per second (30 knots)
- A general passenger population consisting of men, women and children
- Spatial distribution of vertical acceleration to reflect the proposed vessel arrangement

Prince William Sound exposure time is expected to be one-half the exposure time in Southeast Alaska, but wave periods are higher in Prince William Sound (*4*). The end result is expected to be similar motion sickness incidence in both regions.

In order to achieve the optimum running trim throughout the speed range and to satisfy the motion sickness criteria, a dynamic ride control system will be fitted consisting of active trim tabs. The FVF will also be outfitted with the capability to install active T-foils, mounted on the forward keels, if conditions dictate this additional expense and complexity.

Station Keeping

Using a combination of waterjets and bow thruster(s), the vessel will be able to maintain its position and heading when exposed to a steady wind of 14.4 meters per second (28 knots) from any direction. The transverse bollard pull will be measured during trials to verify compliance with required thrust.

Systems

The FVF will operate on #2 diesel oil, with sufficient fuel carried aboard for the longest expected return voyage plus 37% reserve. The fuel and lube oil tanks are to accommodate 105% of required capacity.

The passenger and crew spaces will be air conditioned, but the heating load will exceed the cooling load due to the moderate summer temperatures 21 C (+70 F) and cold winter temperatures – 23 C (-10 F).

All liquid wastes, black and gray water, waste lube oil, coolants and bilge water will be stored aboard for discharge to shore-based treatment facilities. The sanitary flushing system will use seawater with gravity drainage.

The engine exhaust systems will be dry type, with the exhaust outlets arranged and designed to eliminate recirculation of engine exhaust gas into the ventilation systems.

Navigation Equipment

The FVF will be outfitted with state-of-the-art navigation equipment meeting or exceeding all USCG requirements. Generation III night vision hand-held binoculars, with built-in infrared illuminators for extreme low light and no-light situations, will be provided. In addition, a fixed image intensified night vision system and an infrared lighting system will be fitted. The enhanced image is to be displayed on a monitor with on-screen displays of direction, angle of tilt and distance ahead.

MITIGATION OF ENVIRONMENTAL IMPACTS

Wake

The wake wash characteristics of the proposed vessels are an important component in the vessel evaluation. The bidders are being asked to provide wake wash data in their proposals based on model tests or full scale tests. The vessel performance requirements and the preliminary route plans include time delays specifically for wake wash mitigation in order to enable the schedule requirements to be met at design speeds.

Noise

Drive-by exterior noise levels at full rated power are limited to a maximum of 60 dBa at 1000 feet. Interior passenger lounges will have noise levels less than 75dBa. Pilothouse noise levels will be less than 65 dBa.

Air Emissions

All the engines on these ferries are to certified for compliance with IMO, MARPOL Annex VI, and the State of Alaska Administrative Code 18 ACC 50.070, *Marine Vessel Visible Emission Standards* (*8*).

Water Emissions

The vessel will be designed to hold on board for treatment ashore all noxious liquids including sewage, gray water, oily water and waste oil. The hydraulic oil in systems exposed to potential damage outside the vessel such as the waterjet controls will be a biodegradable type.

CONCLUSION

The Alaska Marine Highway System entered into the acquisition of fast ferries with the following overarching goals for the vessels and their operations within the existing fleet:

1. Safety
2. Seaworthiness
3. Ruggedness and simplicity
4. Maintainability and reliability
5. Proven operation by similar vessels and systems
6. Integration with existing AMHS operations
7. Vessels that work for Alaska

We believe the challenges of this new Alaskan transportation endeavor have been diligently addressed and that the vessel requirements set forth in this paper reflect that effort. We also believe that a skilled shipbuilder of aluminum vessels teamed with a proficient fast ferry designer will turn these goals into reality.

ACKNOWLEDGEMENTS

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2. Federal Highway Administration, for funding associated with the FVF Acquisition and the Vessel Suitability Study
3. Kerry Kirkpatrick, State of Alaska DOT and PF, Mapping Division of Statewide Planning, for assistance with Figures 2 and 3.

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8. MARPOL Annex VI, and the State of Alaska Administrative Code 18 ACC 50.070, *Marine Vessel Visible Emission Standards*.

