Vessel Accident Module Updates

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Model Development Team
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Legislative background

- ESHB 1578 was passed in 2019 to reduce the risk of oil spills, and protect Southern Resident Killer Whales

- Ecology’s Spills Program tasked to undertake or assist with multiple policy initiatives in the bill, including the development of an oil spill risk model
Describing oil spill risk

**Scenarios**
- Hazard identification: collision, allision, grounding, etc.

**Probability**
- How likely is each hazard?

**Consequences**
- If an accident happens, how likely is that an oil spill occurs, where will it occur, and what volume and type of oil will be released?
Modeling Approach

Vessel Movement Module
Generates traffic levels, vessel routes, and movements

Encounter Module
Identifies opportunities for collisions and groundings

Vessel Accident Module
From a limited list of hazards, uses probabilities and mechanistic models to estimate accidents

Oil Outflow Model
From a limited list of accidents, uses probabilities and mechanistic models to estimate oil outflows
Changes to Hazard Definitions

• Machinery Spill
  • “An oil spill to water from machinery or equipment onboard a covered vessel. Excludes spills related to overwater oil transfers.”

• Vessel to Vessel Collision
  • “A collision between a covered vessel and another vessel, while both vessels are underway, or while one is underway and one is anchored.”
Updates since last presentation

Adjustments to Anchorages
• Added additional anchorage area near Cherry Pt

Revisions to anchorage alternatives
• Changed alternatives for Yukon Harbor
  • Elliot Bay East and West replaced Smith Cove East and West
• Removed alternatives for the two explosives anchorages.
Adjustments to Model Area
Momentum and Drift Model
Model Hazards

**Direct Model Hazards**
- Allision
- Capsize
- Collision
- Machinery Spill
- Grounding
- Sinking
- Transfer Spill

**Indirect Model Hazards**
- Loss of Propulsion
- Loss of Steering
- Anchor Dragging

- Probabilistic Approach
- Mechanistic Approach
Modeling Indirect Hazards

Indirect Model Hazards
- Loss of Propulsion
- Loss of Steering
- Anchor Dragging
Purpose:

- Simulate ship movement after a total loss of propulsion while underway

Key Considerations:

- Inshore Study Area
Components of Momentum and Drift Model

- Loss of Propulsion
  - Estimate of LOP Probability

- Crew Actions
  - Immediate course change using remaining momentum

- Velocity Vector
  - Ship trajectory

- Self Repair
  - Duration of the LOP, prior to regaining control

- Drift Grounding
  - Overlap between ship draft and grounding contour
Velocity Vector

Ship’s Momentum
• Ship’s mass
• Added mass
• Ship’s speed

External Forces
• Wind
• Current
• Waves

Ship Drag
• Drag Coefficients
• Wind/water exposed areas
• Wind/water densities

\[(m + m') \frac{dv}{dt} = F_{\text{wind}} + F_{\text{current}} + F_{\text{wave}}\]
Velocity Vector

Ship’s Momentum

External Forces and Drag

Course: 100 degrees / Speed 7.3 knots

Velocity Vector

Calculated every 60 seconds
As the momentum drops, the external forces have a larger affect
Eventually, the ship’s momentum is expended, and the external forces and drag forces are responsible for the course and speed of the ship.
Why This Approach

Strengths

• Allows incorporation of ship course and speed at time of LOP (aka “ship’s momentum”)
• Allows crew actions to be included, in form of course changes at moment of LOP
• Physics based model

Weaknesses

• Requires the identification of many parameters
• Not based on experimental or observed drift patterns
• Challenging to validate
Required Parameters

To be calculated with data from Salish Sea Model, IHS Markit, and Model outputs:

- Vessel Mass
- Vessel Length at Waterline
- Relative Air Speed
- Relative Water Speed

To be pulled from existing data:

- Air density
- Water density
- Wave amplitude
- Gravitational acceleration
Required Parameters

Need additional investigation to finalize calculation approach:

- Air dragging coefficient → Dependent on vessel type and angle of attack
- Water dragging coefficient → Dependent on vessel type and angle of attack
- Wave dragging coefficient → Dependent on vessel type and angle of attack
- Wind-exposed vessel area → $5 \times$ or $\frac{1}{5} \times$ water exposed area
- Water-exposed vessel area → Length $\times$ Draft & Beam $\times$ Draft
- Added mass → $\frac{1}{4} - \frac{1}{3}$ of vessel mass
Weather Data for External Forces

Salish Sea Model

- Developed by Pacific Northwest National Laboratory (PNNL) in collaboration with scientists from Department of Ecology

- Simulates hydrodynamic data based on inputs from river, streams, and point sources throughout the region

- Model development will rely on data from 2014, but we will add additional years of data for model analysis.
Components of Momentum and Drift Model

- Loss of Propulsion
  - Estimate of LOP Probability
- Crew Actions
  - Immediate course changes designed to use remaining momentum
- Velocity Vector
  - Ship drift trajectory
- Self Repair
  - Duration of the LOP, prior to regaining control
- Drift Grounding
  - Overlap between ship draft and grounding contour
Crew Actions

What Happens Immediately Following a LOP?

