A Review of Best Available Technology in Tanker Escort Tugs

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Prepared for:

Prince William Sound Regional Citizens' Advisory Council
Anchorage, AK

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EXECUTIVE SUMMARY

In compliance with the Terms of Reference for this study, data was collected on the worldwide fleet of 27 escort-rated tugboats more than 35 metres in length. Performance parameters were established and the current SERVS tugs, the ETT Class and PRT Class tugs specifically, were compared to the rest of the world fleet and to what represents the Best Available Technology (BAT) in escort tug design today. Data was collected directly from Owners or from published reliable data sources, and in some cases, where information was not readily available, performance was calculated.

The roles required of the SERVS tugs as either Primary (PEV) or Secondary (SEV) escort tugs as defined in the Tanker C-Plan were also examined and the performance requirements for each role assessed. It is noteworthy that these distinctions exist; it is clearly not intended that the SEV's have the same escort capability as the PEV's, and in fact their technical missions as defined in the C-Plan are quite different, requiring very different hull forms and propulsion systems in order to best satisfy these individual mission descriptions. This distinction however calls into question the definition of the SEV as an "escort" tug in the truest sense of that word.

In addition, the requirements defined by 33 CFR 168 for any escort tug operating in Prince William Sound were examined, and the SERVS tugs assessed against those regulatory criteria.

The essential conclusions of this comparative performance analysis were:

- The ETT tugs are very typical of a standard large Voith Water Tractor. The ETT tugs are large, powerful, and perform well. However design developments in the past decade have led to a new generation of VSP-propelled tugs with superior performance in all respects. These new tugs are more efficient, faster, and develop more steering force per unit size and per unit of power than do the ETT Class. That said, the spread in performance between the ETT and BAT today is not great (less than 8%). The lack of a fully capable render-recover winch on the ETT tugs is a major shortcoming

- The PRT tugs are large and powerful Azimuthing Stern Drive (ASD) tugs, and are well-equipped for ocean towing. They are not however well-configured to function as a proper escort tug performing indirect or powered indirect towing, taking maximum advantage of the size and power of these tugs. They have no skegs or comparable appendages with which to efficiently generate indirect steering or braking forces. The indirect force generating capability of the PRT Class is about half that of the best ASD escort tugs operating today. The PRT tugs lack a render-recover escort winch forward, and the towing staple position is too far forward

There are some significant gaps between the SERVS vessels and what is considered BAT in escort tugs today. The major deficiencies are:

a. Neither class of tug has a formal "Escort" notation issued by a Classification Society (Class).
b. The ETT tugs do not have a render-recover winch which satisfies Class standards for an escort notation.
c. The PRT tugs do not have a render-recover winch which satisfies Class standards for an escort notation.
d. The PRT hull form is not configured to generate indirect line forces, and lacks appendages such as a skeg or bilge keels which would enhance this capability.
e. The PRT Class tugs are limited in their ability to generate indirect forces sufficient to represent the equivalent tanker rudder force for the larger tankers in the system. They do however, by virtue of their size and power, have sufficient capability to control tankers of 125,000 tonnes DWT or less.

The ETT tugs fully satisfy the requirements of CFR 33 168:50 for tankers up to 200,000 tonnes DWT, and the PRT tugs satisfy CFR 33 168:50 for tankers of 125,000 tonnes DWT or less.

The performance of the ETT tugs would be significantly enhanced by retrofitting a proper escort-rated render-recover winch. The cost of such a refit is roughly estimated at $ 1.5-$2.0 million per vessel.

The performance of the PRT Class tugs could also be enhanced by the following alterations:

- Fit a large forward skeg
- Remove the existing aft skeg
- Fit an escort-rated render-recover type winch on the fore deck
- Provide a towing staple further aft (closer to the winch), with appropriate strength for higher line forces

With these changes, (subject to a much more detailed evaluation and analysis), it is believed that the indirect force generating capability of the PRT tugs would increase to something in the order of 125 tonnes. It would need to be carefully analysed however whether these tugs have the stability necessary to achieve such a rating. These alterations are quite extensive and are roughly estimated to cost approx. $2.5-$3.0 million/vessel.

In summary, neither the ETT Class nor the PRT Class tugs represent BAT in escort tugs today. The research and developments of the past decade have resulted in significant improvements in tug hull design, propulsion equipment advances, and in much improved winch design for this particular application, and most of the more recently built escort tugs significantly out-perform these SERVS vessels. The ETT tugs however are still very effective escort tugs and with a better winch system would be a world-class escort tug. The PRT tugs as presently configured lack a significant escort towing capability and it would be difficult and expensive to change them in a manner which would provide that escort capability.

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A Review of Best Available Technology in Tanker Escort Tugs

For: Prince William Sound Regional Citizens' Advisory Council
Anchorage, AK

1.0 INTRODUCTION

Robert Allan Ltd. was retained by the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) under Contract Number 8010.12.01, dated November 12, 2012, to provide an assessment and professional opinion on the capabilities and performance of the present SERVS escort tug fleet in comparison to the "Best Available Technology" (BAT) available worldwide in this specialized field of ship design and engineering today.

There have been dramatic developments and significant improvements in escort tug design in the past decade. The SERVS tugs; specifically the ETT Class Voith Water Tractors and the PRT Class Azimuthing Stern Drive (ASD) tugs, are now both approaching fifteen years of age and while certainly not old in ship years they do pre-date many of the more innovative developments in escort tug technology of the past decade. It is therefore appropriate to see how these vessels compare to the best escort tugs currently available; identify where there may be gaps in capability; and to identify how the present vessels might be altered to match current BAT as closely as possible.

In this context it is useful to identify precisely what is meant by "Best Available Technology" (BAT) in the context of escort tugs. That definition is contained in the Alaska Department of Environmental Conservation (ADEC) Regulation 18 AAC 75.455(k)(3), as follows:

> *"Technology identified under 18 AAC 75.425(e)(4)(A) [as BAT] will be evaluated using the following criteria, if applicable:*
>
> *(A) whether each technology is the best in use in other similar situations and is available for use by the applicant;*
>
> *(B) whether each technology is transferable to the applicant's operations;*
>
> *(C) whether there is a reasonable expectation each technology will provide increased spill prevention or other environmental benefits;*

(D) *the cost to the applicant of achieving best available technology, including consideration of that cost relative to the remaining years of service of the technology in use by the applicant;*

(E) *the age and condition of the technology in use by the applicant;*

(F) *whether each technology is compatible with existing operations and technologies in use by the applicant;*

(G) *the practical feasibility of each technology in terms of engineering and other operational aspects; and*

(H) *whether other environmental impacts of each technology, such as air, land, water pollution, and energy requirements, offset any anticipated environmental benefits."*

However 18 AAC 75.425(e) speaks more to spill response than to spill prevention through escorting. Nonetheless the broad BAT policy objectives described above can also be used to describe escort tug technology.

This report describes the evaluation process undertaken to conduct this BAT review, and provides the requested assessment of the SERVS tug fleet.

2.0 TERMS OF REFERENCE

The specific terms of reference for this study were the following:

"…Using the project methodology *as presented in the Consultant's proposal as a framework, prepare a detailed work plan and schedule utilizing these deliverable milestones:*

1. Present Vessel Inventory and Data Compilation:

*a. **Data Collection**—collect information on latest escort towing technologies used in other jurisdiction. Contact major towing firms for information concerning their most recent escort tugs. Collect available information on the current Prince William Sound fleet technical details and performance through a document search and contract with Crowley Maritime.*
*b. **Vessel Site Visit**—visit vessels in question to verify the data provide and discuss operators the towing methods used in various operating scenarios.*
*c. **Research Review**—review most recent research pertaining to escort tugs, with a focus on work conducted at SAFETUG on vessel escort performance in high seas states and independent research previously performed by the Consultant.*

2. *Analysis of Vessel Performance:*

   a. ***Indirect Vessel Performance Analysis****—conduct an analysis of the escort performance predictions for the Sea Swift, Invader, Theriot, Utility, Protector, Enhanced Tractor Tug (ETT) and Prevention and Response Tug (PRT) Class vessel by empirical methods to determine which vessel are suitable for safe indirect towing operations. Use the information developed in this process to help formulate the gap analysis of escort tug BAT to be conducted later in this study.*
   b. ***Hinchinbrook Sentinel Tug Analysis****—conduct an analysis of what would constitute BAT for the sentinel tug stationed at Hinchinbrook Entrance, estimating the following required characteristics; particulars, stability, seakeeping, bollard pull, speed, endurance, range, indirect towing capability, rescue towing capability, and towing gear. The Council will work with the Consultant to define the mission statement for the Hinchinbrook Sentinel vessel. (Note: This topic is the subject of a separate report.)*

3. *Best Available Technology Gap Analysis:*

   a. ***Presently Used Escort Vessel Comparison****—compile a comparison of escort vessel technology currently being used to best available today. Comparison will identify performance per vessel length, displacement and power; direct towing performance per unit power, review vessel escort and seakeeping capabilities and availability using Berthsim; stability characteristics, and winch performance versus line forces generated.*
   b. ***Gap Analysis****—identify any Gaps or deficiencies in the present system that could be filled or improved by use of best escort tug designs available worldwide today.*
   c. ***Escort Tug State of the Art****—compare the ETT and PRT vessels used in the present system to the best escort tug designs available worldwide today using the eight (8) stipulated criteria used by the Alaska Department of Environmental Conservation (ADEC). Construct a matrix detailing each of these eight criteria to be included in the final report.*

4. *Draft Final Report:*

   a. *Provide a summary report defining all findings of the study, and advising what would constitute the best available technology for the primary escort tug role, the secondary escort tug role, the Hinchinbrook Sentinel tug role and if there should be a different standard developed for BAT for the primary tug role in service of 90,000 DWT tankers.*

5. *Final Report.*

3.0 CURRENT ESCORT TUG INVENTORY

3.1 Data Collection Procedures

In order to obtain accurate information regarding escort tugs in service worldwide, a variety of sources were contacted and various methodologies employed, including:

- Direct survey enquiry—emailed and mailed
- Internet search
- Direct email enquiries
- Data search—Robert Allan Ltd. files
- Direct requests to PWSRCAC (re SERVS tugs specifically)

The response to the direct survey enquiry was very disappointing, with only a small number of the companies contacted providing detailed responses. The internet search provided more data for a number of vessels but that data cannot always be verified. Direct email follow-up enquiries for specific data on specific tugs were generally not answered, indicating that operators view such information as either proprietary or very confidential or both. A significant amount of data however could be obtained from the files of Robert Allan Ltd., which had the benefit of being fully verifiable in terms of accuracy and also represents a significant percentage of the current world escort tug fleet. Some additional data was obtained from published papers from International Tug & Salvage Conferences and the like. Accordingly it is believed that this compilation is both very representative of the world fleet of true escort tugs, and is accurate.

It should also be noted that the survey was limited to tugs in excess of 35 metres in length, in order to be most relevant to the terms of this study.

3.2 SERVS Fleet

Data on the current SERVS Fleet is as shown on Table 3.1 overleaf (Source: PWSRCAC).

Table 3.1 Particulars of SERVS Tugs in Prince William Sound

PWS ESCORT VESSEL INFORMATION

The following information is provided in order to familiarize Tanker Masters with Escort vessels that may be found within Prince William Sound escort system.

Table 4-1. Principal Dimensions of Charter Escort Fleet

		Invader Class	Theriot Class	Utility Class	Protector Class	PWS Class (ETT)	PRT Class
	Sea Flyer Sea Swift	**Stalwart Bulwark Guardian Warrior Hunter**	**Sea Voyager Sea Venture**	**Endurance**	**Protector Guard**	**Nanuq Tan'erliq**	**Alert Aware Attentive**
LOA	136	136	150	207	120	153	140
Classification HP	5,750	7,200	7,200	5,750	5,500	10,192	10,192
Nominal Bollard Pull	105,300	148,000	210,000	180,000	120,000	210,000	300,000
Maximum Bollard Pull	N/A	N/A	N/A	N/A	240,000 @ 12 knots	420,000 @ 12 knots	N/A
Engines	EMD 16-645-E5	EMD 20-645-E5	EMD 20-645-E5	EMD 16-645-E7A	CAT 3606	CAT 3612	CAT 3612
LWL (ft)	133	133	147.75	193	112.8	138	130.5
Beam (ft)	36.5	36.5	40	40	41.5	48	42
Design Draft (ft)	17	17	18	16.75	16.9	21.8	23
Displacement (lt)	1,063	1,063	1,504	2,158	601.89	1,046	1,680
GM (ft)	3.16	3.16	4.1	5.02	8.71	Per Stability Booklet	Per Stability Booklet
Freeboard (ft)	3.5	3.5	4	4.24	4.6	5.2	3.4
Rated RPM	900	900	900	900	1000	1000	1000
Number of Engines	2	2	2	2	2	2	2
BHP @ Rated RPM per Engine	2,875	3,600	3,600	2,875	2,750	5,096	5,096
Gear Ratio	4.536	4.345	5.92	4.962	13.845:1	13.845:1	5.175:1
Prop Diameter (ft)	10	11	12	11	Size 32	Size 36	9.83
Prop Pitch (ft)	8.29	6.5	12	9.33	Controllable	Controllable	Controllable
Exp. Area Ratio	0.75	0.75	0.63	0.7	N/A	N/A	N/A
Nozzles (Yes/No)	No	No	Yes	Yes	No	No	Yes
Nozzle Diameter (ft)	N/A	N/A	12.06	11.08	N/A	N/A	9.95
Nozzle Length (ft)	N/A	N/A	8.083	5.5	N/A	N/A	4.92
Propeller Type	Open Wheel 5 Blade	Open Wheel 5 Blade	Nozzle 4 Blade	Nozzle 4 Blade CP	Voith Schneider	Voith Schneider	Modified Kaplan CP

(Information from Crowley Maritime Corporation's Website.)

3.3 Escort Tug Characteristics

This study was defined as an evaluation of "escort" tugs only and not of all tugs involved in the complete tanker assistance program, including ship-docking, spill response, etc. It is therefore logical that any vessel which is not equipped in a manner which would satisfy the requirements of a major Classification Society for an "escort vessel" notation does not fall within the purview of this study.

Those Class requirements for escort tugs (citing Det Norske Veritas (DNV) Regulations [1] for example) include:

- *The hull of the tug shall be designed to provide adequate hydrodynamic lift and drag forces when in indirect towing mode. Due attention shall be paid to the balance between hydrodynamic forces, towline pull and propulsion forces*
- *The towing winch shall have a load reducing system in order to prevent overload cause by dynamic oscillation in the towing line, and*
- *The propulsor shall be able to provide ample thrust for manoeuvring at higher speeds for tug being in any oblique angular position*
- *The vessel shall be designed so that forces are in equilibrium with a minimum use of propulsive force except for providing forward thrust and balancing transverse forces during escorting service*
- *In case of loss of propulsion, the remaining forces shall be so balanced that the resulting turning moment will turn the escort tug to a safer position with reduced heel*

It is critically important at this juncture to understand the limitations of various vessel types in the context of providing escort forces, especially when one is attempting to describe the Best Available Technology in this field. The following discussion attempts to illustrate why only certain tug types should qualify for this important "escort" designation.

(a) <u>Conventional Propulsion</u>:

Tugs with conventional propulsion (single or twin screw, with rudder steering) are typically used for coastal or ocean towing. The rudder limits steering force direction to typically 35° or in some more extreme cases 45° from the tug centreline.

