Data Analysis Plan

Tug escort and ERTV Projects

Contents

1 Project Details

Ecology is performing two analyses as directed by the legislature. The Tug Escort Analysis is required by subsection 5 of RCW 88.16.260. The ERTV Analysis is required by subsection 2 of RCW 88.46.250. The two analyses will use a common set of simulated traffic and accident data. Summary reports will include scenario based statistical analysis supplemented by literature review and qualitative analysis. Summary reports are due to the legislature by September 1, 2023.

1.1 Tug Escort Analysis Objective

Evaluate the potential change in oil spill risk from covered vessels resulting from the use of tug escorts by specified tank vessels in waters east of New Dungeness Light and Discovery Island Light.

1.2 Emergency Response Towing Vessel (ERTV) Analysis Objective

Quantitatively assess whether an emergency response towing vessel serving Haro Strait, Boundary Pass, Rosario Strait and connected navigable waterways will reduce oil spill risk from covered vessels.

2 Rescue Tug Analysis Model Overview

The Rescue Tug Analysis Model (Model) is a set of tools we will use to perform the Tug Escort and ERTV analyses. The Model contains five primary components: the Vessel Movement Module, Vessel Accident Module, Momentum and Drift Module, Oil Spill Risk Module, and Vessel Rescue Analysis Module. Details of data inputs and outputs are in Section 5.

2.1 Vessel Movement Module

The Vessel Movement Module generates simulated marine traffic based on historical behaviors observed in AIS data. We will use this to create many "model years" of traffic data. Each year is unique but is based on observed patterns, such as the mix of vessel types, berth and anchorage use, and daily traffic levels.

2.2 Vessel Accident Module

The Vessel Accident Module generates marine incidents for further analysis. The Model applies a probability of loss of propulsion (LOP) and loss of steering (LOS) on a minute-by-minute basis to the simulated traffic from the Vessel Movement Module. Hazard probabilities are based on observed occurrences in the US Coast Guard Marine Information for Safety and Law Enforcement (MISLE) and Transportation Safety Board of Canada's Marine Safety Information System (MARSIS) databases.

2.3 Momentum and Drift Module

The Momentum and Drift Module plots a drift trajectory for a simulated ship that loses propulsion. The model incorporates vessel dimensions, wind and current data, and bathymetry. For each loss of propulsion event, the Model identifies a drift duration, speed, and location of grounding.

2.4 Oil Spill Risk Module

When a simulated ship grounds, it may or may not release oil. The model applies probabilities of release for various vessel types, based on historical observations from grounding events in the MISLE and MARSIS databases. If a grounded vessel does release oil, the model calculates an estimated volume using a probability distribution function based on historical incident records.

2.5 Vessel Rescue Analysis Module

The Vessel Rescue Analysis Module is applied to the results of the other modules and is used to test interventions to prevent drift grounding following loss of propulsion events. The Momentum and Drift Module assumes that when a vessel loses power it will continue drifting until it grounds. Very few loss of propulsion incidents actually result in drift groundings so we will evaluate a series of ship actions for self-rescue to estimate a realistic likelihood of a drift grounding, absent outside intervention. These are:

- **Initial turn using residual momentum –** The ability of a ship to adjust its heading immediately following the loss of propulsion
- **Self-repair –** The time that it takes a ship to recover propulsion after losing it
- **Emergency anchoring –** The ability of a ship to arrest its drift by dropping anchor

We will also evaluate the ability of rescue tugs to intervene and prevent drift grounding when a ship loses propulsion. This is the core of our analyses and allows us to test the relative benefits of tug escorts, tugs of opportunity, and ERTVs.

For each drifting ship, the total time required for a tug to perform a rescue will be calculated. This "time to save" is calculated based on the travel and control time of the nearest escort tug, tug of opportunity, and/or ERTV. This time is compared to the drift duration to determine if the tug could have prevented that drift grounding.

3 Analytical Approach

3.1 Approach Summary

Tug escorts for tank vessels and ERTVs primarily provide rescue towing for disabled ships. The main purpose of this type of intervention is to prevent drift groundings. Our analytical approach is to apply tug escort scenarios and ERTV stationing locations to simulated traffic. This will allow us to test the ability of escort tugs, tugs of opportunity, and ERTVs to intervene in LOP events to prevent drift grounding. Our analysis will highlight which vessels benefit from each type of tug intervention, where, and by how much.