LIST OF FIGURES

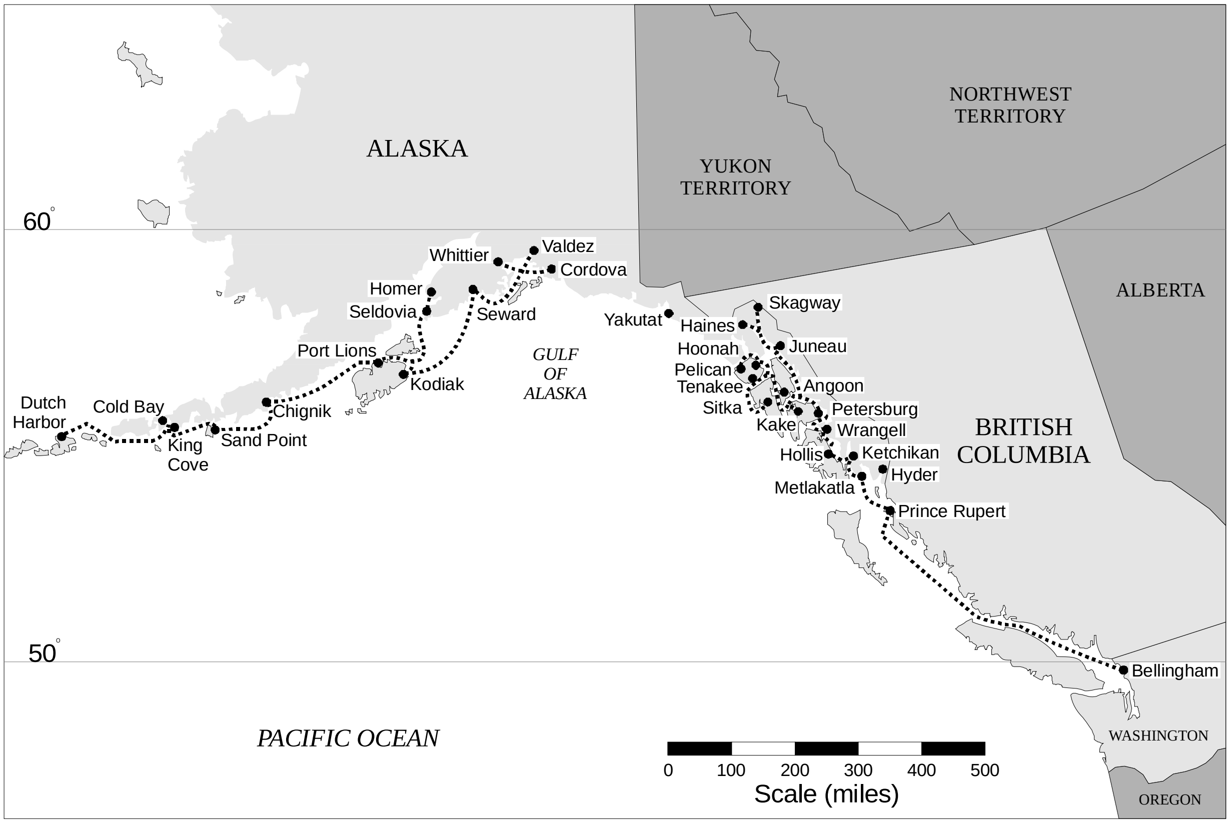

FIGURE 1 AMHS route system overview. (scale is in miles, 1 mile = 1.6 kilometers)

FIGURE 2 Sitka-Juneau FVF route, SE Alaska.