- Momentum allows the crew some ability to control the vessel’s heading.
- As momentum decreases ability to control the ship’s heading is drastically reduced, and quickly resolves to a total lack of control

Why Does This Matter?

- Restricted waters
- Crew ability to avoid immediate grounding hazards
Our Approach to Crew Actions

Existing Approaches
• None found

Review of LOP incident reports
• Reviewed 133 local LOP events that fit our criteria (2007-2021)
• Identified 25 reports that include immediate crew actions

Crew Actions Identified in Historical Data
• Helm Offshore
• Maintain Heading

Helm Offshore
• “I put left rudder on to steer away from browns point”
• “I turned ship to the north to increase distance from ediz hook”

Maintain Heading
• “The helmsman was able to maintain a 046 Degrees True Heading”
• “Was able to keep vessel close to appropriate heading”
Our Approach to Crew Actions

Model Crew Actions:
- Ship may alter course at most 60 degrees to port or 60 degrees starboard.
- Ship prioritizes maintaining original heading, unless danger is close aboard.

Simulation Approach
- Ship evaluates 10 degree “wedges” in a 120 degree forward arc.
- The ship chooses a course within a hazardless wedge
- Ship maintains original heading, unless danger is close aboard.
Rationale for our Approach

Why 120 degree arc?
• 60 degrees to port or starboard allows a ship to avoid immediate danger resulting from operating in restricted waters
• This allows simulated ships that have suffered an LOP to lose momentum and begin drifting

Why Course Change?
• Our model only represents courses, not headings, so we are unable to evaluate ship’s movements in terms of heading change
Components of Momentum and Drift Model

- **Loss of Propulsion**
  - Estimate of LOP Probability

- **Crew Actions**
  - Immediate course changes designed to use remaining momentum

- **Velocity Vector**
  - Ship drift trajectory

- **Self Repair**
  - Duration of the LOP, prior to regaining control

- **Drift Grounding**
  - Overlap between ship draft and grounding contour
Time to Self Repair

What happens during an LOP event?

- When ships unexpectedly lose propulsion, crew works to recover propulsion
- The amount of time it takes to recover propulsion varies substantially
- For our modeling effort, we need a distribution of propulsion recovery times
Our Approach to Establishing a Time to Self Repair

Existing Approaches
• Either based on expert elicitation, or very small datasets

Review of LOP Incident Reports
• Reviewed 133 local LOP events that fit our criteria (2007-2021)
• Identified 31 reports that include timing information

Proof of Concept
• Sufficient data exists for us to produce a distribution of self repair times
Next Steps for Momentum and Drift Model

Velocity Vector
• Parameter Identification

Self Repair
• Identification of additional datasets that might inform the time to self repair distribution

Crew Actions
• Review initial momentum and drift model outputs to determine if crew action module is working as designed

Drift Grounding Criteria
• Determine criteria for groundings
Components of Momentum and Drift Model

- Loss of Propulsion
- Crew Actions
- Velocity Vector
- Self Repair
- Drift Grounding

Interventions
- Tug Intervention
- Emergency Anchoring
Remaining Indirect Models
Potential Components of Anchor Dragging Model

- **Dragging Anchor**: Estimate of Dragging Anchor Probability
- **Velocity Vector**: Ship Trajectory
- **Self Recovery**: Duration of the Anchor Dragging
- **Encounter Model**: Evaluate trajectory for collision and grounding encounters
- **Vessel Accident Model**: Apply probability of encounter resulting in a collision or grounding
Potential Components of Loss of Steering Model

1. **Loss of Steering**
   - Estimate of Loss of Steering Probability

2. **Velocity Vector**
   - Ship Trajectory

3. **Self Repair**
   - Duration of the LOS event, prior to regaining control

4. **Encounter Model**
   - Evaluate trajectory for collision and grounding encounters

5. **Vessel Accident Model**
   - Apply probability of encounter resulting in a collision or grounding
Webinars and Technical Discussions

Vessel Movement Module
Vessel Encounter Module
Vessel Accident Module
Oil Outflow Module

Monthly Discussions

Introduction
June – August 2020

Model Development
September 2020 – October 2021
Upcoming events

September 22\textsuperscript{nd}, 2021 -- 1 pm to 3 pm
- Oil Outflow Module
Analysis Updates

Tug Escort Analysis Draft Scope of Work
- Analysis objectives and high level research questions
- Will be shared via email on August 31

ERTV Analysis Draft Scope of Work
- Analysis objectives and high level research questions
- Will be shared via email on August 31

Questions and comments welcome
Next Steps for Analysis Projects

Tug Escort Analysis
- Review of comments received on draft scope
- Presenting draft scope to Board of Pilotage Commissioners
- Outreach kickoff in early 2022

ERTV Analysis Draft Scope of Work
- Review of comments received on draft scope
- Outreach kickoff in early 2022
Discussion logistics
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