3.1.1 Supplemental Research Items

In addition to the primary analysis of modeled LOP events, the reports will address several additional research items. These are intended to supplement and provide context for the results of the primary analysis.

- LOP will be compared to other hazards in the historical record to provide context for the relative risk associated with LOP and drift grounding
- We will assess potential changes in oil spill risk associated with variations in escort tug operating hours across scenarios. We will do this by applying hazard and oil spill probabilities for that vessel class, to include collision and powered grounding. A full list of hazards is in section 3.5.
- LOS probabilities will be applied to simulated traffic. We will assess how frequently the vessels are escorted or have a tug of opportunity nearby. Drift, grounding, and oil outflow will not be modeled for LOS incidents as there is no clear connection between steering failures and drift grounding. However, tugs may be able to assist a ship experiencing steering problems and this

will allow us to comment on the frequency of this hazard and the availability of tugs when it occurs.

- Effects of anticipated escort tugs related to the TransMountain Pipeline Expansion Project (TMEP) will be evaluated.

3.2 Risk Metrics

The analysis will represent risk in three ways:

- Frequency of drift grounding – Counts of simulated drift grounding events
- Oil volume at risk – Fuel and oil cargo volume estimates for ships which lose propulsion
- Oil outflow – Estimated volume of oil outflow resulting from drift grounding events

Our scenario-based approach allows us to present results as a percentage change from one scenario to the next. In addition to percent change, estimated values for drift grounding frequency, oil volume at risk, and oil outflow volume will be used to provide additional context.

3.3 Study areas

3.3.1 Tug Escort

All connected marine waters east of a line from Discovery Island light to New Dungeness light in the Strait of Juan de Fuca and south of the 49th Parallel in the Strait of Georgia. The Board of Pilotage Commissioners (BPC) has divided this area into 13 geographic zones. Waterways within the study area that are not explicitly contained in the BPC zones are included.

3.3.2 ERTV

Connected US and Canadian marine waters of the Salish Sea and the Strait of Juan de Fuca, bounded to the west by an arc 20 miles west of the J-buoy at the entrance to the Strait of Juan de Fuca, and to the north by a line from Nanoose to Sechelt in the Strait of Georgia. Some connected waters are excluded, including Upper Howe Sound, Fraser River North, Fraser River South, Duwamish River, and Lake Washington.

3.3.3 Geographic Zones

When relevant, Model outputs and risk metrics will be presented in the context of the geographic zones established by the Board of Pilotage Commissioners as required under RCW 88.16.260:

1. Strait of Georgia
2. Strait of Georgia South
3. Haro Strait and Boundary Pass
4. Rosario Strait
5. Bellingham Channel, Sinclair Island, and waters to the East
6. Guemes Channel and Saddlebags
7. Eastern Strait of Juan de Fuca
8. Admiralty Inlet
9. Puget Sound
10. Possession Sound and Saratoga Passage
11. Rich Passage & Sinclair Inlet
12. Colvos Passage
13. South Sound to Olympia

3.4 Scenarios

3.4.1 Tug Escort Scenarios

We will apply three tug escort scenarios.

1. Pre-2020 requirements – Tug escorts only required for laden tank ships greater than 40,000 deadweight tons (DWT)
2. Current requirements – Includes 2020 statutory expansion to ATBs, tank barges greater than 5,000 DWT, and tank ships less than 40,000 DWT
3. Study area – Extend 2020 requirements to all Washington waters east of New Dungeness Light

3.4.2 ERTV Locations

The existing Neah Bay ERTV will be represented in both the tug escort and ERTV analyses. Six additional locations will be considered in the ERTV analysis:

- Port Angeles, WA
- Victoria, BC
- Anacortes, WA
- Roche Harbor, WA
- Sidney, BC
- Delta Port, BC

3.5 Hazards

The following hazards will be represented in the analyses. LOP and LOS will be applied to simulated traffic data for all covered vessels. An additional set of hazards will apply only to escort/assist tugs. Specifically, we will compare operating time for these tugs under each tug escort scenario, and compare those time differences to hazard rates observed in the historical record for that class of vessel. This will allow us to comment on potential risks associated with expansion of this spill prevention measure.