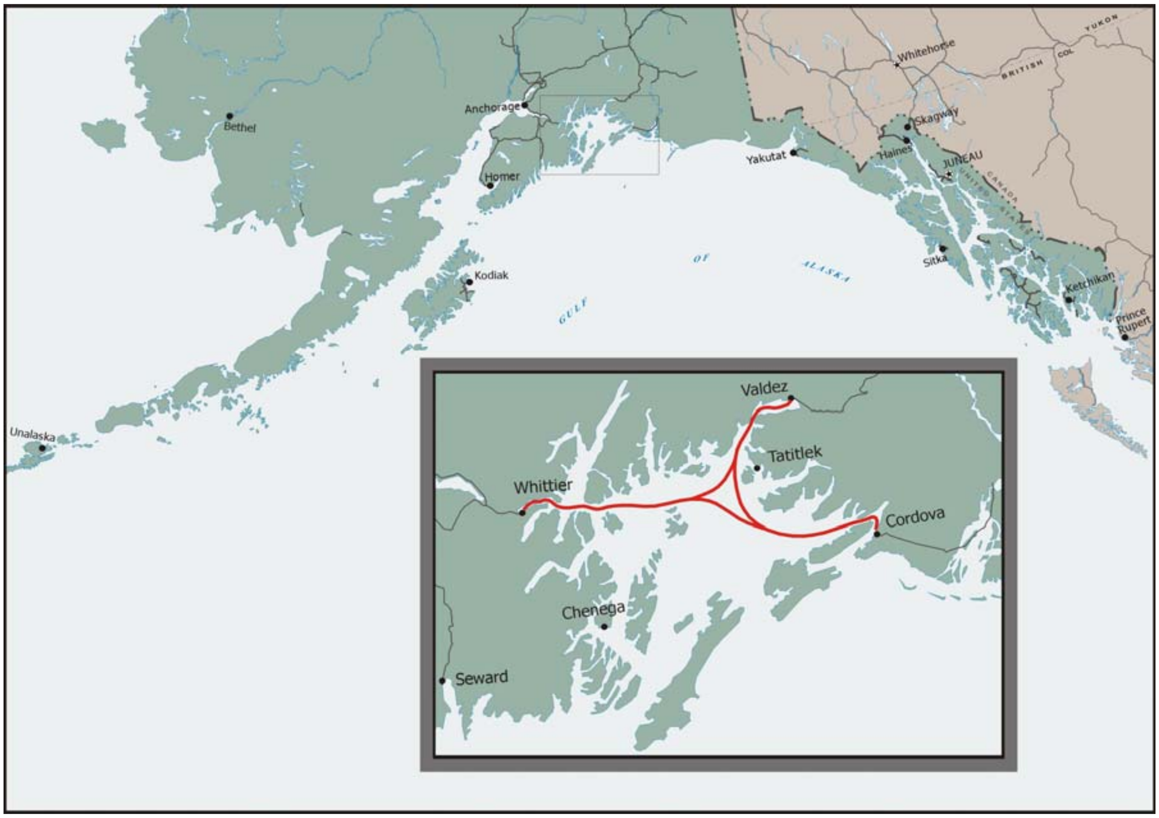

FIGURE 3 Cordova-Valdez-Whittier FVF route, Prince William Sound.

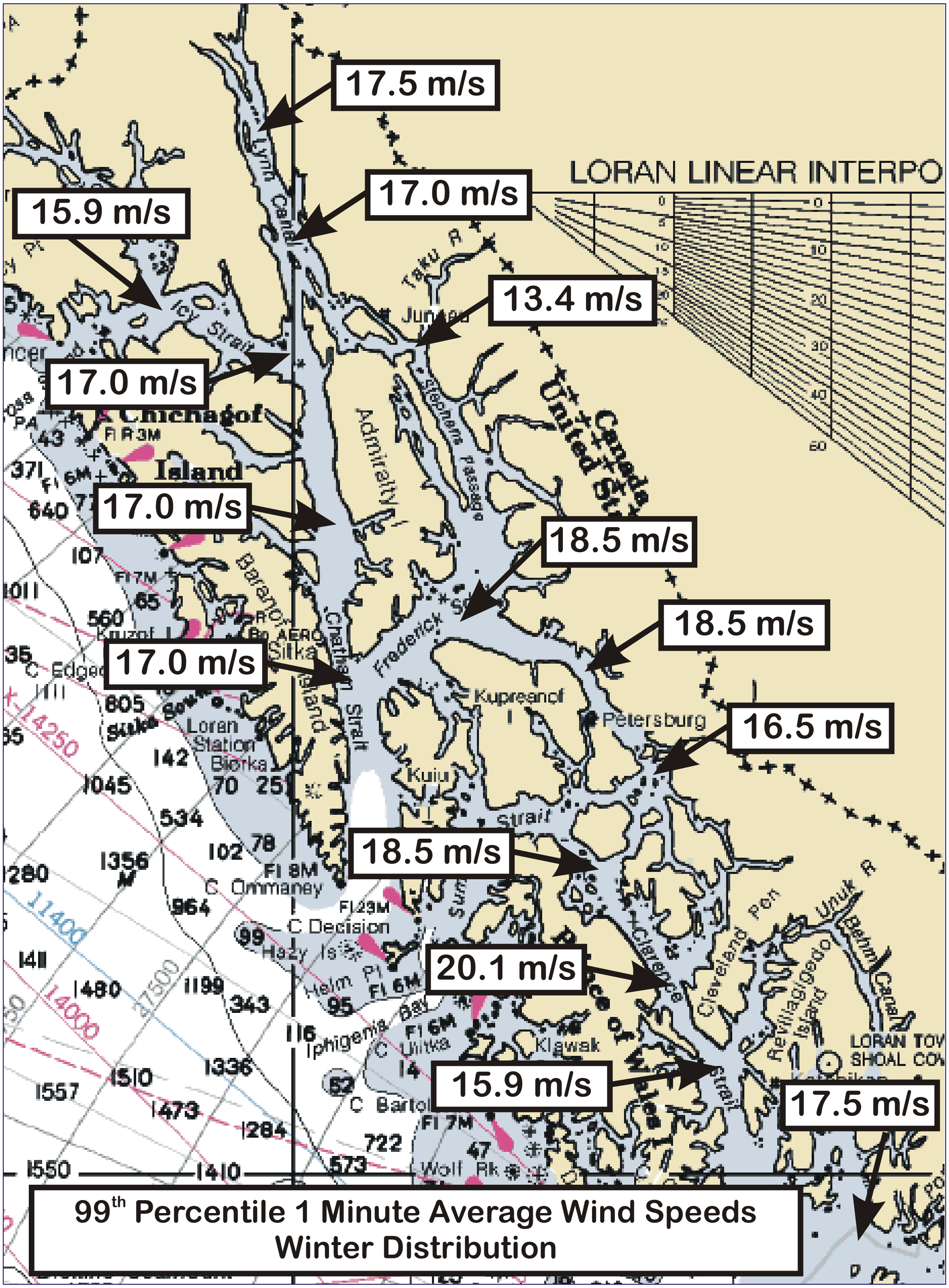

FIGURE 4 Wind speed hindcasts in SE Alaska. (1 m/s = 1.9 knots)