Typical hull forms are designed for in-line towing and seakeeping, and manoeuvrability is not often a major design criteria. Tugs may be flush decked or have raised forecastles depending upon their regulatory constraints and whether intended for sheltered or open water service. A large skeg aft is typical to provide directional stability, but this is counter-productive to any escort operations

Towing is done from a winch located on the aft deck, ideally close to the half-length of the tug. When towed from this position any transverse force results in high heeling forces and the risk of girting (capsizing) the tug. The tug does not have a fail-safe characteristic when towing from the aft winch position. It is very rare for any such tugs to have a winch on the fore deck for ship-handling. It is also very rare for conventional towing winches to have a render-recover capability. Towing is typically done on a mechanical brake.

Figure 3.1 below illustrates a typical conventional twin-screw coastal line-haul tug.

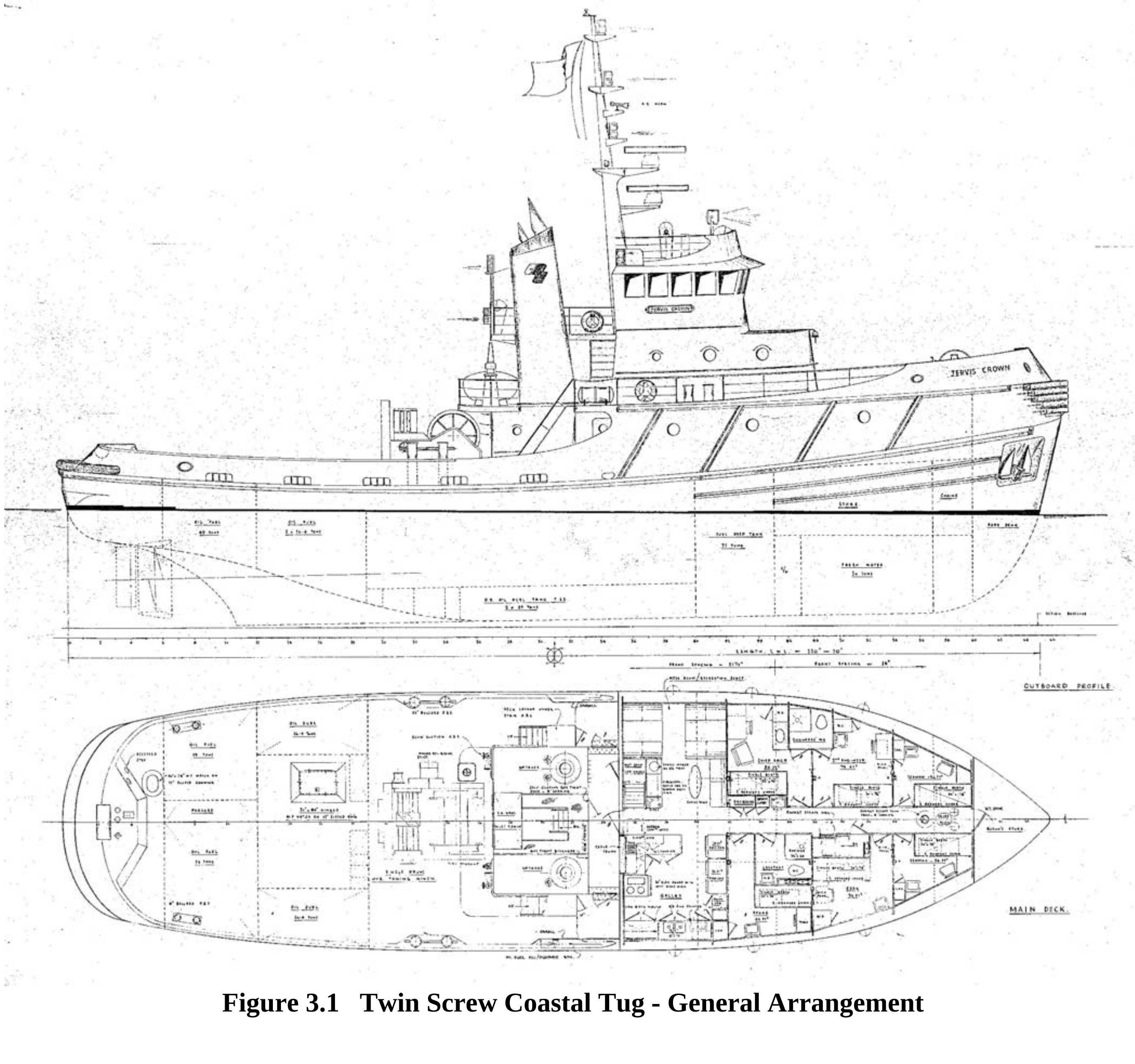

Figure 3.1 Twin Screw Coastal Tug - General Arrangement

(b) <u>ASD Propulsion with Conventional Hull Forms</u>:

Azimuthing propellers (Z-drives) have become the dominant form of propulsion in tugboats over the past 20 years. In many cases however these drives are installed in hulls which are essentially the same as those intended for conventional propulsion. When these drives are installed aft in relatively the same position as in a conventional tug the vessel is referred to as an azimuthing stern drive (ASD) tug. (Note: Even though the term is much misused to describe ASD tugs, these are NOT tractor tugs…a tractor tug has the drives located forward, regardless of whether those are Voith cycloidal propellers or Z-drives.) The advantage of Z-drives is obviously increased manoeuvrability and astern thrust. If however the hull is not designed in a way to provide lift in an indirect attitude then these tugs are still not well-suited to escort work and can even be unsafe in attempting to do indirect operations. The early Z-drive "escort tugs" built for service in the North Sea (Figure 3.2) suffered from this problem and accordingly set Z-drive escort tugs back about 20 years in their development and acceptance. These tugs lacked any skeg to generate hydrodynamic forces and had low freeboard aft. The high forecastles caused very high heeling moments and thus these tugs could not develop any appreciable indirect forces without heeling excessively and submerging their aft decks.

Figure 3.2 Large ASD Tugboat with Conventional Hull Form

Figure 3.3 shows a typical profile of such an ASD tug. This tug, typical of many, had a large towing winch aft and a ship-handling/escort winch forward, but in most cases that forward winch was not a render-recover type.

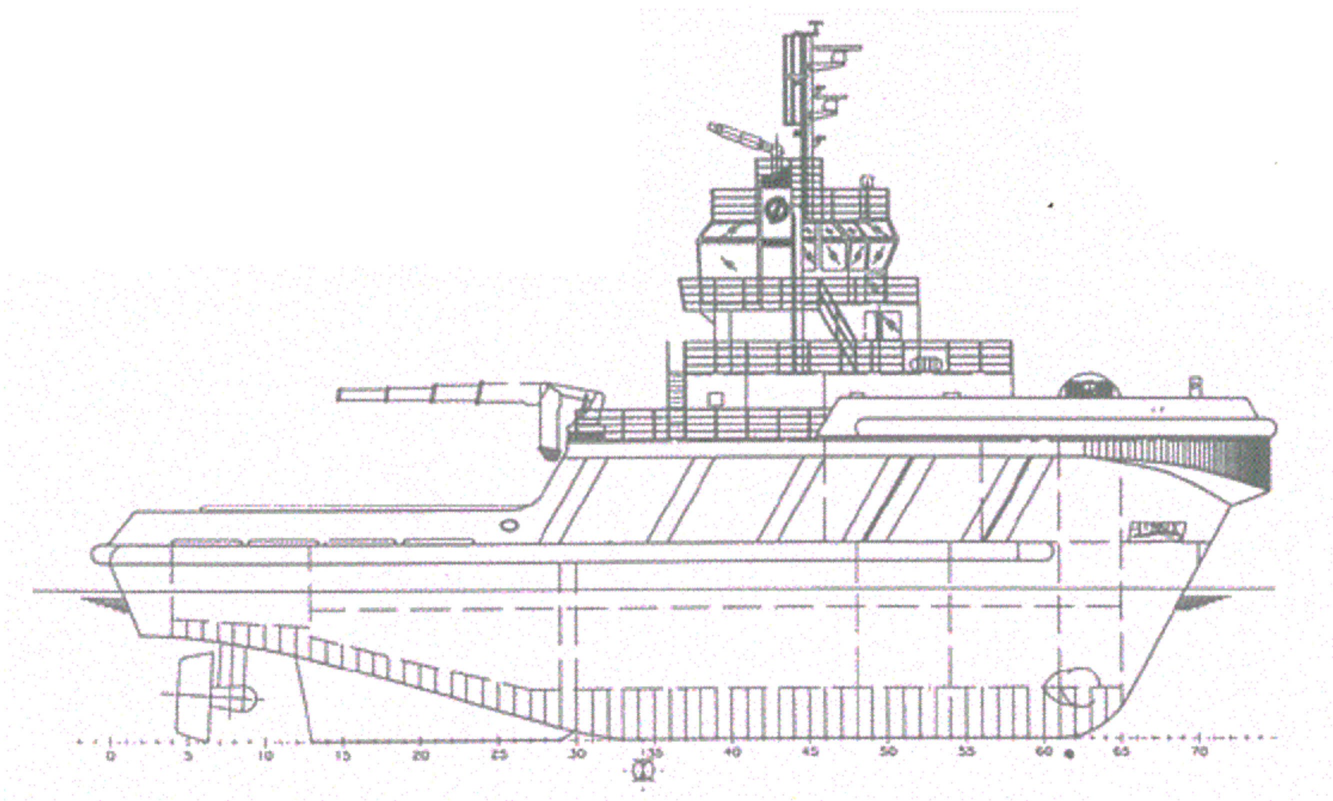

Figure 3.3 Outboard Profile of Large ASD Tug with Conventional Hull

(c) Voith Water Tractor:

The Voith Water Tractor (VWT) was the first tug design type widely accepted as an escort tug because quite simply its basic means of operation since the early days of its development has been to use indirect forces, developed largely through the large fin (or skeg) located above the tow-point. The first generation of VWT designs were all configured for towing over the stern, with drives forward. When ship-handling, the tug simply goes astern, skeg first. The down-side of this configuration is that a tug thus spends its most critical operations going astern and the bridge layout typically is configured best for bow-first operations. Regardless, the first serious escort tugs, developed by Foss for Puget Sound operations, [2] were large and powerful proper VWT escort tugs (Figure 4.4).

Figure 3.4 *Lindsey Foss* – VWT Escort Tugboat

The Norwegian operators Bukser og Berging AS recognized the basic failing of the conventional VWT layout and in 1994 launched the first "skeg-forward VWT", a tug configured in all respects for working always with the fin forward and the VSP drives aft (Figure 3.5). The B&B tugs however have a rather square stern so they are not well-suited for doing any towing in the opposite direction. The Norwegian tug "***Ajax***" (Figure 3.6) and several other "cousins" designed by Robert Allan Ltd. are more bi-directional in shape and are set up to do fin-forward escorting and also towing in the tractor mode with drives forward. The development of these latter designs was extensively described by Allan and Molyneux [3]. These two styles of tug has since become the norm for serious VSP escort tugs.

Figure 3.5 *Bess* – First "Skeg Forward" design of VSP Escort Tugboat

Figure 3.6 *Ajax* – VSP Escort Tug with bi-directional capability

(d) ASD Tug with Hull and Skeg configured for Indirect Escort Work:

In the past decade or less, the use of ASD tugs for escort has finally come into its own, and this type of tug is rapidly gaining acceptance as a serious and viable escort tug. The designs of this new configuration all have large skegs located forward under the tow-point. The skeg works exactly the same as that on a VWT, creating, in conjunction with the hull, the hydrodynamic forces necessary to develop high indirect steering forces. The primary difference is that these skegs tend to have rather a low aspect ratio (depth/length) in comparison to the slightly more efficient higher aspect ratio skegs associated with VWT designs.

Figure 3.7 illustrates the ***Svitzer Kilroom***, one of this new generation of ASD escort tug. Figure 3.8 shows the configuration of hull and skeg on the same tug.

Figure 3.7 *Svitzer Kilroom*: 116 tonne BP ASD Escort Tug

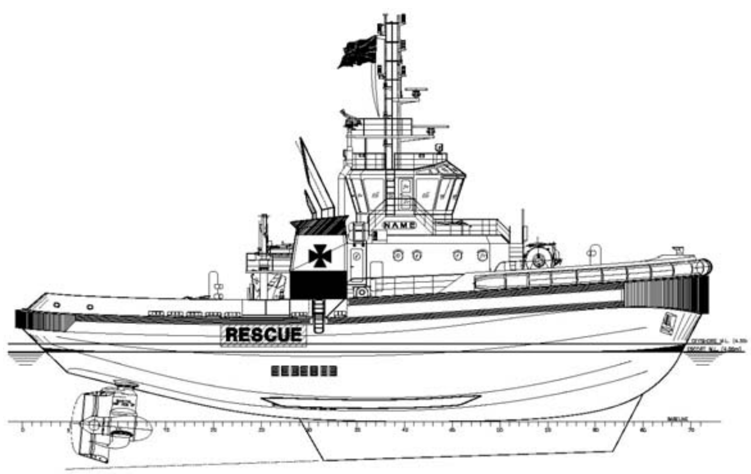

Figure 3.8 *Svitzer Kilroom*: Outboard Profile Showing Deep Skeg Forward

(e) Rotor Tug ™

More recently, the triple Z-drive Rotor Tug™ has been shown to be a very effective candidate for escort operations, as described by Allan [4]. Initially developed as a unique style of Z-drive tug for working in very confined harbours and canals, recent model testing has shown that this tug style can out-perform both VWT and ASD designs of equivalent bollard pull. The Rotor Tug develops indirect forces principally by using the two forward drives instead of a skeg, although there is a significant contribution from the hull as well. The thrust from the drive units acts in the line of the towline and the third drive (aft) is used to maintain the appropriate yaw angle. In this way the Rotor Tug can typically set up for indirect operations more quickly than other types which rely on lift from the skeg to generate indirect forces. Figure 3.9 illustrates a current Escort Rotor Tug design intended for service in Australia.

Figure 3.9 *ART 85-35* Class Escort Rotor Tug

Accordingly only vessels with omni-directional propulsion, load-rated rendering winches, and hull forms/design configurations intended to develop indirect hydrodynamic forces are capable of obtaining a Class "Escort" notation. Therefore the vessels listed in Section 3.2 above which are conventional tugs in every sense of the word are not viable escort tugs in the true meaning of that designation, and are not considered further in this report. The SERVS data in Table 3.1 above confirms this as well, as none of the conventionally propelled vessels are identified for escort duty. Only the ETT Class and the PRT Class tugs of this group qualify for evaluation under this study, and the latter really only because they are actively used as escort tugs in the SERVS system and thus need to be properly evaluated in that role.

3.4 World Fleet

Data on the world fleet of escort tugs was compiled from the various sources described in Section 3.1 above. The data was tabulated and sorted for various means of direct comparison. In the final analysis a total of 27 escort-rated tugs over 35 metres in length were identified, and categorized as follows:

- VWT - Voith Water Tractor Tugs (VSP drives forward/skeg aft)
- ZT - Z-drive Tractors (Z-drives forward/skeg aft)
- ASD - Azimuthing Stern Drive (Z-drive) Tugs (two (2) Z-drives aft/skeg forward)
- Rotor Tugs - a Rotor Tug is a proprietary design developed by Kotug of the Netherlands, employing three Z-drives in a triangular configuration (Figure 3.10) with two drives forward in "tractor" mode, and one aft where a fixed skeg would be on a typical twin-drive tractor tug. It could be considered as a variant of a ZT type, with a "powered skeg". Fixed skegs might also be used in combination with the three (3) Z-drives

Figure 3.10 37 Metre *Rotor Tug* Configured as an Escort Tug (100 tonne BP)

Table 3.2 overleaf lists all the escort tugs identified, with their critical dimensions and performance parameters.

