Regional Citizens' Advisory Council

Date: August 21, 2014
From: Mark Swanson, PWSRCAC Executive Director

When responses for the escort tug BAT study were accepted, the firm of Robert Allan Ltd (RAL) received the best score out of the proposals submitted. The bulk of the work product for this project is found in the report titled *A Review of Best Available Technology in Tanker Escort Tugs* that has been approved by the Council.

The Council went out for a RFP on the sentinel tug issue in 2008. Prices quoted ranged from $52,000 to $368,521 to $450,645. The work was never conduced and the cost was likely too high to continue with the project. The attached Hinchinbrook tug analysis done by RAL is meant to provide a basic framework for what might constitute BAT with the sentinel tug. This as a stepping stone, an effort to lay out some basic requirements and goals for the tug; it was never meant to be an independent study. If there is an attempt to pursue another sentinel tug RFP, this document will greatly aid that effort. The contract with RAL for the Hinchinbrook sentinel tug analysis asked them to:

> 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.

Robert Allan prepared this study as requested and it will prove to be useful to the POVTS Committee and Council going forward. It is an important addition to an excellent study on escort tugs sponsored and approved by the Council.

It should be noted that other specific capabilities and tasks related to the prevention of and response to oil tanker accidents are required by various federal and state laws, and the tanker contingency plan. Specifically, vessels are required to provide laden tanker escorts through Hinchinbrook with very specific associated tasks and performance requirements. Additionally, vessels are required to be on contracted to provide firefighting and marine salvage capabilities in accordance with the USCG Marine Firefighting and Salvage regulations. While it is likely that the Hinchinbrook rescue tug (which is the exclusive subject of this study) would be initially involved in any or all of these escort, firefighting or salvage assistance operations, there is no requirement that this vessel exclusively meet those performance and capability requirements. Other vessels are explicitly named in the contingency plan as providing those capabilities with defined and arrival deployment expectations.

The purpose of this study was to solely define BAT exclusively for the functions and capabilities required of a Hinchinbrook-Rescue tug. Any vessel, including the Hinchinbrook-Rescue tug, assigned to exclusively accomplish these other functions (without additional vessels or resources) should meet BAT for those other functions as well. This may well be impractical as any one vessel design achieving BAT for such functions would likely be prohibitively expensive in comparison to a combination of smaller-function optimized vessels with complimentary capabilities, as are currently assigned within the Alyeska/SERVS fleet.

A Review of B.A.T. for a Sentinel Tug Stationed at Hinchinbrook Entrance

Project 212-090ST Revision 1 January 7, 2014

Prepared for:

Prince William Sound Regional Citizens' Advisory Council
Anchorage, AK

Prepared by:

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A Review of B.A.T. for a Sentinel Tug Stationed at Hinchinbrook Entrance

Document No.: 212-090ST

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

Client's Reference:
Contract No. 8010.12.01

Prepared By:
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Professional Engineer of Record:
Robert G. Allan, P. Eng.

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Confidentiality: **Confidential**

Contents

EXECUTIVE SUMMARY

Robert Allan Ltd. was retained by the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) in December 2012 to conduct a broad review of the current Best Available Technology (B.A.T.) in Escort Tug technology worldwide, and to perform a Gap Analysis of the tugs within the SERVS Fleet against that current B.A.T. A review of the requirements for a "Sentinel Tug" to be stationed at Hinchinbrook Entrance was also required. This report constitutes the findings of this separate Sentinel Tug study.

The requirements for the Sentinel Tug are defined in the VERP as follows:

> *"Hinchinbrook Tug – A vessel (PWS, PRT, or Theriot Class) capable of ocean escort and rescue service. The vessel is stationed in the vicinity of Hinchinbrook Entrance to provide assistance as a Sentinel escort for tankers in ballast transiting Hinchinbrook Entrance, and laden tankers transiting into or out of the Gulf of Alaska to 17 miles of Cape Hinchinbrook. This vessel may also be utilized as a close escort for laden tankers transiting through Hinchinbrook Entrance."*

To this, a Mission Statement prepared by PWSRCAC was added as follows:

> *"…[To perform] tanker/ship rescue towing operations in open ocean conditions 200 miles into the Gulf of Alaska from Hinchinbrook Entrance.*
>
> *…PWSRCAC further believes a dedicated deep-sea style vessel whose primary mission is standby rescue, salvage and towing is preferable as the Hinchinbrook Entrance vessel. PWSRCAC assumes this type of vessel would have to provide rescue towing assistance and preliminary salvage while acting alone in cold weather conditions. As such, this vessel would need to possess extremely high bollard pull and horsepower, a deep draft and high freeboard, excellent sea-keeping characteristics, an elevated working deck aft, tow winch(es) with suitable cable and gear for ocean towing, and excellent manoeuvrability including bow thrusters and multiple propulsion systems. This vessel would be capable of attaching a line and turning a fully loaded, disabled 125,000 deadweight ton tanker into the wind and sea during extreme sea conditions and either tow or hold the vessel in position until conditions improved for towing."*

Regulations, both National and State are silent on the requirements for such a vessel.

The option of providing the required towing capability in a single or multiple tugs represents a tactical choice on the part of operators. This report assumes that a single tug must be capable of satisfying a very high percentage of incidents, and only in the most severe conditions would two or more tugs be required.

The design conditions for the operation of the Sentinel tug were selected as follows:

- 99th percentile wind conditions at Seal Rock = 45 knots, plus a 12 knot margin to account for wave shielding of recording buoy data
- 99th percentile of sea states = 15 feet significant

The performance requirements for the tug were calculated or estimated using published references, and are summarized as listed below. The Sentinel Tug shall:

- If fitted with conventional twin-screw or ASD propulsion, have a nominal static Bollard Pull (BP) not less than 119 tonnes in order to satisfy the Rescue Towing criteria for a 193,000 T DWT tanker, or 101 tonnes BP for a 125,000 tonne DWT tanker
- If of a proper tractor configuration (with drives forward) have BP requirements reduced to 112 and 95 tonnes respectively
- Per the Mission Statement, NOT perform any indirect escort towing
- Have a free running speed in calm water at full load displacement, of about 16 knots
- Have an operating range not less than 2,000 n. miles at full power, and endurance at full power, at an assumed towing speed of 6 knots, of not less 15 days
- For crew safety and comfort, motions-related accelerations not exceeding 0.07G (lateral) and 0.15G (vertical) in the 90th percentile of wind and sea conditions encountered in the Gulf of Alaska (Sea State 6 or lower)
- Fully satisfy the requirements of the US Coast Guard Towing Stability Criteria (46 CFR 173.095). There should be sufficient margin specified in meeting these criteria that the tug will continue to do so throughout its operating life
- To satisfy B.A.T., have omni-directional propulsion and be able to execute a zero speed, 360 degree turn within no more than 110% of its own length, and within no more than 60 seconds
- Have a combination of main propulsion and lateral thrusters which can hold it at a 45° attitude to a 57 knot wind and the effects of 15 foot significant seas
- Have any type of propulsion system which, in combination with lateral thrusters would satisfy the requirements for manoeuvrability and position-keeping described above. B.A.T. would constitute those omni-directional drive systems which incorporate some form of "tractor" configuration (namely VSP, Z-Tractor, or Rotor Tug) which are recommended due to better manoeuvrability, safer towing characteristics and less loss of effectiveness in heavy seas
- Have main towing gear with components rated with a Design Load of at least 3 x Bollard Pull

In addition, the following are recommended:

- A formal drift study be conducted, accounting for the precise influence of wind, waves and currents on a disabled tanker on a time domain basis to verify that 17 miles is the correct offshore tanker transit distance during which the Sentinel Tug should standby
- The use of a towing winch with an automatic rendering capability at a prescribed tension is worth serious consideration for this application

A tug which can satisfy all the defined operational criteria above will have approximately the following principal particulars:

- Bollard Pull = 119 tonnes for 193,000 tonnes DWT, or 101 tonnes for 125,000 tonnes DWT
- Power = 9,371 BHP (for 119 T BP) or 7,954 BHP (for 101 T BP)
- Length overall = 50–52 metres
- Beam = 15–16 metres
- Draft = > 6.5 metres
- Deadweight = app. 500 tonnes min.