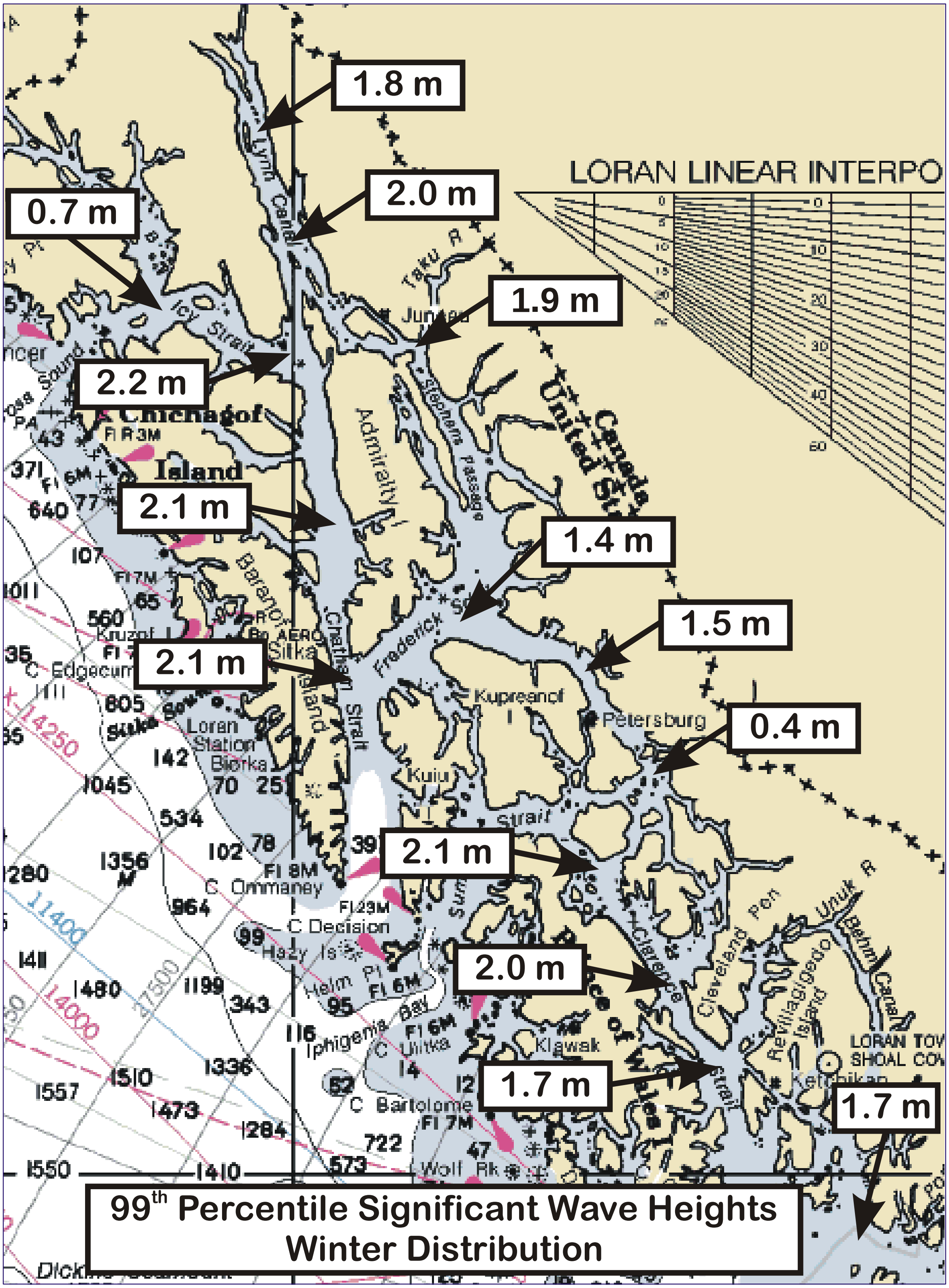

FIGURE 5 Wave height hindcasts in SE Alaska. (1 meter = 3.28 feet)

FIGURE 6 Bergy bits off Sukoi Island near Petersburg, AK, 9 March 2000 (photo taken by Captain Larry Sackett, AMHS).

FIGURE 7 Typical AMHS side loading terminal.