	Image	Vessel Name	Owner	Country	Port of Duty	# Vessels	Built	Class	Designer	Displacement		Draft at DWL	Engine	Power		Type of Escort Tug	Propulsion	Top Speed	Bollard Pull	Length Overall		Length - Waterline	Breadth	Lateral Area	Escort Steering Force (MT)			Escort Braking Force (MT)		
										(LT)	(MT)	(m)		(hp)	(kW)			(knots)	(MT)	(ft)	(m)	(m)	(m)	(m^2)	8 knots	10 knots	12 knots	8 knots	10 knots	12 knots
CROWLEY TUGS		*Alert Aware Attentive*	Crowley	USA	Valdez, AK	3	2000	ABS	Guido Perla Associates Inc. (GPA)	1680	1700	4.88	Twin Cat. 3612B	10,192	7,600	ASD	RR Z-Drives	15	135	140.0	42.7	39.8	12.8	185.9	50	81			190	
		*Nanuq Tan'erliq*	Crowley	USA	Valdez, AK	2	1999	ABS	GPA	1475	1499	3.82	Twin Cat. 3612B	10,192	7,600	VWT	Voith Schneider	14.5	94	153.0	46.6	42.06	14.6	169.9	110	141		145	180	
ROTOR TUGS		*ART 37-100*	Kotug International	Netherlands	(planned for Europort)	tbd	Design Complete	n/a	Robert Allan Ltd	1083	1100	4.00	CAT 3516	8,448	6,300	ART	Triple Z-Drive (Rotor Tug)	14	100	121.4	37	34.13	14	126.1	127	150				
		*ART 85-35*	Kotug International	Netherlands	(planned for Port Hedland, Australia)	16+	Design complete: build contract yet to be awarded	LRS	Robert Allan Ltd.	1080	1097	3.99	CAT 3516C	7,500	5,592	ART	Triple Z-Drive (Rotor Tug)	14.5	88	114.9	35	32.82	14.5	111.8	106	76				
ASD TUGS		*Thorax*	Ostensjo Rederi AS	Norway	(North Sea)	1	1993	DnV	Sven Aarts	1968	2000	6.14	CAT 3612	7,200	5,369	ASD	ASD	15	95	151.0	46	41.1	14.6	212.5		120				
		*Hopetoun*	Targe Towing Ltd	Scotland	Shetland Islands	1	1997	?	Sven Aarts	1968	2000	6.74	Rolls-Royce	9,700	7,233	ASD	ASD	14.5	124	142.8	43.5	#N/A	13.5			#N/A				
		(***RAstar 3900***) *Svitzer Kilroom*	Svitzer AS	Denmark	Milford Haven, UK	1	2008	LRS	Robert Allan Ltd.	1174	1193	4.05	GE 7FDM 16	8,180	6,100	ASD	Z-Drive Schottel SRP 3030 CP 3400mm	15.7	115	128.0	39	37.2	14.7	155.2	122	144		160	150	
		(***Rastar 3800***) *Bourbon Yak Bourbon Auroch*	Bourbon Offshore	France	Vridi Canal, Ivory Coast	2	2009	BV	Robert Allan Ltd	1468	1492	4.88	MaK 9M25E	7,966	5,940	ASD	Z-Drive Schottel SRP 3030 CP	13.5	100	124.7	38	35.3	14.5	149.2	110	123		147	185	
		(***RAstar 3800***) *Rawasi Morooj*	Bakri Navigation Co. Ltd.	Saudi Arabia	Ras Tanura, Saudi Arabia	2	2009	BV	Robert Allan Ltd	1286	1307	4.50	CAT 3606	5,445	4,060	ASD	Z-Drive HRP 8611 2600mm FP	13	65	124.7	38	35.3	14.5	135.3		120				
		(***RAstar 3600***) *Lamnalco Sana'a*	SMIT Lamnalco	UAE	Yemen	4	2009	BV	Robert Allan Ltd	1334	1355	4.05	Wartsila 9L26	8,207	6,120	ASD	Z-Drive Wartsila LIPS CS300-S CP 3000m	13.5	95	118.2	36	33.67	14.5	135.4	110	130		145	165	
		***(RAstar 3600)*** *Svitzer Pembroke*	Svitzer AS	Denmark	Milford Haven, UK	1	2010	LRS	Robert Allan Ltd.	1279	1300	4.20	GE 16V228	8,186	6,104	ASD	Z-Drive Schottel SRP 3030 CP 3400mm	13.5	100	118.2	36	33.5	14.5	139.3	103	127				
		*Al Qubah Alaryam Albuzem 3 Hanyurah Ras Emshaireb*	IRSHAD	UAE	Abu Dhabi	5	2010	BV	Robert Allan Ltd	1181	1200	4.05	GE 16V228	6,517	4,860	ASD	Z-Drive RR US 255 2800mm CP	13	80	118.2	36	33.67	13.5	134.9	106	125		140	160	
		*Costante Neri*	Fratelli Neri	Italy	Livorno	2?	2009	RINA	Cintranaval-DEFCAR	#N/A	#N/A	#N/A	2 x MAN 9L27/38, MCR 6120 kW at 800 rpm	8,300	6,189	ASD	Z-Drive Schottel SRP 3030 CP 3000mm	13.5	110	114.9	35	33.5	14	#N/A		120				
		(***RAstar 3400***) *Svitzer Haven Svitzer Lindsway Svitzer Waterston*	Svitzer AS	Denmark	Milford Haven, UK	3	2008	LRS	Robert Allan Ltd.	1085	1102	4.40	GE 7FDM 16	7,016	5,232	ASD	Z-Drive Schottel SRP 3030 CP 3400mm	13.7	107	111.6	34	31.89	14.5	135.4	90	115		130	150	

		(***RAstar 3400***) *Svitzer Ramsey, Svitzer Caldey*	Svitzer AS	Denmark	Milford Haven, UK	2	2008	LRS	Robert Allan Ltd.	1033	1050	4.40	Niigata 8L28HX	5,917	4,412	ASD	Z-Drive Niigata ZP-41 CP 2700mm	13.5	80	111.6	34	31.89	14.5	132.7	81	100				
		(***RAstar 3400***) 90t	Smit AS	Australia	Gladstone, Queensland	2	In Design Phase	BV	Robert Allan Ltd.	1085	1102	4.47	Wartsila	7,295	5,440	ASD	Z-Drive Rolls-Royce US 35 CP 2800mm	13.5	90	111.6	34	32.12	14.5	139.2	76	100		110	130	
		(***RAstar 3200***) *SMBC Monterrey SMBC Tijuana (Costa Azul tugs)*	Moran/Boluda JV	Mexico	Costa Azul LNG Terminal, Mexico	4	2009	ABS	Robert Allan Ltd.	837	850	4.03	MTU 16V-4000	6,222	4,640	ASD	Z-Drive Rolls-Royce US255 2800mm	13.5	75	105.0	32	31	13.2	114.2	58	47		110	105	
		(***DAMEN 3213***) *Smit Panther Smit Jaguar Smit Cheetah Smit Tiger*	SMIT / Lamnalco	Netherlands	Rotterdam /Europort	4	2009	?	DAMEN	1019	1035	3.97	2 x Caterpillar C280-8/MC	7,268	5,420	ASD	Z-Drive	14.4	95	105.0	32	31	13.3			#N/A				
VOITH WATER TRACTORS		*Garth Foss Lindsey Foss*	Foss Maritime	USA	Anacortes, WA.	2	1993	ABS	Owner & The Glosten Associates	1575	1600	5.64	General Motors EMD ME 16-710	8,000	5,966	VWT	VSP Tractor	13.6	80	137.5	47	#N/A	14	#N/A	90	120		120	130	
		*Ajax*	Ostensjo Rederi AS	Norway	Sture Oil Terminal , Norway	1	2000	DnV	Robert Allan Ltd.	1258	1278	3.80	CAT 3612	9,280	6,920	VWT	VSP Tractor	15	91	136.5	41.6	38.2	14.2	165.8	110	150		145	180	
		*Baut, Boris*	Bukser og Berging AS	Norway	Rypefjord, Norway (near Hammerfest)	2	2003	DnV	Owner	#N/A	#N/A	#N/A	Deutz SBV 16M 628	9,226	6,880	VWT	Skeg forward VSP	15	92	132.9	40.5	38.88	14.3	#N/A		157				
		*Boxer*	Bukser og Berging AS	Norway	Bergen, Norway		1999	DnV	Owner	#N/A	#N/A	#N/A	Deutz SBV 12M 628	6,800	5,071	VWT	Skeg forward VSP	15	67	128.0	39	#N/A	13.7	#N/A	125	150				
		*Response*	Crowley	USA	Puget Sound	1	2002	ABS	GPA (adapted from BuBe)	#N/A	#N/A	#N/A	CAT 3608	7,200	5,369	VWT	Skeg forward VSP	15	67	128.0	39	#N/A	13.92	#N/A	125	150				
		(***AVT 37-80***) *Vortex*	Ostensjo Rederi AS	Norway	Felixstowe UK?	1	2010	DnV	Robert Allan Ltd.	1287	1308	3.75	Wartsila Type 8L26	7,208	5,375	VWT	VSP	14.5	73	123.1	37.5	34.93	14	158.0	105	145		128	170	
		*Velox Apex Phenix Tenax*	Ostensjo Rederi AS	Norway	Crawley Terminal, Southampton UK	4	2004	DnV	Robert Allan Ltd.	1048	1065	3.84	(RR) Bergen C25:33L8PU	6,437	4,800	VWT	Skeg forward VSP	15	68	121.4	37	33.2	14	158.0		130				
		*Messico*	Rimorchiatori Riuniti	Italy	Genoa, Italy	1	2007	RINA	Robert Allan Ltd.	969	985	3.30	2 x MAK 8M25	7,081	5,280	VWT	VSP	13.5	83	120.3	36.65	33.75	13.6	123.1	98	100				
		*Bess Boss*	Bukser og Bergning AS	Norway	Stenungsund, Sweden	2	1994	DnV	Owner	#N/A	#N/A	#N/A	Ulstein Bergen KRMB9	5,450	4,064	VWT	Skeg forward VSP	15	52	118.2	36	#N/A	12	#N/A		90				
Z-DRIVE TRACTO		*Broward*	Hvide Marine Inc.	USA			1995		Elliot Bay Design Group				12 645 F7	5,100	3,803	Z-drive Tractor	Z-Drive Aquamaster 2001/3250		52	98.5	30	29	12		53	60	70	60	75	90

3.5 Escort Tug Roles and Duties in the SERVS System

The Prince William Sound Oil Discharge Prevention and Contingency Plan (The "Tanker C-Plan") [5] contains the following definitions of roles for the escort tug fleet:

a. Primary Escort Vessel

The Primary Escort Vessel (PEV) may be required to:

- Steer the tank vessel
- Counter any undesired swing
- Assist the swing as necessary, and
- Retard the tank vessel's headway

b. Secondary Escort Vessel

The Secondary Escort Vessel (SEV) may be required to:

- Take the tank vessel under tow by the bow after the save is achieved, and
- Control the tow

In addition, the Tanker C-Plan contains the following statement regarding towing connections between tankers and escort tugs:

> *"Each tank vessel operating at the VMT uses the PWS Towing Package, defined in 18 AAC 75.990(96), or its equivalent. The PWS Towing Package is made up and prepared for rapid deployment to an escort vessel. The equipment meets or exceeds International Maritime Organization (IMO), ADEC regulations and USCG standards for such equipment.*
>
> *In addition, each primary escort vessel is fitted with towing equipment designed for rapid deployment to the tank vessel. The nominal breaking strength of the towlines meets or exceeds the requirements of the PWS Towing Package, and is at least twice the maximum bollard pull of the escort vessel. Secondary escorts can either deploy their own towing gear if conditions warrant, or use the towing package mentioned above."*

It is noteworthy that the above distinctions exist; it is (or was?) clearly not intended that the SEV's have the same escort capability as the PEV's, and in fact their technical missions are quite different, thus requiring very different hull forms and propulsion systems in order to best satisfy these mission descriptions. More critically however, as will be elaborated upon in detail in Section 5.1, this distinction calls into question the definition of the SEV as an "escort" tug in the truest sense of that word. While this may appear to be an issue of semantics, the almost universally accepted definitions of an escort tug as defined by the rules of various Classification Societies require the capability to generate indirect steering forces and to maintain essentially constant towline loads through the mechanism of a winch with a render-recover capability. Those capabilities are not part of the mandate for the SEV described above.

4.0 DOCUMENT REVIEW AND COMMENTS

An initial element of this study was to perform a detailed review of existing documents related to the vessels in question, and specifically to identify any comments about vessel deficiencies or specific performance requirements. All the documents received are listed in the Bibliography to this report (ref. Annex A).

Table 4.1 below is a summary of the more salient items or issues regarding the ETT and PRT Class tugboats which were identified in this document review.

The documents cited in this review are as follows:

No. 1 - Technical Specifications for the ETT Class Tugs –Vessel Management Services, Inc. [6]

No. 2 - Classification Society Tug Review for PWSRCAC – Det Norske Veritas [7]

No. 3 - Vessel Escort and Response Plan – 2007 Prince William Sound Tanker Owners/Operators [8]

No. 4 - Escort Tug Analysis for Oil Tankships in Prince William Sound and the Gulf of Alaska, Vince Mitchell (Alyeska/SERVS), Patrick J. Carney (PWS RPG), and George Randall, Tim Jones, and Lynda Hyce (PWS RCAC) [9]

Table 4.1 Summary of Items/Issues from Document Review

No.	Document	Specific Requirements	Vessel Deficiencies
1	ETT Tech Specifications	• ETT maximum allowable heeling moment according to DNV escort stability criteria, Pt. 5, Ch. 7 Sec. 13D, is 2,435.8 LT-ft. • F_s = 141 MT is max steering force that complies with DNV escort stability criteria. The maximum allowable overturning moment is 731 T-m. • At a minimum, in the Valdez Arm, the tug must be able to prevent a fully laden 265,000 DWT tanker from deviating more than 2,500 yards from its initial track given the following set of conditions: 1. 10 knot transit speed (tug tethered to stern of escorted tanker) 2. 40 knots of wind, initially astern 3. 9 foot significant seas, initially astern 4. 10°, 20°, and 35° rudder angle 5. 30 second failure recognition time during which engine remains at transit rpm 6. 30 seconds during which the engine is shut down, but before the tug is notified (no tug forces during this interval) 7. An additional 30 seconds during which the tug is developing full steering and/or braking forces 8. Total time delay from failure to full tug effectiveness is 1 minute 30 seconds • The tug must be able to turn and tow a fully laden 265,000 DWT tanker directly to windward at an over ground speed of 1 knot in wind speeds of 45 knots and 15 foot significant seas. The towing force required has been calculated as 150,000 lbs. • Minimum free running speed of 14 knots at 90% MCR at full load displacement of 1,477 long tons • Minimum static bollard pull of 190,000 lbs. (86.2 MT) • F_s = 93 MT; F_b = 125 MT at 8 knots • F_s = 116 MT; F_b = 154 MT at 10 knots	