The Sentinel Tug should also be fully equipped with a significant fire-fighting capability (Fi-Fi 2 Rating for B.A.T.) and for an active pollution response role.

A Gap Analysis was performed comparing the characteristics of the present SERVS tugs; namely the ETT, PRT and Theriot Class tugs to the B.A.T. characteristics established. The results of that analysis are summarized as follows:

- The ETT tugs lack the power, speed and towing gear to perform the Sentinel Rug role
- The PRT class tugs are sufficiently large and powerful for the Sentinel Tug role; however their main towlines are not quite as strong as recommended
- The Theriot Class tug has sufficient power to handle a 125,000 tonne tanker but falls short of the power recommended for a 193,000 T DWT tanker. The towing gear falls short of the Design Load criteria used

In conclusion, the PRT tugs are quite well-suited to the Sentinel Tug role, although the ideal tug for this role would be somewhat larger, be a Z-Tractor or Rotor Tug configuration, have heavier towing gear, have a greater Fi-Fi capacity and a greater spill response capability. The PRT tugs however are not very deficient in satisfying the majority of the defined criteria. The strength of the towing gear on the PRT tugs is however a concern if tankers larger than 125,000 tonnes DWT are to be towed.

* * *

Project 212-090ST
January 7, 2014
Rev. 1

A Review of B.A.T. for a Sentinel Tug Stationed at Hinchinbrook Entrance

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

1.0 INTRODUCTION

Robert Allan Ltd. (RAL) was retained by the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) in December 2012 (Contract No. 8010.12.01) to conduct a broad review of the current Best Available Technology (B.A.T.) in Escort Tug technology worldwide, and to perform a Gap Analysis of the tugs within the SERVS Fleet against that current B.A.T.. As an adjunct to that report, a review of the requirements for a "Sentinel Tug" to be stationed at Hinchinbrook Entrance was also requested. It was agreed that this topic should be treated in isolation from the broader Escort Tug B.A.T. study, and hence this report constitutes the findings of this separate Sentinel Tug study.

2.0 TERMS OF REFERENCE

The terms of reference for this study were as follows:

"*Conduct an analysis of what would constitute B.A.T. for the Sentinel Tug stationed at Hinchinbrook Entrance, estimating the following required characteristics:*

- *Particulars*
- *Stability*
- *Seakeeping*
- *Bollard Pull*
- *Speed*
- *Range and Endurance*
- *Indirect Towing Capability*
- *Rescue Towing Capability, and*
- *Towing Gear Required*

The Council will work with the Consultant to define the Mission Statement for the Hinchinbrook Sentinel Vessel."

To the above list of characteristics have been added seakeeping, manoeuvrability and position-keeping as pre-requisites for a tug required to make a towing connection to a disabled ship in open ocean conditions. Ancillary functions such as fire-fighting and oil-spill response capabilities also are addressed.

In light of the work already done to review the capabilities of the PRT Class tugs as escort tugs, it is appropriate to extend the terms of reference for this study to include a GAP Analysis of the PRT, ETT, and Theriot Class tugs against the required B.A.T. for the Sentinel Tug as defined by this study.

This report therefore addresses the expanded terms of reference as indicated above.

3.0 MISSION STATEMENT

PWSRCAC provided the following as a basic Mission Statement for the Sentinel Tug:

A. Extract from the Vessel Escort and Response Plan (VERP [1]):

"*Hinchinbrook Tug – A vessel (PWS, PRT, or Theriot Class) capable of ocean escort and rescue service. The vessel is stationed in the vicinity of Hinchinbrook Entrance to provide assistance as a Sentinel escort for tankers in ballast transiting Hinchinbrook Entrance, and laden tankers transiting into or out of the Gulf of Alaska to 17 miles of Cape Hinchinbrook. This vessel may also be utilized as a close escort for laden tankers transiting through Hinchinbrook Entrance.*"

B. PWSRCAC Notes:

The following description of the Mission Statement for this tug [2] was provided by PWSRCAC:

"…[To perform] tanker/ship rescue towing operations in open ocean conditions 200 miles into the Gulf of Alaska from Hinchinbrook Entrance.

PWSRCAC believes a modern deep-sea salvage tug and rescue vessel possesses the necessary qualifications that would allow it to operate in open ocean conditions found in the Gulf of Alaska throughout the year. PWSRCAC further believes a dedicated deep-sea style vessel whose primary mission is standby rescue, salvage and towing is preferable as the Hinchinbrook Entrance vessel. PWSRCAC assumes this type of vessel would have to provide rescue towing assistance and preliminary salvage while acting alone in cold weather conditions. As such, this vessel would need to possess extremely high bollard pull and horsepower, a deep draft and high freeboard, excellent sea-keeping characteristics, an elevated working deck aft, tow winch(es) with suitable cable and gear for ocean towing, and excellent ma-

noeuvrability including bow thrusters and multiple propulsion systems. This vessel would be capable of attaching a line and turning a fully loaded, disabled 125,000 deadweight ton tanker into the wind and sea during extreme sea conditions and either tow or hold the vessel in position until conditions improved for towing."

It must be noted that the mission as defined by PWSRCAC (in B above) is somewhat at odds with the description in the VERP, per A above. The references in the latter to "escort" operations cast a very significant and different light on the vessel to be defined. Accordingly, and to be consistent with the direction provided by PWSRCAC in B above, for purposes of this report it has been assumed that active escorting, involving tethered escort of tankers, and exerting indirect towing forces to correct tanker course or speed are NOT part of the mandate of this Sentinel Tug.

In addition, it should also be noted that the requirement above identifies the "design tanker" for analysis of tug capabilities as 125,000 tonnes DWT, whereas the analysis of the escort tug capabilities in the parallel study of B.A.T. in Tanker Escort Tugs [3] used both a 125,000 tonne DWT and a 193,000 tonne DWT tanker as the basis of design. Accordingly the work supporting this report has used both sizes, and draws conclusions regarding the tug capabilities for both options.

4.0 REGULATORY REQUIREMENTS

There are no specific regulatory requirements for this type of rescue tug. The performance and operational requirements for tanker escort tugs within the Alaskan system are governed by 33 CFR Part 168:

(http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&tpl=/ecfrbrowse/Title33/33cfr168_main_02.tpl)

which are summarized as follows:

"(*a*) *…at all times during the escort transit each tanker to which this part applies:*

(1) Must be accompanied by escort vessels that meet the performance requirements of paragraph (b) of this section (but not less than the number of escorts required by §168.40).

(2) Must have the escort vessels positioned relative to the tanker such that timely response to a propulsion or steering failure can be effected.

(3) Must not exceed a speed beyond which the escort vessels can reasonably be expected to safely bring the tanker under control within the navigational limits of the waterway, taking into consideration ambient sea and weather conditions, surrounding vessel traffic, hazards, and other factors that may reduce the available sea room.

(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° 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 (advance and transfer) that it could turn itself with a hard-over rudder*."

These requirements however strictly apply only to the tugs designated as "Escort" tugs, and as discussed above, that capability is not being considered in this report. Also, as discussed at length in the Escort Tug B.A.T. report [3], tugs to be so designated must have very specific performance attributes as designated by most major Classification Societies.

Of the above criteria however it could be argued that at least the requirement b (1) "*to hold a tanker in position against a 45 knot headwind*" can legitimately apply to a rescue towing application.

Clearly the overall fundamental objective should be to prevent a disabled tanker from grounding in the worst foreseeable conditions, so at the very least a rescue tug should have the ability to turn a disabled tanker into the wind and seas, and hold it there until conditions abate and the tow can make headway. This implies also that the tug is within response range in order to take the tanker under tow in a timely manner.