Table 1: Hazard types by vessel category

Hazard Type	Vessel Type
Loss of propulsion (LOP)	All covered vessels[1]
Loss of steering (LOS)	All covered vessels
Collision (ship-to-ship while underway)	Escort/Assist Tug
Powered Grounding	Escort/Assist Tug
Allision (includes other collisions)	Escort/Assist Tug
Sinking/Capsize	Escort/Assist Tug
Other	Escort/Assist Tug

3.6 Response Tug Assumptions

3.6.1 Which vessels provide rescue towing

The model allows escort tugs, assist tugs, and ERTVs to respond to LOP events. Other tugs, like those engaged in ocean and coastal towing, are not considered tugs of opportunity in the Model because we have no data to support estimates of burdened status. With the exception of ERTVs, only tugs actively underway can be tugs of opportunity since we do not know the level of readiness of a tug at berth.

[1] Modeled covered vessels are ATB, Bulk Carrier, Container Ship, Cruise Ship, Ferry (Car), Fishing Vessel (Large), General/Other Cargo Ship (Large), Tanker (Chemical), Tanker (Crude), Tanker (Liquefied Gas), Tanker (Product), Towing Vessel (Oil), Towing Vessel (Oil) - Bunkering, Vehicle Carrier.

3.6.2 Transit speed
Tugs responding to LOP events will travel at 10 knots.

3.6.3 Mobilization time
Mobilization time is the amount of time required for a tug to start its transit. ERTVs will have a 20-minute mobilization time. Escort and assist tugs serving as tugs of opportunity are already underway and do not have a mobilization time.

3.6.4 Connect & control times
Untethered escort tugs, tugs of opportunity, and ERTVs responding to LOP events in the model require 15 minutes to connect a towline and 15 minutes to control the drifting vessel. In the case of a tethered escort, only the 15-minute time to control applies.

3.6.5 Availability to provide rescue towing
- Escort/Assist tugs are available while underway but not while dockside
- Tugs performing escort service are available to serve as tugs of opportunity
- Assist tugs are available while commuting to and from a job, not while maneuvering a ship
- ERTVs are always available

3.6.6 Cross border response
Escorts, tugs of opportunity, and ERTVs can respond to incidents on either side of the US-Canada border.

3.6.7 Success rate
If a tug reaches a drifting vessel with sufficient time before grounding to connect and control, a save occurs.

3.6.8 Interception point
When calculating the time it takes a responding tug to reach a disabled vessel, the model establishes a route from the tug starting point to the nearest point along the disabled vessel's drift path at which the tug and ship can intersect.

4 Research Questions

4.1 Tug Escort
These research questions are specified in the Tug Escort Analysis scope of work approved by the Board of Pilotage Commissioners. For all questions below, risk is measured in three ways: frequency of drift grounding, oil volume at risk, and oil outflow. Results will primarily be presented as the percent change between scenarios.

4.1.1 How is oil spill risk distributed geographically? How does the use of tug escorts change the way that oil spill risk is distributed geographically?
- Is there a change in drift grounding risk under each tug escort scenario?
  - For the entire study area
  - By zone
- How does risk from escort tugs vary by scenario?
  - Compare operation time per model year for escort tugs under each scenario.

  - Use hazard rates to investigate how a change in operational minutes may affect the risk of selected hazards for escort tugs.

4.1.2 How is oil spill risk distributed across covered vessel types? How does the use of tug escorts change the way that oil spill risk is distributed across covered vessel types?

- How does risk from drift groundings change under each tug escort scenario for each covered vessel type?

4.1.3 How does the 2020 expansion of tug escorts in Rosario Strait and connected waters to the east change oil spill risk from covered vessels?

Highlight the differences between pre-2020 requirements (Scenario 1) and current requirements (Scenario 2) in the discussion of the results from questions 1 and 2.

4.1.4 How does tethering affect oil spill risk?

Tethering refers to the practice of escorting a laden tank vessel with a towline connected.