No.	Document	Specific Requirements	Vessel Deficiencies
2	Det Norske Veritas: Tug Review for PWSRCAC		• DNV could not determine escort rating number of PRT as escort steering test was not performed • The load reducing system on the escort winch of the PRT and ETT does not appear to be satisfactory for escort operation. It may be current practice to use the winch brake during escort operations. This is undesirable as there is higher likelihood of breaking the towline due to shock loads.
3	Vessel Escort and Response Plan	• As a general note, there is a table in this document that seems to imply the escort performance of the ETT tug is significantly inferior to the PRT tug. The tanker off-track distance when the ETT is acting as the tethered escort is 180% higher at 8 knots and 150% higher at 10 knots than the PRT. These values contradict the predicted escort performance of these tugs. The results may have been derived using the bollard pull, rather than indirect escort performance. • Each Escort Captain involved in the tethered operation will be required to participate in the following tethered escort drills: 1. Dual Failure With 60 Second Delay – 6 knots 2. Tug to Re-establish Heading and Steer Vessel for 5 Minutes After a Dual Failure With 60 Second Delay – 6 knots • The escort vessels, acting singly or jointly in any combination as needed, and considering their applied force vectors on the tanker's hull, must be capable of: 1. Towing the tanker at 4 knots in calm conditions, and holding it in steady position against a 45 knot headwind; 2. Stopping the tanker within the same distance that it could crash-stop itself from a speed of 6 knots using its own propulsion system;	

No.	Document	Specific Requirements	Vessel Deficiencies
		3. Holding the tanker on a steady course against a 35° locked rudder at a speed of 6 knots; and 4. Turning the tanker 90°, assuming a free-swinging rudder and a speed of 6 knots, within the same distance.	
4	Escort Tug Analysis	• In confined and protected waters, such as the Valdez Narrows, a pre-tethered escort is indicated for immediate control of the tanker trajectory • A BAT determination for the ETTs was issued by ADEC based on the design criteria, subject to verification after delivery to Prince William Sound. The PRTs were determined to meet BAT requirements based primarily on their superiority to the conventional vessels they were built to replace • Based on a series of full-scale exercises, the RPG also asked that the ETTs and PRTs be considered equivalent for escort duty in Hinchinbrook Entrance	

5.0 VESSEL PERFORMANCE

5.1 Performance Parameters

The following are the critical performance or design parameters which distinguish a true "escort tug" from the more routine type of tugboat:

- A hull form capable of generating large hydrodynamic forces in various operating modes
- Omni-directional propulsion to enable the tug to achieve and sustain oblique angles to the direction of tanker travel
- Freeboard and stability characteristics in compliance with Class requirements for escort towing
- A towing configuration that ensures both maximum steering forces and a "fail-safe" attitude in the event of any propulsion or steering failure on the tug. By "fail-safe" is meant that the tug will, without influence of steering intervention, rotate to align in equilibrium with the towline lead rather than rotating at some acute or oblique angle to the towline
- Omni-directional (fully rotatable or directional) propulsion with controllable-pitch propellers, to ensure that propeller overload in various operating directions will not stall the main engines
- An escort-rated winch which can be set to release tension at a prescribed level and to recover line under tension at the same load rating
- Relatively high speed to ensure fast response and the ability to keep up with tankers

In addition to these power-related factors, the seakeeping performance of escort tugs is very important, especially in an area such as Prince William Sound and environs where high seas can be expected regularly. The seakeeping, measured in terms of response amplitudes and accelerations, was calculated for the SERVS tugs and for a representative sample of escort vessels with acknowledged highly regarded seakeeping capability.

Finally, the escort capabilities of any tug in terms of steering force used must be at least a match for the steering capabilities of the attended ship, which would be as defined under IMO "Interim Standards for Ship Manoeuvrability" [10].

Accordingly, the following parameters were selected as the measures of escort tug performance which could reasonably be expected to be available or measurable as a basis of performance comparison:

- Bollard Pull (BP) per Horsepower: BP is one of the few performance parameters which is directly (and easily) measureable. Converting BP to a thrust per unit power gives a direct measure of the propulsive efficiency.

- Indirect Steering Force (F_s) and Braking Force (F_b) per Lateral Area: These are the true "measures of merit" for escort tugs, indicating the effectiveness of the hull and appendages to generate the hydrodynamic forces necessary to be an escort tug. In this instance the vessels have been compared on two bases:

  - F_s per unit lateral area—where the actual lateral area for a specific vessel was available, this is a clear measure of the effectiveness of the hull and skeg together

  - F_s per Lwl x Draft—where actual lateral area was NOT available, using the gross area of Length times Draft gives a reasonably accurate comparison of hull effectiveness

- Speed/Length Ratio: A classical measure of hull speed efficiency; speed divided by the square root of waterline length

- Displacement/Length Ratio: A measure of the fullness of the vessel, which correlates to some degree to the speed/length ratio. (Calculated as $(\text{Disp.}/(.01\text{x Lwl})^3)$ in Imperial units to be consistent with the typical use of this ratio.

The above data were all tabulated and plotted to illustrate how the SERVS tug performance compares to the world escort tug fleet.

The seakeeping performance (ref. Section 5.5) was calculated using *SHIPMO-3D* software, a well-recognized and widely used seakeeping analysis tool. The ETT and PRT Class tugs were compared on an equal size basis to existing escort tugs with both VSP and Z-drive (ASD) propulsion, namely the VSP tug ***Ajax*** (Figure 5.1) owned by Østensjø Rederi AS, operating at the Statoil Terminal in Sture, Norway, and the ASD escort tug ***Svitzer Kilroom*** (Figure 5.2) owned by Svitzer AS of Denmark, operating at the Milford Haven oil/LNG terminal in South-West England. Both these tugs have sponsoned hull forms for which very positive anecdotal feedback has been received on their seakeeping capabilities.

The ***Ajax*** is quite similar in size to the ETT Class (though somewhat shorter) and has essentially the same power and drive system. The ***Svitzer Kilroom*** is a fully certified ASD escort tug, operating off the foredeck, and hence is a rather different configuration than the PRT tugs which have a higher forecastle, but it is one of the largest and most powerful escort-rated ASD tugs in service and has similar power and performance to the PRT Class, although it is a generally smaller tug.

Figure 5.1 ***AVT 3900*** **Class Escort Tug -** ***Ajax***

Figure 5.2 ***RAstar 3900*** **Class Escort Tug** ***Svitzer Kilroom***

5.1.1 SERVS Fleet

The performance data described above was not readily available for the ETT and PRT tugs, and thus some direct calculations had to be made, as described below.

a. ETT Tugs:

A Lines Plan was available in PDF format for this VSP tug design. In order to conduct the seakeeping analysis however the Lines had to be recreated in *Rhino-3D* . The new Lines were checked for accuracy by checking the hydrostatics at various drafts and adjusting accordingly until all properties matched within a small margin. An indirect escort performance prediction for this design was made available directly from Voith Turbo Schneider Propulsion GmbH & Co. KG (Voith) in Germany. Bollard Pull and other basic data were available from the trials reports and other data provided.

The indirect escort performance of the ETT was calculated by Voith during the design phase of that tug. Additionally, the escort performance and stability was analyzed by GPA using the DNV escort stability criteria. The steering force used by GPA is 6% lower than predicted by Voith and very close to the escort stability limit. Therefore, in order to be conservative, the GPA results are used in the summary below. The particulars of the ETT are shown Table 5.1 below:

Table 5.1 Particulars of ETT Class Tugs

Weight	1,475	LT	1,449	MT
LWL	137	ft.	41.8	m
Beam	47.4	ft.	14.4	m
Waterline ABL	12.5	ft.	3.82	m
GM	7.1	ft.	2.2	m
Bollard Pull	93	LT	94	MT

The ETT escort performance is summarized in Table 5.2. The majority of the values were taken from the GPA escort stability analysis with the remainder estimated from the Voith prediction.

Table 5.2 Escort Performance Summary for ETT Class Tugs

	Unit	Powered Indirect	Combination
Steering Force	MT	141	51
Associated Braking Force	MT	37*	180**
Heel Angle	deg. (°)	13.7	13.5*
Heeling Moment	MT-m	731	700*

*****_Best approximation based on available data._
******_Estimated from Voith Prediction_

The escort stability of the ETT was evaluated against the DNV stability criteria using the 3D model generated from the printed Lines Plan. The maximum heeling moment in the departure condition was 717 MT-m (2,390 LT-ft.). The heeling moment at 10 knots shown in the above table is slightly larger than the allowable limit thus the tug is stability limited rather than steering force limited. Since the 3D model was generated from 2D paper Lines, the 2% discrepancy between the heeling moment and escort limit is within the model margin of error. Therefore, the primary conclusion is that the intact stability and escort performance are well balanced, as long as the tug does not perform indirect escort manoeuvres at speeds above 10 knots.

b. PRT Tugs:

Despite several requests, no Lines Plan was made available in any form for this Class of tug. However the General Arrangement drawing shows the chines and centreline profile of this tug quite clearly. A new set of Lines was therefore generated using the chine and keel profiles, which were assumed accurate. The hydrostatics were compared at various drafts to the PRT hydrostatic data (which was available) to verify accuracy.

No indirect steering or braking performance data was available for this Class of vessel at all. Therefore a prediction of that performance was made using design tools developed by Robert Allan Ltd., The method utilizes Computational Fluid Dynamics (CFD) and has been validated against various model tests and full scale trial results. Bollard Pull and other basic data for the PRT tugs was available from the Trials Reports and other information provided.

The 10 knot indirect escort performance of the PRT in the departure loading condition was predicted using the above-described CFD technique. An initial analytical escort analysis was attempted; however, there was not enough available information to derive accurate lift and drag coefficients of the PRT hull. Thus, using the 3D model generated for the seakeeping analysis, a limited CFD escort prediction was conducted to establish the maximum steering and braking forces of the PRT hull as well as determine the factors limiting the performance. The particulars used in the escort analysis are given in Table 5.3 below:

Table 5.3 Particulars of the PRT Class Tugs

Weight	1,389	LT	1,411	MT
LWL	131	ft.	39.8	m
Beam	42	ft.	12.8	m
Waterline ABL	14.8	ft.	4.51	m
GM	6.0	ft.	1.84	m
Bollard Pull	133	LT	135	MT

The PRT escort performance calculated using Robert Allan Ltd.'s escort performance prediction tool is summarized in Table 5.4 below. It should be noted that this CFD-based predictive method has just recently been type-approved by Bureau Veritas (BV) as suitable for obtaining a Class Certificate for an Escort Rating, hence it is believed to be among the most accurate escort force prediction methods available.

Table 5.4 Escort Performance Summary for PRT Class Tugs

PRT 10 Knot Escort Forces	Unit	Indirect	Powered Indirect	Combination
Steering Force	MT	62	81	28
Associated Braking Force	MT	49	16	190
Yaw Angle	deg. (°)	30	30	35
Heel Angle	deg. (°)	9.4	9.4	8.6
Heeling Moment	MT-m	469	468	430
Z-Drive Azimuth Angle	deg. (°)	59	40	132

The escort stability of the PRT was evaluated against the DNV stability criteria using the 3D model generated from available drawings. The maximum heeling moment found from the industry standard escort stability criteria, found in both DNV and BV rules, is 552 MT-m (1,840 LT-ft.) in the departure loading condition. It is evident from the above table that the PRT is not stability limited in the evaluated loading condition. Rather than being limited by stability, the escort performance of the PRT is limited by insufficient thrust to maintain higher yaw angles. However, this is more a function of the skeg position and hull geometry than lack of available thrust. Since the skeg is biased aft, rather than forward as is standard for an escort tug, the centre of lateral resistance (CLR) is far aft of the towpoint. This results in the majority of the thrust acting to maintain the yaw angle; leaving little remaining thrust to act directly against the towline in the "Powered Indirect" mode. While 81 tonnes of indirect steering force at 10 knots is comparable to many 30 m ASD terminal/escort tugs, it is very low for a 43 m tug with 135 MT of bollard pull.

5.1.2 World Fleet

The data used for comparison to the SERVS tugs was available for all those escort tugs in the database which were designed by Robert Allan Ltd., and for a few of the other vessels where the data was provided by Owner response or from internet data. Accordingly, this data is believed to be accurate.

5.2 General Performance Comparison

Figures 5.2.1 to 5.2.6 illustrate the following comparisons of vessel data:

- Length/Beam Ratios
- Displacement/Length Ratio
- Bollard Pull (BP)/Power
- F_s/Underwater Lateral Area (At)
- F_s/Lwl x t (waterline length x draft)
- Speed-Length Ratio (V/SqRt L vs. Lwl)

In order to determine how the SERVS tugs compare to the world fleet, the data was segregated for plotting: the SERVS data was plotted independently and the rest of the fleet was plotted as a group. Linear or polynomial trend lines for each data set were created. Thus it is very clear to see in general how the SERVS tugs compare to the "rest of the world" fleet. The following observations can be made:

- The SERVS vessel proportions, represented by L/B ratio, are fairly typical of the fleet, although the PRT tugs are rather more slender than the trend for other ASD tugs. This should make for a faster boat
- The Displacement/Length ratios for the ASD tugs demonstrate reasonable consistency over the size range examined, and the PRT tugs are a close match. The VSP tugs, rather surprisingly, are more scattered in this criteria, and the ETT tugs are much lower than the fleet norm. This indicates only that the ETT tugs are lighter for their size than other tugs of this type, and therefore should be faster
- The BP/Power ratios illustrate that both the PRT and the ETT tugs are fairly representative of the performance achieved in their respective propulsion types
- The Speed/Length ratios for all tugs are quite consistent, so in spite of the more slender form of the PRT tugs no speed advantage is apparent
- The Indirect Performance criteria reveal that both Classes of SERVS tugs fall below the trend lines for their respective classes. In the case of the PRT tugs the performance, as illustrated on Figures 5.2.4 and 5.2.5 is rather dramatically below par with a force per unit area capability of only 0.4 tonnes/m^2 whereas the trend line for ASD escort tugs of this size suggests that a value of 0.75 t/m^2 should be expected