Finally, the option of providing the capability in a single or multiple tugs per (b) above represents a tactical choice on the part of operators. The analysis in this report assumes that a single tug must be capable of satisfying a very high percentage of incidents, as discussed later, and only in the most severe conditions would two or more tugs be required.

5.0 DESIGN CONDITIONS

5.1 Tanker Size

The tanker size used as the basis of the primary study [3] for this project was 193,000 tonnes DWT. This contrasts with the 125,000 T DWT tanker referred to in 2B above. Accordingly the analysis herein addresses both vessel sizes.

5.2 Environmental Conditions

The following sea-state and wind conditions were obtained for the Gulf of Alaska from NOAA published data for the buoy at Station 46061 (LLNR 1131), Seal Rocks between Montague and Hinchinbrook Islands, AK [4]. Figure 5.1 identifies the percentage of occurrence for the wind conditions, and Figure 5.2 identifies the percentage of occurrence for the sea states.

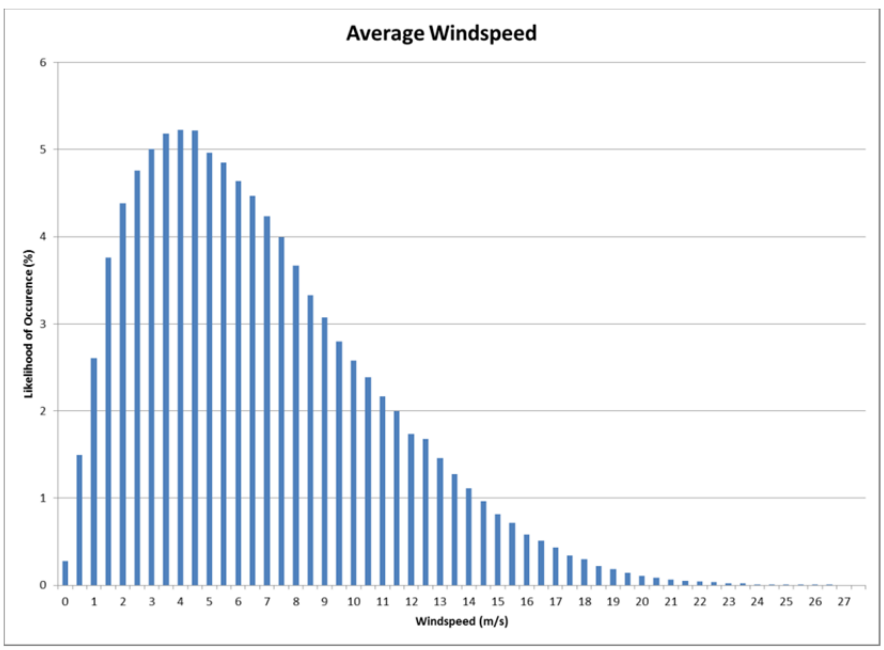

Figure 5.1 Percentage of Occurrence of Wind Conditions

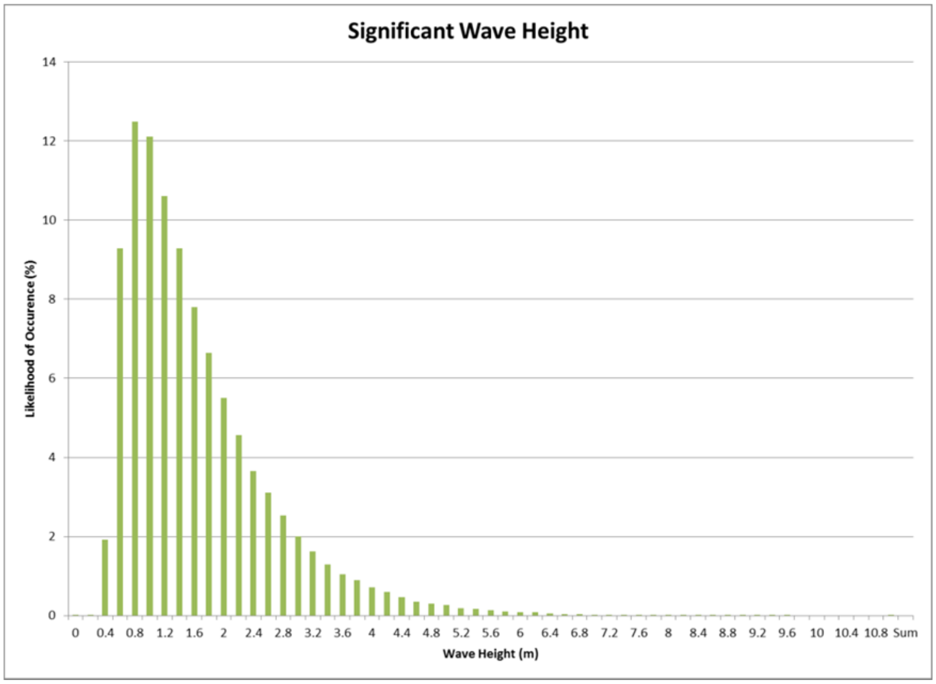

Figure 5.2 Percentage of Occurrence for Sea States

Table 5.1 identifies the percentiles of occurrence for various wind and wave conditions.

% Occurence	Windspeed (m/s)	Windspeed (kts)	Wave Height (m)
99%	18.04	35.08	4.98
98%	16.61	32.29	4.34
97%	15.66	30.44	3.98
96%	14.94	29.04	3.72
95%	14.35	27.90	3.51
90%	12.36	24.02	2.85

Table 5.1 Percentage Occurrences for Met-Ocean Data – Gulf of Alaska (Station 46061 - Seal Rocks)

From this data it can be seen that the 45 knot (23.15 m/second) wind speed criteria established in 33CFR 168 is well above the 99th percentile of occurrences. What is not stated in the CFR is the sea-state to be considered in association with that wind force, but if one assumes the 99th percentile then a wave height of about 5 metres is not unreasonable, and is also reasonably consistent with the 15 foot wave height cited in the VERP as the design closure condition for operations.

It is important to note that there is reason to believe that the wave buoy data referenced in [4] above is likely to under-report the actual sustained wind speeds. Ref. [5] suggests that due to the buoy-based anemometer being alternately at the crest and the trough of a wave, that the difference between sustained wind speeds and gusts is in the range from 9 to 16 knots, and that the gust values are more accurate due to the trough shielding phenomenon. Therefore in the final analysis it is justifiable to add say an average 12 knot wind speed margin to the applied environmental criterion. This has therefore been done in this evaluation. Thus the 45 knot condition cited in 33CFR 168 should actually be treated as a **57 knot** wind speed. This certainly puts the wind speed criterion well above the 99th percentile condition. It is also noted that the Seal Rock buoy location is slightly sheltered from open ocean conditions, so somewhat more extreme wave conditions are likely to exist in the open gulf.

6.0 PERFORMANCE REQUIREMENTS

As described in the Terms of Reference, the Sentinel Tug performance is to be expressed in terms of clear criteria for each of the following parameters:

- Bollard Pull
- Rescue Towing Capability
- Indirect Towing Capability
- Speed
- Range and Endurance
- Towing Gear required
- Stability
- Seakeeping
- Manoeuvrability
- Position-Keeping

The requirements for each of these criteria have been assessed and are discussed in the following sub-sections. In addition recommendations for typical vessel particulars and ancillary functions commensurate with the defined performance requirements are presented.

6.1 Rescue Towing Capability

6.1.1 Calm Water Towing

The steady state force required to tow a ballasted 193,000 tonnes DWT tanker at 4 knots in calm conditions, per CFR 33 168 b (1), is calculated to be approximately only 10 tonnes. This is much below that which can be produced by the expected total power in the tug (app. 9,000 to 10,000 bhp), hence is not a limiting factor. It does however have a bearing on the results of the analysis of requirements for holding in a seaway, as discussed in the following section.