- If tethering is applied to all escorted vessels, is there a reduction in risk from drift groundings?
  - For the entire study area
  - By zone
  - By escorted vessel type

4.1.5 How do key design characteristics for escort tugs affect oil spill risk?

We will answer this question through a combination of literature review and examination of escort systems and case studies.

4.1.6 Are there new safety measures adopted since July 1, 2019? If so, what are the benefits of these measures?

We will answer this question through a literature review.

4.2 ERTV

These research questions are specified in the ERTV analysis scope of work approved by the Ecology Spills Program Executive Committee for modeling and analysis. For all questions below, risk is measured in three ways: frequency of drift grounding, oil volume at risk, and oil outflow. Results will primarily be presented as the percent change between scenarios.

4.2.1 How is oil spill risk distributed geographically in the study area? How does an ERTV serving the study area change this risk distribution?

- To what extent could an ERTV reduce spill risk for each zone when tugs of opportunity are allowed?
  - For each ERTV location
  - For each tug escort scenario
- To what extent could an ERTV reduce spill risk for each zone when tugs of opportunity are not allowed?
  - For each ERTV location
  - For each tug escort scenario

4.2.2 How is oil spill risk distributed across covered vessel types? How does an ERTV serving the study area change this distribution?

- To what extent could an ERTV reduce spill risk for each vessel type when tugs of opportunity are allowed?
  - For each ERTV location
  - For each tug escort scenario
- To what extent could an ERTV reduce spill risk for each vessel type when tugs of opportunity are not allowed?
  - For each ERTV location
  - For each tug escort scenario

4.2.3 How do the following variables change these distributions? ERTV location, tank vessel escort scenarios, tug of opportunity scenarios

These variables from the scope of work are incorporated directly into the other ERTV question sets. For the purposes of this analysis, Tug of Opportunity scenarios include the Tug Escort Scenarios and the TMEP traffic scenario.

4.2.4 How do key design characteristics of emergency towing vessels affect oil spill risk?

We will answer this question through a combination of literature review and examination of escort systems and case studies.

4.3 Context for Both Analyses

4.3.1 Drift grounding in context

To provide context for the relative frequency and severity of drift groundings, we will make comparisons using historical records in the MISLE and MARSIS databases.

- How frequent are drift groundings?
  - In the study area
  - In the larger hazard count area
- How does spill risk from drift grounding compare to other hazards?
  - In the study area
  - In the larger hazard count area

4.3.2 Evaluation of Ship Actions

Assessment of the relative importance of each ship action on LOP outcomes.

- What effect does the inclusion of the Initial Turn have on drift times and LOP outcomes?
- What effect does the inclusion of Self-Repair times have on LOP outcomes?
- What effect does the inclusion of Emergency Anchoring have on LOP outcomes?

4.3.3 Evaluation of Rescue Towing Assumptions

The following questions are intended to evaluate to what degree different values for key rescue towing assumptions affect outputs. These will be tested using current tug escort requirements (Scenario 2), for all zones and vessel types combined.

- What effect do time to connect and control assumptions have on modeled oil spill risk?
  - Increase time by 50% (45 minutes total)

    - Reduce time by 50% (15 minutes total)
- What effect do rescue tug transit speed assumptions have on modeled oil spill risk?
    - Increase speed by 25% (12.5 knots)
    - Reduce speed by 25% (7.5 knots)
- What effect does 100% success rate of rescue towing have on oil spill risk?
    - Apply 50% success rate
    - Apply 90% success rate

4.3.4 TransMountain Pipeline Expansion Project (TMEP)

A traffic simulation will be run to include projected levels of round-trip tank ship transits from the J-Buoy at the entrance to the Strait of Juan de Fuca to Westridge Terminal in Burnaby, BC. The outbound laden transit is escorted, inbound unladen transit is unescorted. Questions below will be assessed against current tug escort requirements (Scenario 2).

4.3.4.1 Both Analyses

Does drift grounding risk change when projected TMEP tank ship and escort traffic is included?

    - By zone
    - By vessel type

4.3.4.2 ERTV Analysis

Does the effect of an ERTV on drift grounding risk change when projected TMEP traffic is included?

    - By zone
    - By vessel type
    - By ERTV location

4.3.5 Loss of Steering

For each simulated loss of steering event:

- How many occur while the vessel is escorted?
- For those that occur while unescorted, how much time is required for nearest tug of opportunity to arrive?