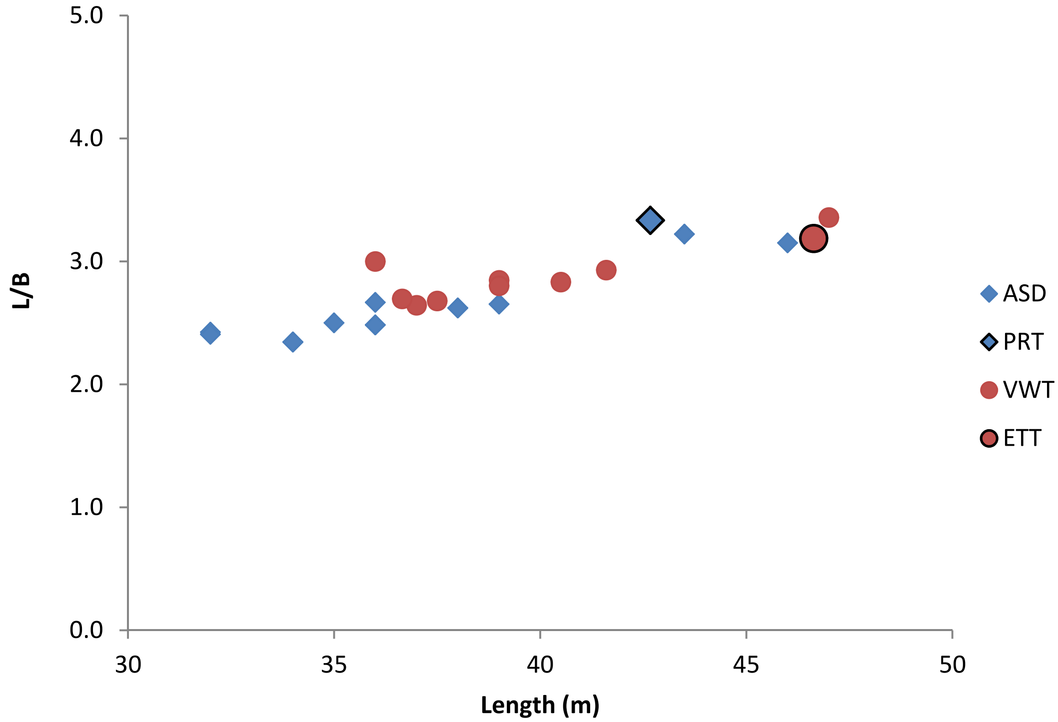

Figure 5.2.1 Length/Beam Ratios

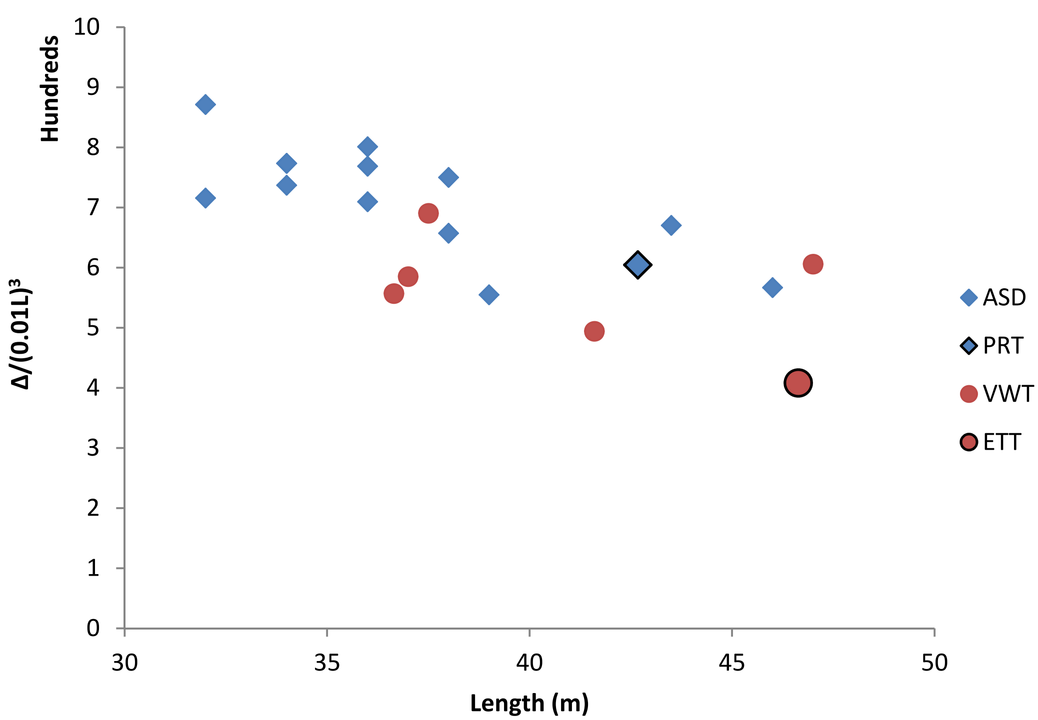

Figure 5.2.2 Displacement/Length Ratio

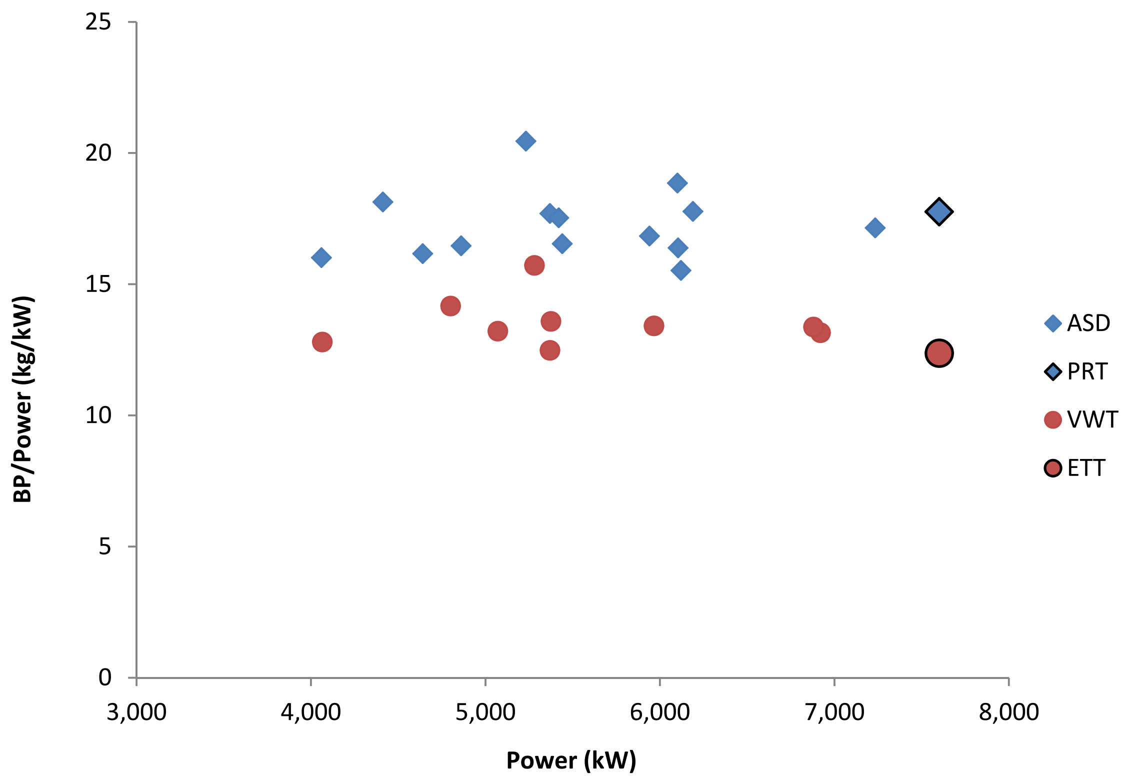

Figure 5.2.3 Bollard Pull (BP)/Power

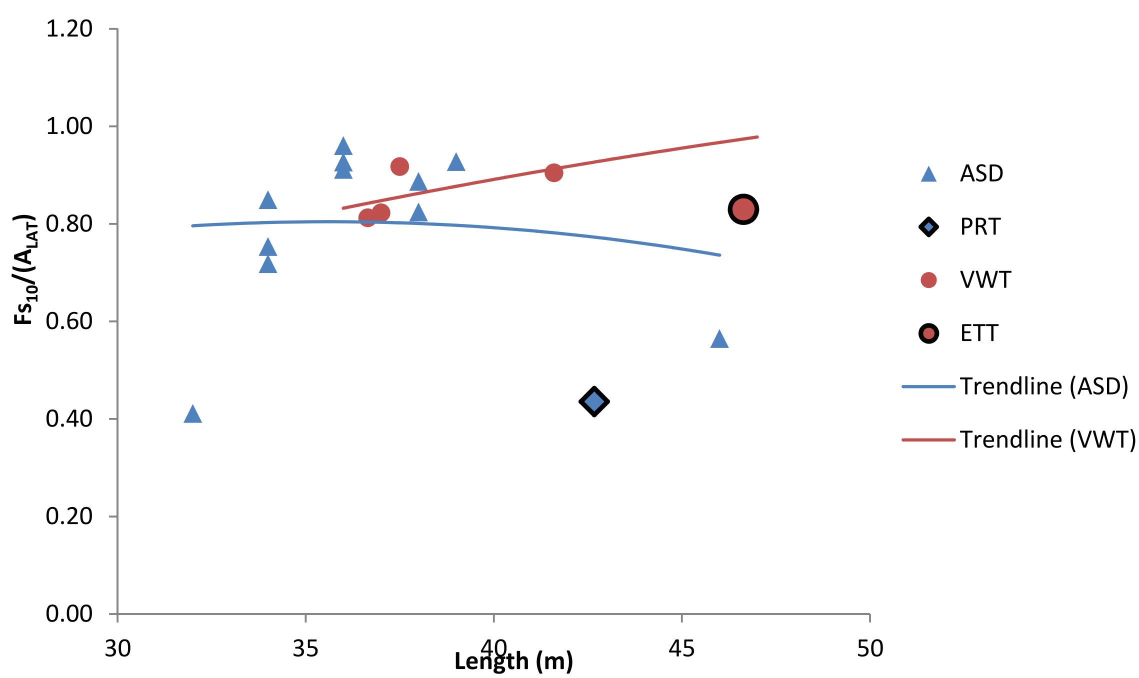

Figure 5.2.4 F_S/Underwater Lateral Area (At)

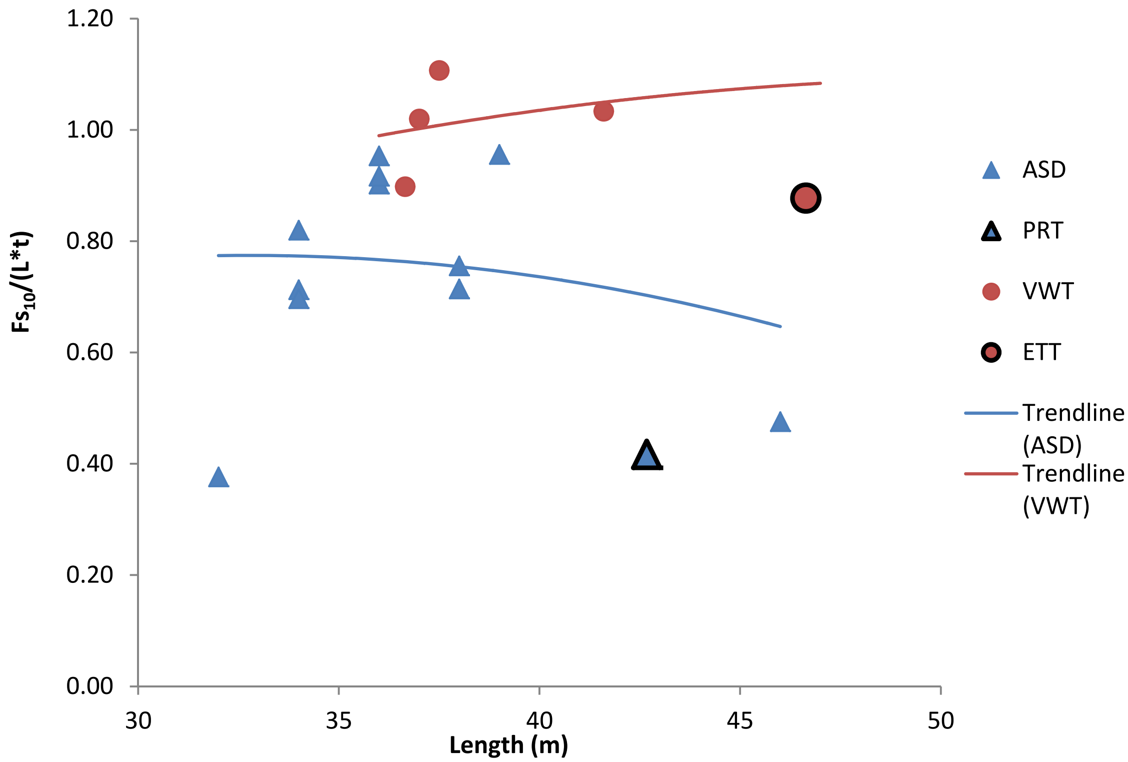

Figure 5.2.5 F_s/Lwl x t (waterline length x draft)

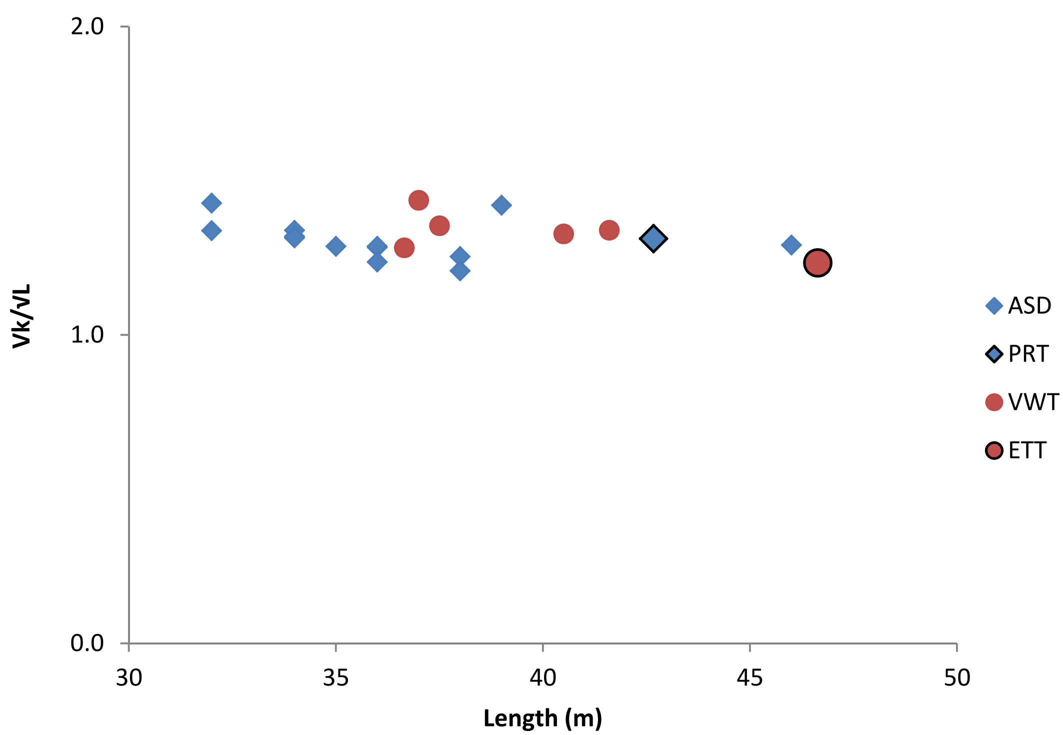

Figure 5.2.6 Speed-Length Ratio (V/SqRt L vs. Lwl)

5.3 Escort Stability Review—SERVS Tugs

5.3.1 ETT Class Tugs

The initial load condition for the ETT escort stability check is based on the normal departure condition (Loading Condition #3) assessed in the original stability documentation for the ETT vessel, [11] developed by GPA in 1997.

Based on the GPA stability book, Loading Condition #3, the total weight and centre of gravity (CG) listed below were applied to the stability model, to replicate the fully loaded departure condition. It should be noted that this weight was applied as a single load at the resultant departure CG and represents the combined load of lightship weight, provisions and other weight items, as well as the loaded tanks. A constant free surface moment (FSM) was applied as per the GPA stability documentation to account for the effect of liquids in the tanks (the RAL model used does not include tanks).

Weight =	1,449.10	LT
LCG =	68.18	ft. aft of Fr. 0
TCG =	0.07	ft. (+ Stbd)
VCG =	22.19	ft. ABL
FSM =	2,040.5	ft.-LT

Table 5.5 below compares the General Hydrostatic Software (GHS) output for the replicated departure condition using the RAL model with the output contained within the GPA stability documentation for Loading Condition #3.