6.1.2 Static Holding in a Seaway

Recent studies indicate that simply calculating head-on forces will be insufficient to accurately predict the actual tug thrust necessary to control a tanker in wind and waves. A disabled tanker will typically assume a position broadside to the wind and waves, where the forces are orders of magnitude greater than those directly on the head of the ship. The tug must therefore also be able to overcome these considerable side forces and bring the ship's head to wind, which involves executing a turning manoeuvre of the ship, experiencing substantial lateral ("Y") forces in the process. Based on a detailed evaluation of this phenomenon performed at Robert Allan Ltd in recent similar studies, it is recommended that an additional 20 – 25% should be added to the calculated dead ahead forces to account for the added influence of the lateral components of the wind and wave forces.

As discussed in [3], allowances must also be made in such calculations for the loss of effectiveness of any tug when operating in a seaway. GL-Noble Denton [6] suggests an efficiency of 75% in 5 m H_s, based on conventional propulsion. A "tractor" style tug (either VSP or Z-drives) with more deeply submerged propellers would fare better, so say 80% efficiency.

Considering all the above, the forces required to hold station in a 57 knot head wind and the associated typical 15 foot H_s head sea are as shown in Table 6.1 (from Table 6.1 from [3]) below, for the sizes of tanker involved. However this equates to the absolute bare minimum thrust requirement. Anything less would potentially represent a ship aground; anything more is only a positive benefit ensuring that the tug can out-perform the weather. Accordingly it is strongly recommended that the tug should have the ability to make reasonable headway (say 3–4 knots) against these limiting weather conditions. This represents, per 6.1.1, an additional 10 tonnes of Bollard Pull.

This evaluation is based on the premise that a single tug should be able to handle the 99th percentile conditions. It is therefore also assumed that on those rare occasions when a response is required in more severe conditions, then multiple tugs from within the SERVS system would respond, with more than enough total towing capacity

Table 6.1 Required Forces to Hold Tankers in a Seaway

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 57 knot winds and 15 ft (4.5 metre) significant wave height	65.6	75.6	74.6	96.5	67.9	80.8	74.0	95.0	**84.8**	**101.0**	**92.5**	**118.8**	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%

As the windage is approximately 80% larger in the ballasted condition than in the loaded condition, the ballasted condition is clearly the limiting condition.

Therefore the Sentinel Tug should have the ability to develop a total calm water BP as follows:

(a) Conventional or ASD Configuration:

- 125,000 T DWT Tanker - BP = 101 tonnes
- 193,000 T DWT Tanker - BP = 119 tonnes

(b) Tractor (VSP or Z-Tractor) Configuration:

- 125,000 T DWT Tanker - BP = 95 tonnes
- 193,000 T DWT Tanker - BP = 112 tonnes

> **Conclusion 1:** The Sentinel Tug, if fitted with conventional twin-screw or ASD propulsion, must have a nominal static Bollard Pull (BP) of not less than 119 tonnes in order to satisfy the Rescue Towing criteria for a 193,000 T DWT tanker, or 101 tonnes BP for a 125,000 tonne DWT tanker. If the tug is of a proper tractor configuration (with drives forward) the BP requirements would reduce to 112 and 95 tonnes respectively.

6.2 Indirect Escort Towing

The Mission Statement proposed for the Sentinel Tug (Section 2.0) has no requirement for indirect escort towing. Accordingly, for purposes of this study, it is assumed that the Sentinel Tug will NOT perform any indirect escort towing.

> **Conclusion 2:** For purposes of this study it is assumed that the Sentinel Tug will NOT perform any indirect escort towing.

6.3 Speed

The speed of this vessel should be dictated by the desired response time to any incident in the area of responsibility. That response time has not been defined in the mission statement, however the VERP states the following:

> *"Two close escorts are required through Hinchinbrook Entrance. After a tanker leaves Prince William Sound, a rescue tug must stay on station near Hinchinbrook Entrance until the tanker is at least 17 miles out to sea."*

That implies about a one hour period of loitering by the rescue tug.

The total area of response is bounded by the 200 nautical mile limit of jurisdiction. Obviously response time is critical in such cases, but it is also less critical the further offshore the incident occurs. Assuming a 200 mile response it would be desirable to reach the ship within a maximum of 24 hours, hence a speed of 200/24 = 8.3 knots. The top speed of the type of tug anticipated will undoubtedly be closer to twice that figure, which would be achieved in ideal, calm conditions. In the predicted 15 feet sea-states or even in higher wave conditions further offshore, although tug motions will be uncomfortable (e.g. Figure 6.1), a net transit speed of about 8 knots is probably realistic. Per [6], the predicted loss of speed in these sea conditions will be about 40%, hence the free-running, calm water speed should be approximately 16 knots. This objective will, to a large degree, dictate the required length of tug.

Figure 6.1 Heavy Weather Conditions in the Gulf of Alaska.

In the final analysis, it should be verified that the 17 mile tanker "offset" is in fact sufficient given the design environmental conditions. That distance represents roughly a 2 hour transit by the tug, during which time the tanker could be approaching the shore at a drift rate of about 2-3 knots. In such a circumstance the tug would have only about 3-4 hours of window remaining in which to make a connection to a tanker and take full control of its drift, which represents very little margin for error. While empirical estimates of tanker drift can be made, which would generally assume a worst case co-linear confluence of wind, waves and currents in the worst possible orientation, it is much more defensible to analyze the drift on a time domain basis, at the very least reflecting the tidal cycles. Therefore if it has not already been performed, a formal drift study should be conducted, accounting for the predicted drift of a disabled tanker under influence of the agreed wind, waves and current conditions within the response area.

Conclusion 3: The free running speed of the Sentinel Tug, in calm water at full load displacement, should be about 16 knots.

Conclusion 4: It is recommended that a formal drift study be conducted, accounting for the precise influence of wind, waves and currents on a disabled tanker on a time domain basis to verify that 17 miles is the correct offshore tanker transit distance during which the Sentinel Tug should standby.

6.4 Range and Endurance

The range of the Sentinel Tug should be sufficient to enable a tow of a disabled tanker to a port where repairs can be properly affected. In this case that would mean a tow from the area of recovery to a major drydock in the vicinity of Victoria, BC or Seattle, a distance of at least 1,500 n. miles. To this should be added the range involved in the process of initiating the tow, which could involve more than 200 n. miles plus the time involved making towing connections, etc., say the equivalent of travelling 250–300 n. miles. Thus the range for this tug should be at least 2,000 n. miles at essentially full power.

The endurance is defined by two requirements; the time involved in executing the tow described above, at an assumed average tow speed of say 6 knots, or the time required to execute a rescue tow, returning the tanker to Valdez for at least assessment or minor repairs rather than heading directly to the south.

The time involved would be:

- Tow to the South = 2,000 miles at 6 knots = 333 hours
- Rescue tow, returning to Valdez = say 500 miles at 6 knots plus an allowance of 24 hours for mobilization and making connections, so a total of approximately 110 hours of operation

Conclusion 5: The operating range for the tug should be not less than 2,000 n. miles at full power, and the endurance at full power, at an assumed towing speed of 6 knots, should be not less than 333 hours (say 15 days).

6.5 Seakeeping

Seakeeping is difficult to define quantitatively. Typically it is expressed in terms of limiting motions aboard the vessel such that crew members can conduct their tasks in safety, recognizing that a rescue tow in the Gulf of Alaska is unlikely to be a pleasant operation and is most likely to challenge the extreme capabilities of the crew if not the tug itself. It is important to note that human endurance is the limiting factor in seakeeping standards, and not the structural or mechanical integrity of the tug itself.

Seakeeping is also very much a function of vessel size, where the larger and heavier the vessel involved, the less are its motions. Table 6.2 below presents motions criteria which have typically been used in various similar analyses as limiting conditions for crew comfort and safety. These are typical for workboats such as fishing vessels and tugs, and represent reasonable human endurance limits but NOT the limiting conditions for vessel operations. Above these limits crew will need to use handrails, etc. to steady themselves during routine activities. Ultimately crew should be able to stay on their feet as long as accelerations are less than 1G, although 0.5 G is typically recognized as a practical upper limit objective.