4.3.6 Analysis of the Model

The analysis report will include a discussion of model validation findings. There will be two types of model validation, validating the individual components of the model and validating the overall results of the Model.

The validation of the individual components will entail checking if the general trends observed in the simulated results are similar to what was observed in historical data. For the vessel movement module, summary statistics for simulated vessel movement will be compared to summary statistics for the observed historical AIS. Similarly, the simulated output for the vessel accident module and the oil outflow module will be compared to observed accident and oil spill data. The functionality of momentum-drift model will be validated against real-world cases.

5 Data

5.1 Dataset Inputs

Table 2: Data sources for model

Category	Source(s)	Notes
Bathymetry	NOAA	Data used created from multiple bathymetric survey projects
Incident Records	USCG – MISLE TSBC – MARSIS Ecology – SPIIS IHS Markit	USCG and MARSIS 2002-2019 used for hazard counts. SPIIS & IHS used for supplemental information only.
Laden Status	AIS from SiiTech	2018
Oil Transfer Records	Ecology ANT data	Used to estimate bunkering frequency and locations
Self-repair times	BPC Marine Occurrence Records Ecology - Neah Bay ERTV callouts	Used to assess duration of complete loss of propulsion
Traffic Simulation	AIS from Marine Cadastre	2015-2019
Vessel Characteristics	IHS Markit – Seaweb	Supplemented by other public domain sources
Wind & Current	Salish Sea Model LiveOcean (evaluating)	2014 2017-2020

5.2 Simulated Data Outputs

5.2.1 Vessel Traffic

- Without escort/assist tugs
- Apply tug escort scenarios to each model year
- Supplemental
    - Traffic including TMEP traffic projections
    - Tug Escort time exposure per scenario

5.2.2 Accidents

- Probabilities of LOP and LOS are applied to each model year for each scenario.

5.2.3 Measured Metrics

The following metrics will be calculated for each hazard applied to the simulated covered vessel traffic.

5.2.3.1 Loss of Propulsion

- Self-repair time
- With Initial Turn
    - Drift time
    - Emergency anchoring
    - ERTV rescue time
    - Escort scenario 1
        - Escorted rescue time (tethered/not tethered)
        - Tug of Opportunity rescue time
    - Escort scenario 2

        - Escorted rescue time (tethered/not tethered)
        - Tug of Opportunity rescue time
    - Escort scenario 3
        - Escorted rescue time (tethered/not tethered)
        - Tug of Opportunity rescue time
    - Drift grounding location
        - Coordinates
        - Geographic Zone
    - Oil volume at risk
        - Fuel capacity
        - Cargo capacity, if laden
    - Oil outflow volume
- Without Initial Turn
    - Drift time
    - Emergency anchoring
    - ERTV rescue time
    - Escort scenario 1
        - Escorted rescue time (tethered/not tethered)
        - Tug of Opportunity rescue time
    - Escort scenario 2
        - Escorted rescue time (tethered/not tethered)
        - Tug of Opportunity rescue time
    - Escort scenario 3
        - Escorted rescue time (tethered/not tethered)
        - Tug of Opportunity rescue time
    - Drift grounding location
        - Coordinates
        - Geographic Zone
    - Oil volume at risk
        - Fuel capacity
        - Cargo capacity, if laden
    - Oil outflow volume

5.2.3.2 Loss of Steering

- Escort scenario 1
    - Vessel escorted (tethered/not tethered)
    - Nearest Tug of Opportunity
- Escort scenario 2
    - Vessel escorted (tethered/not tethered)
    - Nearest Tug of Opportunity
- Escort scenario 3
    - Vessel escorted (tethered/not tethered)
    - Nearest Tug of Opportunity

5.3 Software

Table 3: Key software for modeling

Category	Software
Database Management	Microsoft SQL Server Management Studio
Model Code & Analytics	R, Python
Statistical Analysis	R, Python
Geospatial	R, Python, ArcGIS

5.4 Computing Infrastructure

Simulations run on a 55-core Windows server using Intel Xeon Gold processors (2.90 GHz). Model input and output data is saved in Microsoft SQL Server 2016.