Table 5.5 Comparison of Hydrostatic and Stability Data for ETT Tugs

	Displ. (LT)	LCF Draft (ft.)	Trim (deg. + aft)	GM (ft.)	Heel Angle (deg. + stbd)	LCB (ft.)	VCB (ft.)	LCF (ft.)
GPA Stability	1,449.09	21.145	0.63	6.55	0.53	68.25	15.46	68.28
RAL check	1,449.10	21.172	0.494	6.70	0.60	68.25	15.59	68.37
	Difference:	0.027	-0.136	0.15	0.07	0	0.13	0.09
	%:	0.1%		2.3%		0.0%	0.8%	0.1%

The escort criteria used is the industry standard criteria, found in both DNV and Bureau Veritas (BV) Rules [12]. Down-flooding points were applied to the RAL model as per the GPA stability calculation. The maximum allowable heeling moment to meet the BV Escort Stability Criteria was found to be 2,390 ft.-LT.

5.3.2 PRT Class Tugs

The initial condition for the PRT escort stability check is based on the regular departure condition with full fuel and water (Loading Condition #3) assessed in the original stability documentation for the MV *Alert*, done by GPA in January 2000 [13].

Based on the GPA Stability Book, Loading Condition #3, the total weight and CG were applied to the stability model to replicate the fully loaded departure condition. Again, this weight was applied as a single load at the resultant departure CG and represents the combined load of lightship weight, provisions and other weight items, as well as the loaded tanks. A constant free surface moment (FSM) was applied as per the GPA stability documentation to account for the effect of liquids in the tanks (the RAL model does not include tanks).

Weight =	1,376.56	LT
LCG =	61.31	ft. aft of Fr. 0
TCG =	0.01	ft. (+ stbd)
VCG =	14.35	ft. ABL
FSM =	743.4	ft.-LT

Table 5.6 below compares the GHS output for the replicated departure condition using the RAL model with the output contained within the GPA stability documentation for Loading Condition #3.

Table 5.6 Comparison of Hydrostatic and Stability Data for PRT Class Tugs

	Displ. (LT)	LCF Draft (ft.)	Trim (deg. +aft)	GM (ft.)	Heel Angle (deg. + stbd)	LCB (ft.)	VCB (ft.)	LCF (ft.)
GPA Stability	1,376.56	14.778	-0.84	6.04	0.07	61.22	8.65	69.54
RAL check	1,376.56	14.629	-1.79	6.12	0.09	61.21	8.52	70.2
	Difference:	-0.149	-0.95	0.08	0.02	-0.01	-0.13	0.66
	%	-1.0%		1.3%		0.0%	-1.5%	0.9%

The escort criteria used is the industry standard criteria, found in both DNV and BV Rules. Down-flooding points were applied to the RAL model as per the GPA stability calculation. The maximum allowable heeling moment to meet the BV Escort Stability Criteria was found to be 1,840 ft.-LT.

5.4 Winch Performance

The characteristics of the winches and other towing gear on the SERVS tugs were evaluated in depth in a 2012 study for PWSRCAC by Robert Allan Ltd. [14]. The following extract from that study summarizes the findings regarding winch characteristics and winch performance.

"…Therefore measured against those more stringent (DNV) *criteria, the SERVS vessels fail to satisfy the following requirements:*

- *ETT:*

  - *Escort winch does not have the ability to reduce tension when tension exceeds 50% of towline breaking strength*
  - *Escorting not to be done on brake*

- *PRT:*

  Although the PRT's do not do any indirect escort towing, they are still deployed in an escort mode using the small bow winch, and are then used to apply direct pull. Accordingly it seems appropriate that the bow towing system should comply with Class requirements for escort towing and the aft towing system should simply meet the requirements for ocean towing gear. The following deficiencies therefore are noted:

  - *Escort winch does not have the ability to reduce tension when tension exceeds 50% of towline breaking strength*
  - *Escorting not to be done on brake*
  - *Main aft towline (SWR) achieves only 96-97% of DNV Class requirement for breaking strength*

It is important to note the differences between the ABS requirements for an Escort Class Notation and those of DNV and a few other Class Societies, in order to justify the statement that ABS do NOT at present represent the highest standards for escort tugs in the industry. The critical differences are as follows:

- *Stability Requirements: ABS require only that maximum applied forces do not immerse the deck edge of a tug. DNV et al have criteria that define the required ratio of righting moment to heeling moment and which therefore includes some margin of freeboard*
- *Winch Specifications: ABS has no requirement for winches to carry the line load on winch power, and only requires an "abort" mechanism. DNV et al. require that the maximum towline force be carried on winch power only and be able to be rendered and recovered during the escort operation*

On these two factors alone a vessel with an Escort Tug notation from ABS could be substantially less effective and less safe than one classed similarly by DNV, GL, or BV."

5.5 Seakeeping Performance

An independent analysis was commissioned to compare the seakeeping characteristics of the ETT and PRT Class tugs to other comparable escort tugs.

As a sub-contract to Robert Allan Ltd., Alion Canada Ltd. conducted a seakeeping analysis on four separate escort tugboat hull forms; the ETT and PRT Class tugs which are part of the SERVS Escort Tug Fleet, and the ***RAstar 40-100***, and ***AVT 43-100*** Class escort tugs designed by Robert Allan Ltd., which represent more recent hull forms. The analysis was conducted for ten (10) separate sea conditions, covering Sea State (SS) 4 through SS 7, and for three-wave periods: 8, 10, and 12 seconds.

As each of the vessels has a low L/B ratio, a panel theory code (specifically DRDC's ShipMo3D) was used to predict the ship motions for each vessel in each sea condition. The motions examined were:

- Roll, pitch, heave;
- Vertical acceleration at three (3) positions; and
- Lateral acceleration at three (3) positions.

A nominal set of acceptance criteria was defined, representing internationally accepted standards for crew tolerance of motions, from various sources. That set of criteria is shown in Table 5.5.1 below.

Table 5.5.1 Typical Workboat Seakeeping Limits

Motion	Criteria	Value
Roll	Angle, RMS	<4.50°
Pitch	Angle, RMS	<3.75 °
Heave	Metre, RMS	<1.50 m
Vertical Acceleration	Acceleration, RMS	<0.15g
Lateral Acceleration	Acceleration, RMS	<0.07g

{Values are only valid up to a wave height of 4.0m (top of Sea State 5}

Overall, all four vessels demonstrate good seakeeping characteristics. Below SS 6, the vessel motion responses are below the notional motion criteria presented in Table 5.5.1 and for SS6 and above, all of the vessels exceed the notional seakeeping criteria to a greater or lesser extent depending on the vessel, ship speed, and heading relative to the waves. However, failure to achieve the criteria in no way means that the vessels are unsafe to operate for the following reasons:

- The seakeeping criteria have been determined to be the "operational" limitations of a fully adapted mariner to be able to undertake his or her work in a safe and uninterrupted manner. Exceeding these limitations simply means that the mariners will occasionally have to support themselves, or limit the work they are doing to lighter loads. Additionally, these seakeeping criteria are generally only applicable up to the top of SS 5 (4.0 m significant wave height), and should only be used for guidance, and for comparison purposes only when used as the limiting criteria for greater sea states

- The vessels under examination are all reasonably small vessels, and are being analysed for operations in seas with wave-lengths from twice to almost five times the vessels' length. As such, although the roll, pitch, and heave results indicate that the vessels have poor sea-keeping responses, the acceleration responses are low enough to suggest that the vessels are simply "riding the waves" and that changes in the ship's attitude in relation to the still water surface are "adding" to the overall reported motion results

The comparative analysis indicates that the ***AVT 43-100*** has the best all-round performance of the three hulls examined, with the ETT a close second. The ***RAstar 40-100*** and the PRT, with almost identical responses, still exhibit acceptable seakeeping responses for relatively small vessels operating in such high sea states.

The ***RAstar 40-100*** results, particularly in the transverse plane, are considered to principally reflect the fact that the natural roll period of that vessel is noticeably closer to the wave periods of the sea conditions being examined than the other vessels, and as a result, motions are higher. The PRT is fitted with fewer, and smaller, underwater appendages, and as such has less motion damping than the other hulls.

From this analysis it can be concluded that the ETT and PRT vessels have seakeeping performance only slightly less than the best available today. Some improvements to the PRT Class tugs in particular could be made to improve motion damping.

6.0 ESCORT VESSEL PERFORMANCE ASSESSMENT

6.1 Regulatory Requirements

It is important in the context of this evaluation to understand the regulations which apply to the vessels in question. CFR 33 168 is the over-arching document in the context of what is actually required of any escort tugs operating within Prince William Sound. The salient elements of this specific piece of legislation, enacted soon after the introduction of OPA '90, are as follows:

- *CFR 33 168.01 – Purpose:*

  (a) This part prescribes regulations in accordance with section 4116(c) of the Oil Pollution Act of 1990 (OPA 90) (Pub. L. 101-380). The regulations will reduce the risk of oil spills from laden, single hull tankers over 5,000 GT by requiring that these tankers be escorted by at least two suitable escort vessels. The escort vessels will be immediately available to influence the tankers' speed and course in the event of a steering or propulsion equipment failure, thereby reducing the possibility of groundings or collisions.

- *CFR 33 168.40*:

  The requirements of this part apply to the following waters:

  (a) Prince William Sound: Each tanker to which this part applies must be escorted by at least two escort vessels in those navigable waters of the United States within Prince William Sound, Alaska, and the adjoining tributaries, bays, harbors, and ports, including the navigable waters of the United States within a line drawn from Cape Hinchinbrook Light, to Seal Rocks Light, to a point on Montague Island at 60° 14.6' North, 146° 59' West, and the waters of Montague Strait east of a line between Cape Puget and Cape Cleare.

…and finally the most critical section:

- *CFR 33 168:50 - Performance and Operational Requirements*:

  (b) The escort vessels, acting singly or jointly in any combination as needed, and considering their applied force vectors on the tanker's hull, must be capable of:

  1) Towing the tanker at 4 knots in calm conditions, and holding it in steady position against a 45-knot headwind;
  2) [Reserved];
  3) Holding the tanker on a steady course against a 35-degree locked rudder at a speed of 6 knots; and
  4) Turning the tanker 90 degrees, assuming a free-swinging rudder and a speed of 6 knots, within the same distance (advance and transfer) that it could turn itself with a hard-over rudder.

It is critical therefore to understand exactly what forces are required by the tugs to meet CFR 33 168:50. Accordingly, estimates were made of the forces required to satisfy each of the criteria listed. The applied force requirements were calculated for both a 100,000 and 200,000 tonne tanker using the methodology defined by OCIMF [15]. However recent experience in similar analyses indicates that this method can significantly under-estimate the actual forces, as ships adrift or under tow inherently will tend to yaw and sway under the influence of these external environmental forces and thereby cause a significant (but oscillating) increase in the resulting forces due to the induced lateral "y" factor. The forces for any intermediate size tanker can be determined closely enough by linear interpolation.

Finally, it must be noted that for a tug to generate these forces in exposed sea conditions, some degradation factor to its nominal calm water performance must be applied due to the pitching and rolling of the tug. This is an area where there is not a great deal of information but the "Guidelines For Marine Transportations" from GL Noble-Denton [16] indicate that a thrust augment of not less than 20% should be considered in relatively calm conditions and 25% in more severe conditions. Figure 6.1 below is an extract from those GL-ND guidelines.

Tug efficiency, T_e, depends on the size and configuration of the tug, the seastate considered and the towing speed achieved. In the absence of alternative information, T_e may be estimated for good ocean-going tugs according to the following Table 12-3. However tugs with less sea-kindly characteristics will have significantly lower values of T_e in higher sea states.

Table 12-3 Values of Tug Efficiency, T_e

Continuous Bollard Pull (BP), tonnes	Tug Efficiency, Te %			
	Calm	H_{sig} = 2 m	H_{sig} = 3 m	H_{sig} = 5 m
BP ≤ 30	80	50 + BP	30 + BP	BP
30 < BP < 90	80	80	52.5 + BP/4	7.5 + 0.75 x BP
BP ≥ 90	80	80	75	75

Figure 6.1 Extract from "Guidelines for Marine Transportations" (GL-Noble Denton)

Therefore in order to satisfy the CFR requirements, considering 125,000 tonne and 193,000 tonne DWT tankers (the typical and maximum sizes respectively of tankers within the SERVS system), and assuming that 2 m H_s is a reasonable condition to use as the basis of analysis, representing just over a 5% occurrence as illustrated in the wind and wave data compiled for the operating area (Ref. Annex B) (hence ~95% of all conditions are better than this), the data presented in Table 6.1 overleaf represents the total resultant applied forces required of any tug operating in the SERVS system in Prince William Sound.

Table 6.1 Predicted Tug Forces Applied to Tankers to Satisfy CFR 33.168:50

CFR REQUIREMENTS for ESCORT of TANKERS

Criteria	Required Force								Corrected for Tug Efficiency				factor
	100,000 DWT		200,000 DWT		125000 Dwt		193,000 Dwt		125000 Dwt		193,000 Dwt		
	Loaded	Ballast	Loaded	Ballast	Loaded	Ballast	Loaded	Ballast	Loaded	Ballast	Loaded	Ballast	
Tow at 4 knots – Calm1	5.8	4.8	10.0	7.0	6.9	5.4	9.7	6.8	**8.2**	**6.4**	**11.6**	**8.2**	20%
Holding station against 45 knot winds and 15 ft (4.5 metre) significant wave height	47.0	53.0	55.0	68.0	49.0	56.8	54.4	67.0	**61.3**	**70.9**	**68.1**	**83.7**	25%
Hold the Tanker on a steady course against a 35 degree locked rudder at 6 knots2	43.0	43.0	59.0	59.0	47.0	47.0	57.9	57.9	**56.4**	**56.4**	**69.5**	**69.5**	20%
Turn the tanker 90 degrees, assuming free-swinging rudder, at 6 knots with the same performance as the tanker with hard-over rudder3	43.0	43.0	59.0	59.0	47.0	47.0	57.9	57.9	**56.4**	**56.4**	**69.5**	**69.5**	20%

From Table 6.1 it can be seen that the CFR requirements dictate the following tugboat performance:

a. For 125,000 tonne DWT Tankers:
   - Bollard Pull > 71 tonnes
   - Indirect Steering at 6 knots > 56 tonnes

b. For 193,000 tonne DWT Tankers:
   - Bollard Pull > 84 tonnes
   - Indirect Steering at 6 knots > 70 tonnes

6.2 Performance Summary

The comparisons made in Section 5.0 of this report give a reasonable picture of how the ETT and PRT Class tugs compare to similar escort tugs in similar service worldwide. The parameters used for this comparison, in order to be consistent with the Class requirements for assigning an Escort Notation to any tug, are, as described previously in Section 5.1, as follows:

- A hull form capable of generating large hydrodynamic forces in various operating modes
- Omni-directional propulsion to enable the tug to achieve oblique angles to the direction of travel
- Freeboard and Stability characteristics in compliance with Class requirements for escort towing
- Omni-directional propulsion with controllable-pitch propellers, to ensure that propeller overload in various operating directions will not stall the main engines
- A towing configuration that ensures a fail-safe attitude in the event of any propulsion or steering failure on the tug
- An escort-rated winch which can be set to release tension at a prescribed level and to recover line under tension at the same load rating
- Relatively high speed to ensure fast incident response and the ability to keep up with tankers

In addition, the following general design and performance characteristics were compared to give some measure of the operational efficiency of all the tugs compared:

- Specific thrust capability (BP per unit power)
- Speed/length ratio
- Indirect steering force generating capacity per unit of lateral area
- Seakeeping responses

Table 6.2 summarizes the data for the ETT Class tugs in comparison to the norm of other VSP Tractor tugs as well as to three other specific large VSP tugs that are generally considered the best escort tugs of this type afloat today. These include the ***"Ajax"*** (Figure 6.2) and "***Velox***" Class (Figure 6.3) tugs operated by Østensjø Rederi AS of Norway and the "***Baut***" Class (Figure 6.4) operated by Bukser og Berging AS, also of Norway.