Table 6.2 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}

It would be impossible to stipulate that a Sentinel tug MUST achieve these target performance criteria in all operating conditions, but rather it is reasonable to state that a tug should be designed to achieve them in (say) at least the 90th percentile of conditions in which rescue tows might be expected to be performed. This would represent a 2.85 m H_s, per Table 5.1. As the seakeeping analysis conducted as part of the main study [1] found that all the tugs studied would satisfy these criteria in Sea State 6 (i.e. winds of 22–27 knots and seas up to 3 m) and lower, one can conclude that a tug in the region of 45–50 metres in length will satisfy this criteria.

Conclusion 6: For crew safety and comfort, the motions-related accelerations aboard the Sentinel Tug should not exceed 0.07G (lateral) and 0.15G (vertical) in the 90th percentile of wind and sea conditions encountered in the Gulf of Alaska (Sea State 6 or lower). While these values may seem modest, they represent accepted values for sustained human endurance at sea in a working environment, and in no way represent a structural or mechanical limit for the tug itself.

6.6 Stability

The towing stability criteria for such a vessel are mandated by the US Coast Guard for inspected towing vessels, under 46 CFR 173.095 defining a minimum GM (based on an empirically derived lateral thrust) or a minimum area under the GZ curve when a heeling arm is applied, the latter also derived empirically according to estimated lateral thrust As these criteria are amongst the most stringent of this type worldwide, this is a very conservative choice of criteria, as well as a regulatory requirement. There should also be sufficient margin specified in meeting these criteria that the tug will continue to do so throughout its operating life.

The stability criteria for escort towing vessels may be more severe, but those are also predicated on there being a rendering mechanism on the winch which would release tension at a prescribed value. That type of rendering capability is rarely if ever used on a towing winch, where the catenary of a long steel towline typically provides the damping required between tug and tow. However there may be a good argument for having an automatic rendering type winch for this application, particularly when the towline is short at the early stages of a connecting situation

Conclusion 7: The Sentinel Tug should fully satisfy the requirements of the US Coast Guard Towing Stability Criteria (46 CFR 173.095). There should be sufficient margin specified in meeting these criteria that the tug will continue to do so throughout its operating life.

Conclusion 7b: The use of a towing winch with an automatic rendering capability at a prescribed tension is worth considering for such an application.

6.7 Manoeuvrability

The most critical aspect of tug manoeuvrability for a rescue towing situation is to be able to manoeuvre close to the disabled ship and to pick up the emergency towing gear which would be deployed from the ship, with lowest possible chance of colliding with the ship. The more manoeuvrable (and controllable) the tug, the faster and safer this connecting procedure will be. Obviously working in close proximity to a ship in high seas is a very dangerous and risky task, and the tug must not risk contact with the ship or getting fouled in the towing gear. While conventional twin-screw tugs have performed this type of rescue/salvage work for many years, the operational advantages of having omni-directional propulsion such as Voith Propellers or Z-drives are so significant that they cannot be ignored and should be an essential feature of a dedicated rescue tug today; essentially the Best Available Technology for this task. Expressed quantitatively, B.A.T. for this type of vessel, with omnidirectional propulsion, would be to execute a zero speed, 360° turn within no more than 110% of its own length, at a rate which would complete the turn in 30-40 seconds. That high standard is probably not essential for a rescue tug but a similar, slightly lesser standard should be readily achievable; say 60 seconds for a 360° rotation.

> **Conclusion 8:** To satisfy B.A.T., a Sentinel Tug should have omni-directional propulsion and be able to execute a zero speed, 360° turn within no more than 110% of its own length, and within no more than 60 seconds.

6.8 Position-Keeping

Somewhat akin to the issues of manoeuvrability, a rescue tug must be able to hold position during critical activities, especially when attempting to connect to a stricken ship. This may involve holding the tug in an attitude to wind and waves which is not necessarily the most favourable. Therefore the tug must have some combination of directional thrusters which can at least maintain a fixed attitude against wind and wave forces. It is not essential to hold a precise x-y station (as would be required for example by a vessel with dynamic positioning), but rather to maintain orientation. The same conditions as defined for rescue towing (Section 6.1) would apply, so the position-keeping criteria would be to hold position at say 45° against the combined forces of 57 knots of wind and 15 foot H_s waves.

> **Conclusion 9:** The Sentinel Tug must have a combination of main propulsion and lateral thrusters which can hold it at a 45° attitude to a 57 knot wind and the effects of 15 foot significant seas.

6.9 Propulsion

Given the various performance criteria described above, the following types of tugs, as defined by their propulsion systems, could be considered as candidates for the Sentinel Tug role:

6.9.1 Voith Water Tractor

The Voith propulsion system of cycloidal propellers offers exceptional control, position-keeping and manoeuvrability. The drives are located deep in the water and are thus less susceptible to thrust loss in waves, and can be configured to provide roll-reduction in heavy seas. The response time of VSP units to commands is better than any alternative. VSP propulsion is however larger, heavier, and considerably more expensive than the Z-drive alternatives. Training to use VSP drive tugs is always considered very easy and straightforward. This system does however require about 20% more input power to achieve the same Bollard Pull as does a screw propeller or Z-drive. The difference in power input required at higher speeds however is not as great. VSP is currently limited to a maximum of approximately 50 tonnes thrust per unit, so in the conventional Water Tractor configuration one is limited to a maximum of 100 tonnes BP, which is sufficient for this role.

Some form of lateral thruster would likely be required in addition to the VSP units to achieve the position-keeping objectives.

6.9.2 ASD Tug

Azimuthing Stern Drive (ASD) tugs dominate the ship-berthing tug sector worldwide by a wide margin in comparison to VSP drive tugs. There is no reason at all not to consider this drive system for a larger ocean rescue tug application, as the enhanced manoeuvrability and control will be major assets.

The major benefits of Z-drive propulsion are relatively high thrust efficiency, excellent manoeuvrability, and excellent control. Training is straightforward but does require an aptitude for understanding vectors! The drives can be fairly easily replaced if damaged.

In combination with a tunnel type bow thruster, an ASD configuration would provide all the required manoeuvrability and position-keeping necessary for this application.

6.9.3 Tractor Tug

A Z-Tractor tug is essentially the same configuration of tug as a Voith Water Tractor, but using 2 Z-drive units instead of Voith cycloidal propellers. The advantages are much lower cost and higher thrust efficiency, at the expense of slightly less response time. One major advantage is the use of a tractor configuration (drives forward) for towing, with the drive units well forward of the towing point for much enhanced safety on the towing vessel, with any risk of girting virtually eliminated. Another benefit (common to the Voith tractor) is that the operating efficiency in a seaway is quite high with the drives deeply immersed and not so close to the ends of the tug.

6.9.4 Rotor Tug

A Rotor Tug is a relatively new configuration of tug, with two Z-drives forward in a "tractor" configuration, and a single drive aft where normally a fixed skeg would be (as in a Voith Tractor). The Rotor Tug offers all the advantages of a Z-Tractor, especially towing safety, with the added advantage of the extra directional control of a third larger steerable thruster aft. Operational efficiency is, as per a Z-tractor, very good with the drives located deep in the water.

The Rotor tug is the only configuration which would not have to add an additional lateral thruster device in order to satisfy the position keeping requirement. The additional redundancy of a third drive is also a benefit in an emergency response vessel of this type.

6.9.5 Conventional Twin-Screw

Although omni-directional propulsion has many attributes for this Sentinel Tug application, this does not necessarily preclude the use of a well-designed conventional twin (or even triple) screw tug, with the addition of a powerful bow thruster(s). The advantages of a conventional configuration are as follows:

- Lowest cost alternative
- Probably the most efficient of all options in terms of thrust to power ratio
- Lowest maintenance costs
- Simple and reliable system

> **<u>Conclusion 10</u>:** Any type of propulsion system which, in combination with lateral thrusters would satisfy the requirements for manoeuvrability and position-keeping described above would be suitable for the Sentinel Tug. B.A.T. would constitute those omni-directional drive systems which incorporate some form of "tractor" configuration (namely VSP, Z-Tractor, or Rotor Tug) which are recommended due to better manoeuvrability, safer towing characteristics and less loss of effectiveness in heavy seas.

6.10 Towing Gear Required

There are no prescriptive regulatory requirements in the US for towing gear on inspected towing vessels. Equipment is typically selected by the Owner according to their various needs and operating experience. Appropriate references for the equipment necessary for such duties are found in the US Navy Towing Manual [7], and in various other guides to towing operations. Amongst the latter is IMO MSC Circ. 884 "Guidelines for Safe Ocean Towing" (Dec.'98) [8].

The latter are invariably based on the author's individual experience in the towing or salvage industries. Using the USN Towing Manual as perhaps the most comprehensive publication on the subject, the following can be considered as a basic list of requirements for emergency/rescue towing:

- Towing winch
- Towing bitt
- Stern towline roller and tow pins
- Main towline/hawser
    - SWR
    - synthetic
- Synthetic spring line element
- Lead chain or wire pendant
- Chain bridle/chafing gear
- Connecting "jewelry"
- Spare components:
    - secondary towline

At least as critical as the list of gear is the relative strength of all the components and their relationship to the anticipated applied forces. The maximum static applied force, resulting from the largest anticipated tanker adrift in the 99th percentile conditions, as shown in Table 6.1, is 119 tonnes (for a 193,000 tonne DWT tanker). To this must be added a dynamic factor to account for the surge loads induced by the relative motions of the tug and tow. The US Navy Towing Manual [5] recommends a dynamic factor of 5 if towing on the winch brake without a spring element in the towline, or 4 if a spring element is fitted. The IMO Guideline [8] provides the following formulae for determining the "Mean Breaking Load (MBL) of the main towline:

Bollard pull (BP) (tonnes)	< 40	40–90	> 90
MBL (tonnes)	3.0 x BP	(3.8–BP/50) BP	**2.0 x BP**

and, per Clause 12:14 of [8]:

"*All connecting items like shackles, rings, etc., should have an ultimate load bearing capacity of minimum 50% in excess of the documented minimum breaking load (MBL) of the towing arrangement to be used*."

Clearly there is a significant difference between the strength requirements of the IMO guidelines and that of the US Navy. Industry experience suggests that the criteria of the US Navy are extremely conservative, and at the power levels under consideration would result in extremely heavy gear. At the same time our industry experience suggests that the IMO guidelines appear rather light, based as they are on more routine towing rather than "rescue" towing which is more likely to have to contend with heavy weather. A detailed study of the Canadian towing industry, undertaken for Transport Canada in 1992 [9] indicates an industry standard for tugs with more than 34 tonnes BP as follows:

Towline Breaking Strength (BS = MBL) (in pounds) = 300,000 + 0.75 x (BP - 75,000)

Thus for a 119 tonne BP tug, the towline BS = 440,546 lbs. = 200 tonnes (BS = 1.68 x BP), which is a surprisingly low number. The BS/BP ratio amongst the six highest powered tugs in the sample used for that study ranged from 1.86 to over 5, with an average of 2.96, but none of the sample exceeded 60 tonnes BP.

It should be noted that the Transport Canada study dealt only with coastal barge towing vessels primarily of much more modest power than contemplated for the Sentinel tug, therefore this BS/BP ratio should not be considered as a direct reference, but it does highlight that standards for conventional coastal towing are considerably less than for tugs dedicated to emergency towing duties.

Therefore for purposes of this analysis a minimum ratio of **3:1** for Towline Breaking Strength/Bollard Pull is recommended. This also represents the standard currently used at Robert Allan Ltd. for conventional towing system design.

The minimum breaking strength of the weakest link in the towing system for a Sentinel tug must therefore be at least as follows; values which can be considered as the "Design Load" for the towing system:

BP = 119 tonnes: Design Load = 357 tonnes
BP = 101 tonnes: Design Load = 303 tonnes

It remains then to relate the relative strength of all the towing system components to this basic criterion, and identify what the "weak link" in the system is intended to be. Clearly one should not design a towing system for the failure of the main towline, nor should there be any structural failures on the tug or attended ship. The logical weak link is a device which is controllable, does not lose control of the tow, and from which line recovery can be made relatively easily in event of a release. The obvious point for the weak link is thus the winch brake. It can be set relatively easily to release at an excess load, but the line is not fully aborted, and can be rewound in the event of a release. So if the brake set point is the Design Load (of 303 or 357 tonnes) as defined above, then all other components must have an ultimate strength rated above that value by some reasonable margin, say at least 10-15%. Table 6.3 below summarizes the towing system components and the recommended minimum ultimate strength ratings, as well as the number or type of each.

Table 6.3 Rated Strength of Towing System Components

Component	*Rating Factor*	*Rated Breaking Strain of component (tonnes)*			
		Stern Props		*Tractor*	
Tug Bollard Pull		**101**	**119**	**95**	**112**
Design Load	3.00	**303**	**357**	**285**	**336**
Winch Brake	3.00	303	357	285	336
Towline	3.15	318	375	299	353
Towing Bitt	3.00	303	357	285	336
Stern tow pins	3.00	303	357	285	336
Norman Pins	2.00	202	238	190	224
Surge Gear / Spring	3.25	328	387	309	364
Lead Wire Pendant	3.25	328	387	309	364
Chafing gear	3.25	328	387	309	364
Connecting Hardware	3.25	328	387	309	364

Conclusion 11: The main towing gear for the Sentinel Tug should have components rated according to the recommendations above, in particular with regard to having a Design Load of at least 3 x Bollard Pull.

6.11 Particulars

Given the above basic performance requirements it remains to determine into what size of box to put them all! The following are the most critical parameters:

- Speed of 16 knots:

  Typically the maximum speed of a full displacement hull form such as a tug is about 1.33 x the square root of the length (in feet), so to achieve an assured 16 knots the tug must be at least 145 feet on the waterline. As waterline length (Lwl) is typically about 95-96% of Loa, this leads to a tug of about 151 feet LOA. Other factors such as load displacement and seakeeping will also influence length, so the above should be considered as minimums.

- Bollard Pull and Power:

  To achieve the required BP values, reflecting the extra thrust required to cope with sea-state induced performance losses, and assuming Z-drive propulsion, will require installed power as indicated below, according to the size of tanker evaluated:

  - 125,000 tonne DWT tanker - 101 tonnes BP tug at 5,933 kW (7,954 bhp)
  - 193,000 tonne DWT tanker - 119 tonnes BP tug at 6,991 kW (9,371 bhp)

- Beam:

  Beam is governed by requirements of both displacement and stability, and also influences speed. Typical proportions for a vessel of this type suggest an L/B ratio of about 3:1, or perhaps slightly higher, thus the beam is expected to be in the order of 45 to 50 feet. This may be influenced by the presence of sponsons or similar to improve the seakeeping capability of the tug. Much further analysis than that required by the terms of this report is necessary to be more specific on this parameter.

- Depth:

  Depth is governed by the requirements of the International Loadline assignment, for hull volume, working space, stability and freeboard to the working decks. It is expected to be in the order of 22–25 feet.

- Draft:

  Draft will be primarily a function of the vessel displacement and the type and configuration of the selected drive units. In the absence of any draft constraints associated with the operating area, the deeper the draft the better, as this will reduce the potential for propeller emersion in waves. Tugs with Voith Propulsion are typically at least about 2 feet deeper than a tug with an ASD configuration. The overall draft is expected to be 20–25 feet.