Table 6.3 summarizes the data for the PRT Class tugs in comparison to the norm of other ASD Z-drive tugs, as well as to those specific ASD tugs that are generally considered the best escort tugs of this type afloat today. These include the various sizes of ***RAstar*** Class ASD tugs operated by Svitzer AS of Denmark, and in particular the ***Svitzer Lindsway*** type ***RAstar 3400*** Class of 34 metre tugs (Figure 6.5) and the ***RAstar 3900*** 39 metre ***Svitzer Kilroom*** (Figure 6.6), all of which operate at the Milford Haven terminal in SW England (an area notorious for rough seas).

Figure 6.2 AVT 3900 Class Tug *Ajax*

Figure 6.3 AVT 3500 Class Tug *Velox*

Figure 6.4 *Baut* Class Fin-Forward VWT

Figure 6.5 *RAstar 3400* Class ASD Tug *Svitzer Lindsway*

Figure 6.6 *RAstar 3900* Class ASD Tug *Svitzer Kilroom*

Table 6.2 BAT Performance for VSP Propelled Escort Tugs

Performance Parameter	Units	BAT - 2013	ETT	% Variance	Reasons for ETT deficiency
Bollard Pull / Unit Power	*Kg/kW*	12.65	12.36	-2%	with an input power of 10,192 BHP into VSP 36GII/270, Voith predict a bollard pull of 96.2 tonnes with today's new blade design
	lbs/BHP	20.81	20.34		The lower value in the ETT can be explained by any of several different sources:
					- Old blade design
					- Quality of the guard
					- Pitch adjustments during the trial not optimal
Speed/Length ratio		1.34	1.23	-8%	lower than expected speed suggests that either the hull form is fuller than normal (which is not obvious), and/or drag associated with VSP guard plate and associated struts may be higher than normal
Indirect Steering Force per Unit Hull lateral Area	*Tonnes/ Sq.M*	0.90	0.83	-8%	Sponsoned hull form provides more stability to resist heeling forces. More refined skeg foil shapes provide more lift
Render-recover Winch		Rated to maximum line force capability	Rated to only __% of max line force		Winch does not match current Class requirements for escort-rated winches
Towing Staple Position		located to maximize Fs while maintaining a fail-safe capability	as stability and force generation capabilities are well-matched, staple position appears optimum for this hull		

Table 6.3 BAT Performance for Z-Drive Propelled Escort Tugs

Performance Parameter	Units	BAT - 2013	PRT	% Variance	Reasons for PRT deficiency
Bollard Pull / Unit Power	*Kg/kW*	18.9	17.80	-6%	swept up buttock lines of PRT class result in higher thrust deduction, probably representing a 2-3% loss. Nozzle type is conventional 19A type rather than more recent high-Lift" types; probably another 3% loss
	lbs/BHP	31.00	29.21		
Speed/Length ratio		1.34	1.31	-2%	PRT hull form has more transom immersion and a more square stern than faster hulls
Indirect Steering Force per Unit Hull lateral Area	*Tonnes/ Sq.M*	0.90	0.44	-51%	The PRT was clearly not designed to develop indirect steering forces: it has no forward skeg to develop high lateral forces, and the aft skeg moves the centre of lateral area very far aft.
Render-recover Winch		Rated to maximum line force capability	Rated to only __% of max line force		Winch does not match current Class requirements for escort-rated winches
Towing Staple Position		located to maximize Fs while maintaining a fail-safe capability; typically would be 10-15% of Lwl aft of FP	Forward staple is well forward, further reducing potential for any indirect towing		

Some basic conclusions can be drawn from the performance data tabulated above to establish how the SERVS escort tugs measure up against the present best in the world fleet.

- The ETT tugs are very typical of a standard large Voith Water Tractor, with lines probably prescribed by Voith in the first instance, as is very common. The ETT tugs are large, powerful, and perform well. However design developments in Canada and in Norway in the past decade have led to what may be considered as a new generation of VSP-propelled tugs with superior performance in all respects. The new tugs are more efficient, faster, and develop more steering force per unit size. That said, the spread in performance between the ETT and BAT today is not great (less than 8%). The lack of a fully capable render-recover winch on the ETT's is however a major shortcoming
- The PRT tugs are large and powerful ASD tugs, and are well-equipped for ocean towing. They are not however well-configured to function as a proper escort tug performing indirect or powered indirect towing, taking maximum advantage of the size and power of these tugs. They have no skegs or comparable appendages with which to efficiently generate indirect forces. They lack a render-recover winch forward, and the towing staple position is too far forward

6.3 B.A.T. in Escort Tug Technology Today

The following opinions are offered with regard to the BAT available today for various roles within the SERVS fleet.

6.3.1 Primary Escort Role

The Primary Escort Vessel (PEV) must provide the highest escort capability available. The PEV is the tug tethered to a tanker during an escort operation and thus by definition is the first tug required to apply corrective forces in the event of an incident.

The PEV must, according to the ADEC regulations, *"...be available immediately <u>to provide the intended assistance</u> to the tank vessel as required by 18 AAC 75.027(e)*". However the cited regulation 75.027(e) provides no further definition of the expected escort tug capabilities, stating only in a completely circular fashion that, "*A tank vessel under escort by another vessel must, at all times, be operated in a manner that permits the escort vessel to be available immediately <u>to provide the intended assistance</u> to the tank vessel.*"

According to the minimum capabilities for an escort tug as described in Section 5.1, the PEV must:

(a) be designed and constructed such that it could achieve a full Escort Tug designation by a recognized Classification Society;
(b) be capable of generating forces, under the strictures of the above Class requirements, which would at the very least represent those forces generated by the rudder of the attended ship, in accordance with the guidelines defined by IMO Resolution A.751 (18) (Nov. '93) "Interim Standards for Ship Manoeuvrability";
(c) be equipped to provide a Spill Response capability, including spill containment, skimming and recovery capabilities;
(d) be equipped to provide an emergency towing capability;
(e) represent the Best Available Technology in the manner and the speed with which it develops the forces described in (a) and (b) above.

The quantitative definition of the regulatory minimum expected of the PEV is defined by CFR 33 168, as described in Section 6.1. Those forces are satisfied by the ETT Class tugs. *It must also be assumed that the physical capabilities of the ETT tugs (at least) have been verified through prior analysis as suitable for their intended tasks.* Per (b) above however it is also possible to identify from various sources such as Hensen [17], as illustrated in Figure 6.6 below, that the minimum rudder force associated with a TAPS tanker of 265,000 tonnes DWT travelling at 10 knots is approximately 110 tonnes. This value is not dissimilar to those calculated under the CFR standards (noting that was for a smaller ship). The ETT tugs, developing 141 tonnes of F_s clearly satisfy this fundamental criterion.

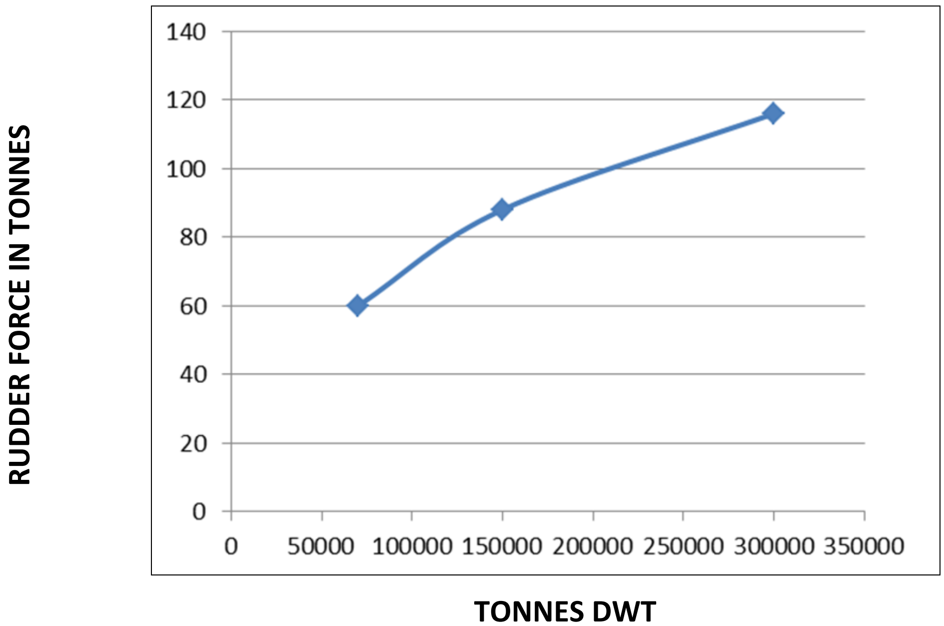

Figure 6.6 Rudder Force vs. Tanker Size at 10 knots, from Hensen [17]

6.3.2 Secondary Escort Role

As discussed in Section 4.5, the Tanker C-Plan [5] defines the role of the secondary escort tug solely as:

- *Take the tank vessel under tow by the bow after the save is achieved, and*
- *Control the tow*

The PRT tugs are well-equipped and more than capable to fulfill this SEV role, however it is difficult to consider this as a true "escort" role as defined by all the literature on the subject, lacking as it does any reference to indirect towing operations. Certainly without these indirect capabilities it is <u>not possible</u> for the SEV to act as a backup or substitute for the PEV; hence there is no redundancy to the PEV role provided by the SEV vessels as presently defined.

6.3.3 Primary Escort of Tankers < 90,000 Tonnes DWT

The terms of reference for this study ask "*Should there be a different standard for BAT for primary role in service of 90,000 T DWT tankers?*"

In many respects the size of the attended ship is immaterial to the risk associated with an incident, as the potential for a spill is determined primarily by human factors, and the size of a spill is governed more by the individual cargo tank capacities than by sheer vessel size. Although the forces associated with corrective action to a smaller tanker are obviously less than those required for the largest vessels in any escort system, that simply means that a rescue should be performed more quickly and in less distance by the same escort vessel, thus significantly reducing the risk of a casualty with smaller vessels. It is reasonable however to apply the same standard of safety to all escorted vessels, (say for example "*limit the transfer of any tanker to within 200 metres of the shoreline*") in which case the required escort tug for smaller ships could indeed be smaller than that required for the largest tankers in the system. However the performance criteria per tanker size, should be exactly the same. This suggests that a much smaller VSP or ASD escort-rated tug should be able to provide escorts for smaller tankers, but what does NOT change with ship size is the weather and sea conditions. Smaller tugs are much more severely impacted by sea conditions than are larger tugs, and their performance deteriorates more quickly in heavier seas. Therefore it is important to judge not just the required forces to be developed by any escort tug but the conditions under which those forces must be consistently and safely generated. Therefore in order to provide the same standard of safety and effectiveness, the actual required escort tug for a smaller ship of 90,000 tonnes or less will be larger in proportion to the ship than the escort tug required for the largest tanker.

It is possible however to consider the use of the PRT Class tugs as "escort" tugs for smaller tankers, where the forces that can be generated by the PRT tugs (by brute force rather than by indirect operations) can effectively control a smaller vessel. Referring to Table 5.2 it can be seen that the PRT Class tugs can generate from 62 to 81 tonnes of steering force in the indirect or powered indirect mode. Figure 6.6 shows that these forces (however developed) are sufficient to control a tanker of approximately 125,000 tonnes DWT at 10 knots. The analysis of the CFR requirements supports this conclusion.

Therefore the PRT Class tugs certainly have the performance necessary to be the primary escort vessel for tankers under 90,000 tonne DWT. In this context therefore, although the use of these tugs in this manner is far from representing BAT, it is a viable use of the available resources.

6.4 SERVS Tug Performance Summary

Table 6.4.1 below summarizes the performance minimums which are suggested by the overall assessment of the requirements for BAT in both primary and secondary escort tugs. It is interesting to note that the ADEC requirements do NOT specifically cite the requirements of CFR 33 168.

Table 6.4.1 SERVS Tug Performance Summary

	Performance Criteria per ADEC	BAT Requirement	ETT Class	PRT Class	Notes
1	Be designed and constructed such that it could achieve a full Escort Tug designation by a recognized Classification Society.	ABS or equal "Escort" Notation	Notation +A1 Towing Service, +A1 AMS, +A1 FiFi Class 1, U.S. Domestic Service *Is not classed for escort*	Notation +Al Towing Service +AI AMS +Al FiFi Class 1 and non dedicated OSRV *Is not classed for escort*	ABS Escort Notation = A1 Offshore Support Vessel (Escort)
2	Be capable of generating forces, under the strictures of the above Class requirements, which would at the very least represent those forces generated by the rudder of the attended ship, in accordance with the guidelines defined by IMO Resolution A.751 (18) (Nov.'93) "Interim Standards for Ship Manoeuvrability"	Fs = 110 tonnes at 10 knots	Fs = 141 tonnes @ 10 knots	Fs = 62 tonnes (indirect) or 81 tonnes (powered indirect) @ 10 knots. These forces are only adequate to escort tankers of 125,000 tonnes DWT or less	*The PRT escort performance prediction performed only considers the hydrodynamics of the hull as well as the thrust and towpoint locations. It does not consider the bow fairlead strength or the bow winch capabilities.
3	Be equipped to provide a Spill Response capability, including spill containment, skimming and recovery capabilities	Be equipped with: - spill containment boom(s), readily deployable - an oil skimmer - either internal recovered oil capacity or ready means of storage in the form of bladders or an available barge or similar	Equipped with*: 2 x 1800 ft Vikoma Hydra ocean boom 2 x DESMI 250 Oil Skimmers 2 x 35 ft Dispersant Spray Arms 73,200 gallons Recovered Oil Capacity	Equipped with: 2,000 ft Kepner Sea Curtain Boom 2 x DESMI Oil Skimmers 2 x 20 ft Kvichak Workboats 43,000 gallons Recovered Oil Capacity	
4	Be equipped to provide an emergency towing capability	(a) Have a BP sufficient to keep a disabled tanker off a lee shore in worst conditions (b) Be equipped with: - a double drum towing winch with suitable wire and surge gear for rescue towing - towing pins or similar (c) have sufficient fuel capacity to carry out rescues within the required geographic area	(a) Assumed part of original design criteria (b) check (c) Assumed part of original design criteria	(a) Assumed part of original design criteria (b) Yes (c) Assumed part of original design criteria	
5	Represent the *Best Available Technology* in the manner and the speed with which it develops the forces described in (1) and (2) above	(a) have high performance omni-directional Propulsion (b) have a hull form and appendages which will generate high indirect forces (c) have a towing staple position which ensures a fail-safe towing configuration (d) have a render-recover winch which will limit towline forces to pre-detrmine d amximums and significantly reduce the risk of failure of the towline	(a) Yes (b) Yes (c) Yes (d) No	(a) Yes (b) No (c) Yes (d) No	

From this summary it can be readily seen that there are indeed some gaps between the SERVS escort tugs and what is considered BAT today. The deficiencies are:

(f) Neither Class of tug has a formal "Escort" notation.
(g) The ETT tugs do not have a render-recover winch which satisfies Class standards for an escort notation.
(h) The PRT tugs do not have a render-recover winch which satisfies Class standards for an escort notation.
(i) The PRT hull form is not configured to generate indirect line forces, and lacks appendages such as a skeg or bilge keels which would contribute to this capability.
(j) The PRT Class tugs are limited in their ability to generate indirect forces sufficient to represent the equivalent tanker rudder force for the larger tankers in the system. They do however have sufficient capability to steer tankers of 125,000 tonnes DWT or less.

7.0 B.A.T. GAP ANALYSIS

The Terms of Reference for this study included a requirement to "*Compare the present escort vessels to the current best escort tug design standards worldwide using the eight (8) stipulated criteria used by the Alaska Department of Environmental Conservation (ADEC).*"

Table 7.1 below provides that evaluation for the ETT and PRT Class tugs in a side by side comparison.

Table 7.1 ADEC TECHNOLOGY COMPLIANCE MATRIX

Note: for completeness the comments from Ref. [__] related to the winches found on the ETT and PRT tugs are repeated here

Evaluation Criteria	Criteria Description	ETT Class Tugs	PRT Class Tugs
A	*Whether each technology is the best in use in other similar situations and is available for use by the applicant;*	*Hull:* The ETT tugs are effective escort tugs but are not as efficient or as effective as more recent VWT Escort tugs currently in service elsewhere. ETT tugs miss BAT by about 8% in terms of hull performance. The ETT tugs fully satisfy the requirements of CFR 33 168:50 for tankers up to 200,000 T DWT. *Winch*: The winch fitted fails to meet BAT by a significant amount. Winches with higher performance as used in other jurisdictions are readily available from a number of capable suppliers.	*Hull:* The PRT tugs are not well suited to tanker escort service, lacking the ability to effectively develop indirect forces. PRT tugs fail BAT by significant margins (abt. 50%) in terms of hull performance compared to modern ASD escort tugs. The PRT Class are large powerful tugs however, and can exert effective escort forces on smaller tankers using direct forces only. The PRT tugs satisfy CFR 33 168:50 for tankers of 125000 T DWT or less. *Winch:* The winch fitted fails to meet BAT by a very significant amount. Winches with higher performance as used in other jurisdictions are readily available from a number of capable suppliers.
B	*Whether each Technology is transferable to the applicant's operations*	*Hull:* the differences in hull form between BAT and the ETT tugs are not practicably transferable. *Winch*: a higher performance winch could be fitted to the ETT tugs. That would require extensive changes to the power generation system aboard the tug, plus likely some structural support changes.	*Hull:* the differences in hull form between BAT and the PRT tugs, specifically the aft end geometry and the use of a sponsoned hull shape are not practicably transferable. Changes to the appendages would also significantly improve escort capability. *Winch*: a higher performance winch could be fitted to the PRT tugs. That would require extensive changes to the power generation system aboard the tug, plus likely some structural support changes. The bow towing fittings would also need to be strengthened in proportion to the winch capability.
C	*Whether there is a reasonable expectation each technology will provide increased spill prevention or other environmental benefits;*	*Hull*: A faster, more efficient hull form would translate into faster and more effective responses to tanker failure incidents, thus reducing the time to save a ship and reduced advance and transfer distances. In theory therefore the potential for an oil spill would be reduced. *Winch*: The use of a high-performance render-recover winch would ensure safe escort operations in more severe weather conditions, which also coincides with the conditions most likely to cause ship control problems. A minor secondary benefit would be that using electrical winches there is less chance of a hydraulic oil spill on deck.	*Hull:* the PRT tugs would be far more effective as escort tugs with the ability to develop higher indirect forces. At speeds in the range of 8-10 knots indirect forces can be 50% or more greater than the direct forces currently being applied by the PRT tugs. This would translate into faster responses to stop a disabled tanker, with reduced advance and transfer distances, thus significant reduction in the potential for an oil spill . This capability would also expand the potential role for the PRT Class as proper escort tugs. *Winch:* As the existing system has proven (post 1990) incident free, there is no correlation between an improved winch type and increased environmental benefits. A minor secondary benefit would be that using electrical winches there is less chance of a hydraulic oil spill on deck

D	*The cost to the applicant of achieving best available technology, including consideration of that cost relative to the remaining years of service of the technology in use by the applicant;*	*Hull:* it is not feasible to upgrade or replace the ETT hulls. *Winch:* To replace the winch on an ETT would cost at least about $1.5-$ 2 million per vessel, including the impact of changing generators etc. There is good residual value in the present winches which could be re-used on other more conventional tugs.	*Hull:* it is not feasible to upgrade or replace the ETT hulls. However a forward skeg could be added, in conjunction with the removal of the present aft skeg. This should only be done however in concert with a winch upgrade. ROM cost to do the skeg mods is about $ 0.5M. *Winch:* To replace the winch on an ETT would cost at least about $2.0 - $2.5 million per vessel, including the impact of changing generators etc. There are more structural alterations required on the PRT tugs than on the ETT Class. There is good residual value in the present winches which could be re-used on other more conventional tugs.
E	*The age and condition of the technology in use by the applicant*;	*Hull:* The hulls of the ETT Class tugs are in very good condition and are likely at less than 1/3rd of their useful life. *Winch:* The existing winches are 14 years old and in a very well-maintained condition.	*Hull:* The hulls of the PRT Class tugs are in very good condition and are likely at less than 1/3rd of their useful life. *Winches:* The existing winches are 14 years old and in a very well-maintained condition.
F	*Whether each technology is compatible with existing operations and technologies in use by the applicant;*	*Hull:* The ETT tugs have been previously evaluated and tested to satisfy the operational criteria of the Alyeska tanker fleet, and as such are considered compatible with current operations. *Winch:* The existing winch/rope system is quite compatible with the capabilities of the tugs and the operational processes.	*Hull:* The PRT tugs are NOT effective escort tugs in terms of their ability to substitute for the ETT Class tugs, and are therefore not considered compatible with the current operations. *Winch:* The existing winch/rope system is quite compatible with the capabilities of the tugs and the operational processes. Should the escort capabilities of these tugs be enhanced in any way in the future, say for instance changes to enable some indirect towing to be performed, then the existing winches would need to be replaced.
G	*The practical feasibility of each technology in terms of engineering and other operational aspects*	*Hull:* It is not practical to change the hull form of the ETT tugs. *Winch:* It is certainly feasible to consider replacing the winch. That would involve taking the vessel out of service for at least 4-6 weeks however	*Hull:* It is not practical to change the hull form of the PRT tugs. The re-configuration of the skegs however is not difficult. *Winch:* It is certainly feasible to consider replacing the winch. That would involve taking the vessel out of service for at least 4-6 weeks however
H	*Whether other environmental impacts of each technology, such as air, land, water pollution, and energy requirements, offset any anticipated environmental benefits.*	There are no negative environmental impacts of the alternate winch technology.	There are no negative environmental impacts of the alternate winch technology.

8.0 SUMMARY AND CONCLUSIONS

Under the terms of this study, an extensive technological review has been conducted of certified escort tugs in operation worldwide, and the performance of the best of those vessels, representing the current Best Available Technology (BAT), has been compared to that of the ETT and PRT Class tugs operating within the SERVS Fleet.

Since the ETT and PRT tugs were built 14 to 15 years ago, much has changed in the understanding of escort towing operations and in the design of high-performance escort tugs. In the past decade or so a new generation of high-performance escort tugs has emerged, certainly raising the bar for tanker escort performance and operations.

Major advances have been made in hull form development for escort tugs, and with the judicious application of well-designed appendages to generate indirect steering forces. Modest improvements have been made in the propulsion technologies used on these vessels, providing more thrust per unit power than previously. For example Voith Turbo have improved the blade design on VSP drive units and thrust-augmenting nozzle shapes on Z-drives have been improved. In addition, the methods of applying escort forces have been studied in more detail and the level of understanding among both Pilots and Tug Masters in the application of these forces has generally improved.

The regulatory performance requirements for tugs operating as escorts in Prince William Sound, as defined by 33 CFR 168:50 have been calculated for tankers of 100,000 to 200,000 tonnes DWT. The requirements for tankers of 125,000 and 193,000 tonnes DWT are as follows:

a. For 125,000 tonne DWT Tankers:
   - Bollard Pull > 71 tonnes
   - Indirect Steering at 6 knots > 56 tonnes

b. For 193,000 tonne DWT Tankers:
   - Bollard Pull > 84 tonnes
   - Indirect Steering at 6 knots > 70 tonnes

These forces are actually rather modest; the ETT tugs fully satisfy all of these requirements, but the PRT tugs satisfy the requirements only for tankers of 125,000 tonnes DWT and less.

The ETT tugs are among the largest and most powerful escort tugs in operation worldwide, and still are very effective escort tugs. Their relative performance however has fallen behind that of more recent large VSP escort tugs, and most critically their capability is limited by the lack of a high-capacity render-recover hawser winch. The hull and machinery of the ETT Class tugs are only about 8% below the current highest standards available, and thus these vessels can still be categorized as high-performance escort tugs, able to perform the defined Primary Escort Tug role. The winch however limits the ability of the tug to consistently apply the forces generated in the range of environmental conditions encountered. It is impractical to contemplate any changes to the hull or the machinery of these tugs for what are likely only very modest gains. Improvements to the render-recover capabilities of the main winch however would significantly raise the overall capability of these tugs for service in more severe conditions, and increase the reliability of the towing system in poor weather and sea conditions.

The PRT tugs are more of a problem: if the role of these tugs is solely to be the Secondary Escort Vessel, as defined in the C-Plan, then the tugs are totally adequate. The PRT tugs are large and powerful ASD tugs, and are well-equipped for ocean and rescue towing. They are not however well-configured to function as a certified escort tug. They have no skegs or comparable appendages with which to efficiently generate indirect towline forces. They lack a proper render-recover winch forward, and the towing staple position is too far forward. The indirect line force generating capacity of these tugs is therefore about 50% of that of the best ASD escort tugs in service today. The PRT tugs can however provide an escort capability by sheer brute force, acting normally by "direct" towing in line with the direction of the towline, but that limits the forces which can be generated at higher towing speeds. Thus the response capabilities of the PRT Class tugs are limited until the speed of a tanker is brought down to something in the order of 6-7 knots, where the high power of these tugs is most effective.

Regardless of these limitations however, by virtue of their size and power the PRT tugs can generate moderate escort forces which are adequate for use on tankers of 125,000 tonnes DWT and less. This use certainly does not represent BAT, but it is an effective use of these large and expensive resources.

Some relatively straight-forward changes could be made to the PRT tugs to improve their indirect line force generating capabilities. These changes would include:

- Fit a large forward skeg
- Remove the existing aft skeg
- Fit an escort-rated render-recover type winch on the fore deck
- Provide a towing staple further aft (closer to the winch), with appropriate strength for higher line forces

With these changes, subject to a much more detailed evaluation and analysis, it is believed that the indirect force generating capability of the PRT tugs would increase to something in the order of 125 tonnes. It must be verified however that these tugs have the necessary stability to support such higher forces; there is some margin available within Class limits.

In summary, neither the ETT Class nor the PRT Class tugs represent BAT in escort tugs today. The research and developments of the past decade have resulted in significant improvements in escort tug hull design, in propulsion systems, and in winch design for this particular application, and most of the more recently built escort tugs significantly out-perform the SERVS vessels. The ETT tugs however are still very effective escort tugs and with a better winch system would be a world-class escort tug. The PRT tugs however lack a significant escort towing capability and it would be difficult and expensive to change them in a manner which would provide that capability. Due to their size and power however the PRT tugs have the ability to escort tankers of 125,000 tonnes DWT or less. They are however hampered by the lack of a proper escort winch forward to be certifiable for this role.

The fitting of proper render-recover type escort winches to both Classes of SERVS tugs, compliant with Class Society requirements would significantly improve the rating of both tugs in the world scale; not quite to BAT, but certainly much better than by their current ratings.

for **ROBERT ALLAN LTD.**

Robert G. Allan, P. Eng.
Executive Chairman of the Board

RGA:da

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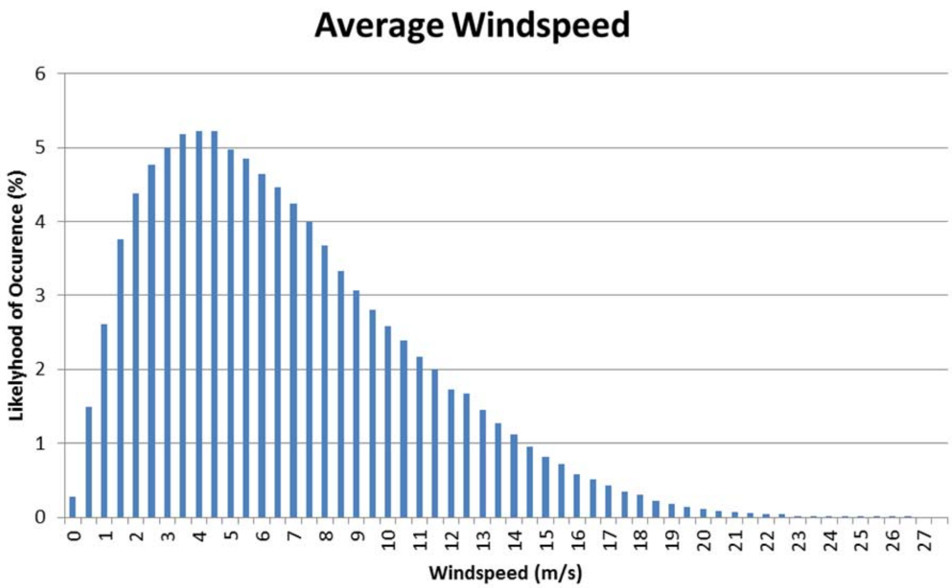
Annex B

Hinchinbrook Entrance Metocean Data Histograms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Likelyhood of Occurence (%)
Windspeed (m/s)
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3
4
5
6
0
1
2
3
4
5
6
7
8
9
10
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23
24
25
26
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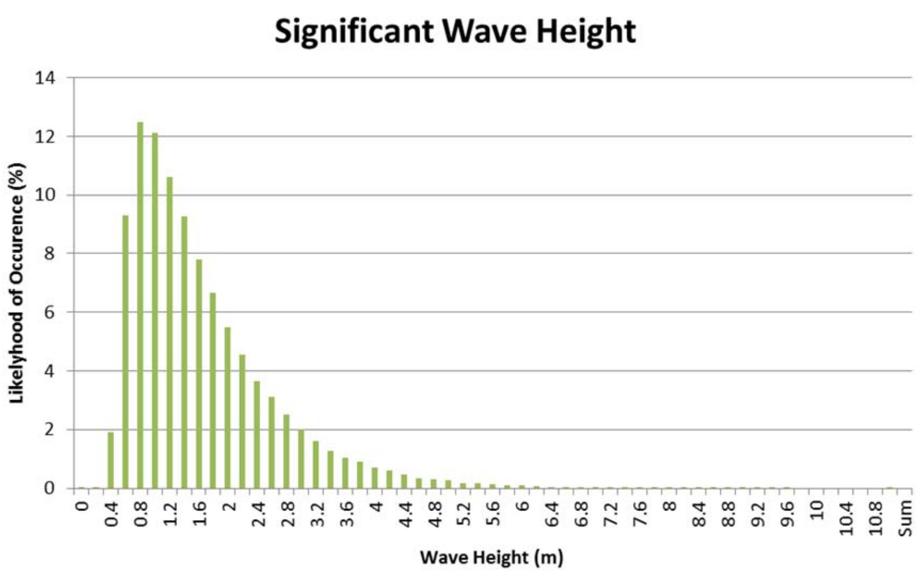
Significant Wave Height
Likelyhood of Occurence (%)
Wave Height (m)
0
2
4
6
8
10
12
14
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
3.6
4
4.4
4.8
5.2
5.6
6
6.4
6.8
7.2
7.6
8
8.4
8.8
9.2
9.6
10
10.4
10.8
Sum