- Capacities:

  Fuel and oil tank capacities are primarily driven by the range and endurance requirements defined in Section 6.4, and of course are dependent on power. Potable water and stores are dependent on crew size and the endurance only. Ballast is required to compensate for the fuel, oil and water consumed in order to maintain suitable draft for towing and to ensure correct stability. For the sentinel tug preliminary projections of tankage requirements are as per Table 6.4 below:

Table 6.4 Preliminary Tank Capacities for a Sentinel Tug

		101 t BP	119 tBP	
Item	***Criteria***	***Capacity***		***Units***
Power		7954	9371	bhp
Fuel Oil	2000 n. mile range @ 6 knots with 15% reserve	421	496	tonnes
Potable Water	15 days endurance at 25 gallons per person per day	5500	5500	gallons
Lube Oil	One full oil change per each engine	app. 1500	2000	gallons
Hydraulic Oil	per steering or winch requirements	app. 500	500	gallons
Water Ballast	to compensate for at least 80 % of fuel	337	397	tonnes
Sewage	to match endurance, assuming10 gallons per person per day	2250	2250	gallons
Grey water	included in the sewage volume	0	0	

Conclusion 12: A tug which can satisfy all the defined operational criteria above will have approximately the following principal particulars:

- Bollard Pull = 119 tonnes for 193,000 tonnes DWT, or 101 tonnes for 125,000 tonnes DWT
- Power = 9,371 BHP (for 119 T BP) or 7,954 BHP (for 101 T BP)
- Length overall = 50–52 metres
- Beam = 15–16 metres
- Draft = > 6.5 metres
- Deadweight = app. 500 tonnes min.

7.0 ANCILLARY EQUIPMENT REQUIREMENTS

Assuming, as stated before, that this vessel is NOT required to perform any escort towing duties, then the following major components are suggested as apropos to the Sentinel Tug role:

- Fire-fighting - at least the equivalent of an ABS Fi-Fi 1 notation, and preferably the greater Fi-Fi 2 rating. Note*:* a Fi-Fi 1 pump capacity of 2,400 m^3/hour corresponds to the ABS Fi-Fi 1 rating; this is rather small when considered in the context of a major tanker fire, and considering the size of the tug in question and the length of stream flow from its monitors. The greater Fi-Fi 2 notation, with a total of 7,200 m^3/hour and a throw of 180 metres is recommended as B.A.T. for a tug of this size and duty
- Pollution response - it was not possible to identify any regulatory requirements for oil spill response equipment to be carried aboard any tugs operating within the SERVS system. However the following, as carried aboard the ETT tugs, is considered appropriate:
  - 3,300 feet of oil containment boom (suitable for open water use)
  - 2 deployable oil skimmers
  - 70,000 gallons of recovered oil storage capacity
  - dispersant spray arm systems

Conclusion 13: The Sentinel Tug should be fully equipped with a significant fire-fighting capability (Fi-Fi 2 Rating for B.A.T.) and for an active pollution response role.

8.0 B.A.T. FOR A SENTINEL TUG

Based on the foregoing, the B.A.T. in a Sentinel Tug for Hinchinbrook Entrance can be summarized as follows:

a) Bollard pull - > 119 tonnes for a 193,000 tonne DWT tanker, **or**
> 101 tonnes for a 125,000 tonne DWT tanker

b) Free-running speed - > 16 knots

c) Manoeuvrability - able to execute a zero speed 360° turn within 1.1 ship-lengths in 60 seconds or less

d) Position keeping - able to hold orientation at 45° to a 55 knot wind and 15 foot significant seas (note: NOT to hold an exact x-y station)

e) Sea-keeping - for human endurance and safety, motions-related accelerations should not exceed 0.07G (lateral) and 0.15G (vertical) in the 90th percentile of wind and sea conditions encountered in the Gulf of Alaska (Sea State 6 or lower)

f) Propulsion System - B.A.T. would be a Z-Tractor or Rotor Tug configuration for maximum towing effectiveness and towing safety

g) Towing system
- a double drum towing winch, each side equipped with 3,000 feet of SWR with a breaking strain > 3.15 BP
- brake rating at least 3 x BP: B.A.T. would be to have a dynamic brake with a tension load setting and an automatic rendering capability to ensure that the towline is not over-stressed
- additional towing system components:
  - synthetic stretcher
  - wire pendant
  - chafing gear
  - an array of connecting hardware: shackles, links, etc.
- onboard towing system gear, including:
  - H-Bitt (unless incorporated directly into winch)
  - towline roller in bulwarks
  - towing pins and hold-down block
  - Norman pins

h) Ancillary features
- tug equipped for additional rescue/safety/emergency roles:
  - fire-fighting, at least ABS Fi-Fi 2 rating recommended
  - pollution response gear- equivalent to that carried aboard the ETT tugs

i) Range - min. 2,000 n. miles at full power
j) Endurance - min. 15 days of continuous operation

9.0 GAP ANALYSIS OF SERVS TUGS AS SENTINEL TUGS

Table 9.1 following summarizes the above-stated elements of B.A.T. in a Sentinel Tug for Hinchinbrook Entrance, and compares those to the ETT , PRT, and Theriot Class tugs currently within the SERVS system.

The ETT tugs have insufficient Bollard Pull to handle even the 125,000 tonne DWT Class of tankers in a rescue role. Their speed is also somewhat slower than desirable for key response. Their towing gear is also dedicated to escort towing and is not suitable for the serious rescue towing envisaged.

> **Conclusion 14:** The ETT tugs as presently configured lack the power, speed and towing gear to perform the Sentinel Rug role effectively.

The PRT tugs satisfy the majority of criteria for the Sentinel Tug role. Their towline, which at 2.5" diameter has a breaking strength of 302 S. Tons (604,000 lbs.) (assuming IPWC wire) is somewhat smaller than recommended. The BS/BP = 3.0 criteria suggests a towline diameter of 3" for the power of these tugs.

The other shortcoming of the PRT class tugs is the lack of a bow thruster which would aid in holding the tugs head up to weather during an incident. This would be especially useful in close quarters manoeuvres when connecting to a disabled tanker.

The fact that the PRT class are ASD tugs as opposed to being a tractor configuration is not over-ly prejudicial to their ability to perform rescue tows; it is just not as effective as the tractor type, and is more prone to propeller emergence in a seaway.

> **Conclusion 15:** The PRT class tugs are sufficiently large and powerful for the Sentinel Tug role; however their main towlines are not quite as strong as recommended.

The Theriot Class tug *Sea Voyager* is defined in the PWS Tanker Escort System as a "Hinchinbrook Tug alternate". This class of tug is a large and moderately powerful ocean-going tug, with twin-screw, fixed pitch propellers in fixed nozzles. There is no bow thruster fitted. Twin-screw vessels of this type have been used for many years as ocean towing tugs, but cannot be considered as B.A.T. for a rescue towing role today, largely due to their inherent lack of close-quarters manoeuvrability and position-keeping capability. With fixed pitch propellers, holding station in this tug would also require frequent use of the clutch, leading to the potential premature failure of this critical component.

This tug has sufficient power to handle a 125,000 tonne tanker but falls short of the power recommended for the larger 193000 T Dwt tanker. The towing gear on this tug falls short of the Design Load criteria used.

Conclusion 16: The Theriot Class tug has sufficient power to handle a 125,000 tonne tanker but falls short of the power recommended for a 193,000 T DWT tanker. The towing gear falls short of the Design Load criteria used.

Table 9.1 Comparison of B.A.T. for a Hinchinbrook Sentinel Tug to the Characteristics of the ETT, PRT, and Theriot Class SERVS Tugs

Item No.	*Criteria*	*Performance*	*units*	BAT	ETT Class	PRT Class	Theriot Class
1a	Bollard Pull (125,000 Dwt Tankers)		*tonnes*	101	84	123	109
1b	Bollard Pull (193,000 Dwt Tankers)		*tonnes*	119	84	123	109
2	Speed	> 16 knots	*knots*	16	14.5	16	est. 15; no CPP
3	Manoeuvrability	Execute a zero speed 360 degree turn within 1.1 ship-lengths in less than 30 seconds	*ship-lengths*	1.1	<1.1	estimated at > 1.1 (no bow thruster)	twin-screw, no bow thruster
			degrees/ second	12	assumed 12 or better	estimated at > 12 deg/sec: no thruster	unable to do this without a bow thruster
4	Position-Keeping	Hold position at 45 degrees to a 45 knot wind and 15 foot significant seas		hold position	guesstimated as not able to hold: no bow thruster	guesstimated as not able to hold: no bow thruster	unable to do this without a bow thruster
5	Seakeeping	Accelerations should not exceed 0.07G (lateral)and 0.15G (vertical) in Sea State 6 or lower		0.07G lateral 0.15G vertical	verified as meeting the criteria	verified as meeting the criteria	not analyzed: due to size of tug estimated as very similar to PRT
6	Propulsion	configuration for maximum towing effectiveness and towing safety		VSP tractor, Z-Tractor or Rotor Tug	VSP Tractor	ASD	twin-screw
		Most efficient in terms of kG thrust per kW		ASD, Z-Tractor or Rotor Tug	VSP Tractor	ASD	Twin-screw; nozzles
7	Towing System:						
7.1	winch			double drum	double drum-escort	double drum	double drum
7.2	towline		*type*	SWR	HMPE	SWR	SWR
			feet	3000	1000	2500	3000 / 3600
		(for 101 / 119 T BP)	*inch dia.*		3.50	2.5	2.25
7.3	stretcher/surge gear	synthetic: nylon or polyester		200' nylon	250' nylon	nylon: 200' x 15"circ.	no info
						chain: 45' x 2"	
7.4	pennant	steel wire		200'	100' x 10" circ Spectra	200' x 10"circ Spectra	no info
7.5	Alternate/Emergency Towing Gear					400' x 9" circ Amsteel Blue	300' x 10"circ Spectra
						300' x 5" circ poly messenger	
7.6	tow-pins	vertical retractable					assumed from photos
7.7	stern towline roller	flush with bulwarks					assumed from photos
8	Range	2000 n.miles	*n.miles*	2000			
9	Endurance	12 days	*days*	12			
10	Fire-Fighting	Fi-Fi 2	*cu.m/hr*	7200	Fi-Fi Class1	Fi-Fi Class 1	not fitted
11	Pollution Response gear:	oil containment boom	*feet*	3300	3300	3000	no mention in data available
		oil skimmers		2	2	?	no
		recovered oil capacity	*gallons*	70000	70000	43500	no
		dispersant spray system		yes	yes	?	no
12	Approximate Particulars:						
	Length Overall		*metres*	50	46.63	42.67	45.55
	Beam		*metres*	15	14.63	12.8	12.19
	Max. Draft		*metres*	7.5	7.30	4.88	no info
13	Capacities: *based on tow of 193000 TDwt tanker*						
	Fuel Oil		*tonnes*	315	441	490	779
	Potable water		*tonnes*	20		35	31
	Lube Oils		*tonnes*	9			14
	Ballast water	75% of fuel	*tonnes*	330 / 367	280	195	?
	Recovered Oil		*cu.m*	300	317	166	0

10.0 CONCLUSIONS

The following are the primary conclusions of this review of the Best Available Technology for a Sentinel Tug to be stationed at Hinchinbrook Entrance:

- **Conclusion 1:** The Sentinel Tug, if fitted with conventional twin-screw or ASD propulsion, must have a nominal static Bollard Pull (BP) of not less than 119 tonnes in order to satisfy the Rescue Towing criteria for a 193,000 T DWT tanker, or 101 tonnes BP for a 125,000 tonne DWT tanker. If the tug is of a proper tractor configuration (with drives forward) the BP requirements would reduce to 112 and 95 tonnes respectively

- **Conclusion 2:** For purposes of this study it is assumed that the Sentinel Tug will NOT perform any indirect escort towing

- **Conclusion 3:** The free running speed of the Sentinel Tug, in calm water at full load displacement, should be about 16 knots

- **Conclusion 4:** It is recommended that a formal drift study be conducted, accounting for the precise influence of wind, waves and currents on a disabled tanker on a time domain basis to verify that 17 miles is the correct offshore tanker transit distance during which the Sentinel Tug should standby.

- **Conclusion 5:** The operating range for the tug should be not less than 2,000 n. miles at full power, and the endurance at full power, at an assumed towing speed of 6 knots, should be not less than 333 hours (say 15 days).

- **Conclusion 6:** For crew safety and comfort, the motions-related accelerations aboard the Sentinel Tug should not exceed 0.07G (lateral) and 0.15G (vertical) in the 90th percentile of wind and sea conditions encountered in the Gulf of Alaska. (Sea State 6 or lower). While these values may seem modest, these represent accepted values for sustained human endurance at sea in a working environment, and in no way represent a structural or mechanical limit for the tug itself.

- **Conclusion 7:** The Sentinel Tug should fully satisfy the requirements of the US Coast Guard Towing Stability Criteria (46 CFR 173.095). There should be sufficient margin specified in meeting these criteria that the tug will continue to do so throughout its operating life.

- **Conclusion 7b**: The use of a towing winch with an automatic rendering capability at a prescribed tension is worth considering for such an application.

- **Conclusion 8:** To satisfy B.A.T., a Sentinel Tug should have omni-directional propulsion and be able to execute a zero speed, 360° turn within no more than 110% of its own length, and within no more than 60 seconds.

- **<u>Conclusion 9</u>:** The Sentinel Tug must have a combination of main propulsion and lateral thrusters which can hold it at a 45° attitude to a 57 knot wind and the effects of 15 foot significant seas.

- **<u>Conclusion 10</u>:** Any type of propulsion system which, in combination with lateral thrusters would satisfy the requirements for manoeuvrability and position-keeping described above would be suitable for the Sentinel Tug. B.A.T. would constitute those omni-directional drive systems which incorporate some form of "tractor" configuration (namely VSP, Z-Tractor, or Rotor Tug) which are recommended due to better manoeuvrability, safer towing characteristics and less loss of effectiveness in heavy seas.

- **<u>Conclusion 11</u>:** The main towing gear for the Sentinel Tug should have components rated according to the recommendations herein, in particular with regard to having a Design Load of at least 3 x Bollard Pull.

- **<u>Conclusion 12</u>:** A tug which can satisfy all the defined operational criteria above will have approximately the following principal particulars:

    - Bollard Pull = 119 tonnes for 193,000 tonnes DWT, or
      101 tonnes for 125,000 tonnes DWT
    - Power = 9,371 bhp (for 119 T BP) or 7,954 bhp (for 101 T BP)
    - Length overall = 50–52 metres
    - Beam = 15–16 metres
    - Draft = > 6.5 metres
    - Deadweight = app. 500 tonnes min.

- **<u>Conclusion 13</u>:** The Sentinel Tug should be fully equipped with a significant fire-fighting capability (Fi-Fi 2 Rating for B.A.T.) and for an active pollution response role.

- **<u>Conclusion 14</u>:** The ETT tugs as presently configured lack the power, speed and towing gear to perform the Sentinel Rug role effectively.

- **<u>Conclusion 15</u>:** The PRT class tugs are sufficiently powered for the Sentinel Tug role; however their main towlines are not quite as strong as recommended.

- **<u>Conclusion 16</u>:** The Theriot Class tug has sufficient power to handle a 125,000 tonne tanker but falls short of the power recommended for a 193,000 T Dwt tanker. The towing gear falls short of the Design Load criteria used

Although the ideal tug for this role would (a) be somewhat larger than the PRT tugs, (b) be a Z-Tractor or Rotor Tug configuration, (c) have heavier towing gear, (d) have a greater Fi-Fi capacity and (e) a greater spill response capability, the PRT tugs are not very deficient in satisfying the majority of the defined performance criteria, and are quite a good fit for the role. The strength of the towing gear on the PRT tugs is however a concern if tankers larger than 125,000 tonnes DWT are part of the equation.

for **ROBERT ALLAN LTD.**

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Executive Chairman of the Board

RGA:da

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