Vessel Accident Module

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Model Development Team

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Today’s outline

1. Background
2. Hazard Identification
3. Break for 1st Discussion
4. Establishing Probabilities
5. Next Steps and 2nd Discussion
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
Hazard Identification

Existing Approaches
• Not comprehensive
• Based on accident databases
• Lack of consensus in the literature

Mechanistic Approach
• Starting with four ways to have a maritime oil spill:
  • Hull damage
  • Submergence
  • Transfer Spill
  • Deck/Mechanical Spill
Initial List of Hazards

Model Hazards
• Allision
• Capsize
• Collision
• Deck Spill
• Grounding
• Sinking
• Transfer Spill

What further detail are we interested in?
• Scenarios that lead to hazards
• Additional specification of hazards
Hazard Identification – Scenarios that lead to hazards

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

**Direct Model Hazards**
- Allision
- Capsize
- Collision
- Deck Spill
- Grounding
- Sinking
- Transfer Spill
Hazard Identification – Additional specification

Collision
• Vessel to Vessel Collision
• Tug to Barge Collision

Allision
• Navigational Allision
• Berth Allision

Other
• Catch-all category that includes, for example:
  • Fire/Explosion
  • Metal fatigue/cracking
  • Spills of unknown/unreported cause
### Combined List of Model Hazards

<table>
<thead>
<tr>
<th>Hazard Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powered grounding</td>
</tr>
<tr>
<td>Tug to barge collision</td>
</tr>
<tr>
<td>Vessel to vessel collision</td>
</tr>
<tr>
<td>Navigational allision</td>
</tr>
<tr>
<td>Berth allision</td>
</tr>
<tr>
<td>Sinking</td>
</tr>
<tr>
<td>Capsizing</td>
</tr>
<tr>
<td>Deck spill</td>
</tr>
<tr>
<td>Transfer spill</td>
</tr>
<tr>
<td>Other spill</td>
</tr>
<tr>
<td>Loss of propulsion grounding</td>
</tr>
<tr>
<td>Anchor dragging grounding</td>
</tr>
<tr>
<td>Loss of steering grounding</td>
</tr>
<tr>
<td>Anchor dragging collision</td>
</tr>
<tr>
<td>Loss of steering collision</td>
</tr>
</tbody>
</table>

**For each:**
- we must identify a probability
- we must identify a probability and a mechanism
Hazard Identification – Probabilistic Approach

- Probability of sinking
- Probability of capsizing
- Probability of deck spill
- Probability of other spills

**VESSEL ENCOUNTER MODULE**
- Berth approach model
  - Probability of berth allision
  - Probability of power grounding
  - Probability of navigational allision
  - Probability of vessel-to-vessel collision
- Tug & barge model
  - Probability of tug & barge collision
- Oil transfer model
  - Probability of spills during oil transfer

- Probability of propulsion
- Probability of anchor drag
- Probability of loss of steering
- Momentum and drift model
- Anchor dragging model
- Loss of steering model

**OUTCOMES**
- Sinking
- Capsizing
- Deck Spill
- Other spills
- Berth allision
- Power grounding
- Navigational allision
- Vessel-to-vessel collision
- Tug & barge collision
- Transfer spill
- Drift grounding
- Anchor dragging grounding
- Anchor dragging collision
- Loss of steering grounding
- Loss of steering collision
Hazard Identification – Probabilistic Approach

- Berth approach model
  - Probability of sinking
  - Probability of capsizing
  - Probability of deck spill
  - Probability of other spills

- Vessel encounter module
  - Probability of berth Allison
  - Probability of power grounding
  - Probability of navigational Allison
  - Probability of vessel-to-vessel collision
  - Probability of tug & barge collision

- Tug & barge model
  - Probability of spills during oil transfer

- Oil transfer model
  - Probability of loss of propulsion
  - Probability of anchor drag
  - Probability of loss of steering

- Momentum and drift model
- Drift grounding
- Anchor dragging model
- Anchor dragging grounding
- Loss of steering model
- Loss of steering grounding
- Loss of steering collision

- Berth allision
- Power grounding
- Navigational Allison
- Vessel-to-vessel collision
- Tug & barge collision
- Transfer spill
Hazard Identification – Mechanistic Approach
Strengths and weakness

Probabilistic Approach
Vs
Mechanistic Approach
Probabilistic Approach

**Strengths**

- Based on data, to the extent possible
- Best chance at evidence based probability

**Weaknesses**

- Most prevention strategies cannot be evaluated for these hazards
- Only very limited scenarios can be tested
Probabilistic Approach

What can we estimate?
- Oil spill risk from a listed hazard
  - E.g. What portion of oil spill risk is from vessels sinking?

What can we estimate, if sufficient data exists?
- Effect on spill risk for a listed hazard for factors like weather, ship age, flag...
  - E.g. How would a change in ship age affect the risk from vessels sinking?

What can’t we estimate?
- Oil spill risk from a non-listed hazard
- Effect of training, crewing levels, or other human factors based interventions on spill risk
- Effect of maintenance, onboard equipment or lack thereof, on spill risk
Mechanistic Approach

**Strengths**

- Allow us to test tug interventions associated with loss of propulsion, loss of steering, and anchor dragging events.

**Weaknesses**

- Mechanistic model is a simplification
- Outputs not linked to historical data
Mechanistic Approach

What can we estimate?

• Oil spill risk from a listed hazard
• Ability of a tug to physically intervene prior to a drift grounding, or collision associated with a loss of steering or anchor dragging event.
  • E.g. What proportion of drift groundings can be averted by stationing an ERTV in a given area?

What can’t we estimate?

• Effect of training, crewing levels, or other human factors based interventions on spill risk for these hazards
• Effect of any risk intervention not specifically linked to a tug’s ability to physically intervene in the accident chain for these hazards
  • E.g. How would additional escort training affect oil spill risk from loss of steering events?
How it fits together
Why this combined approach?

**Why not take probabilistic path for all hazards?**
- Tug intervention questions could not be evaluated

**Why not take mechanistic path for all hazards?**
- How most indirect hazards lead to accidents is not specifiable due to a lack of data
  - The mechanistic path between loss of propulsion and drift grounding is uniquely transparent
- Other hazards do not offer such transparency:
  - E.g. The accident chain between water ingress and sinking
End of Part 1: Questions and comments

Is this list of hazards sufficient?
• Suggested additions or reorganization?

Does this model structure allow us to answer the questions we are interested in?
• In the near term?
• In the long term?
Part 2: Establishing likelihood

**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?
What makes a probability?

A probability consist of two parts:

- The number of occurrences
  - E.g. the number of accidents of a particular type

- A measurement of opportunities
  - E.g. the number of encounters, ship-years, operation hours, or nautical miles sailed
  - The “exposure variable”

Some examples:

- 0.00232 serious collisions per ship year
- 0.0000000386 serious collisions per nautical mile sailed

**Probability = \( \frac{0.0000000386 \text{ serious collisions}}{1 \text{ nautical mile sailed}} \)**
Establishing a Probability – Standard Method

**Standard Methodology**

- Define a “population of interest”
- Count occurrences within that population
- Count opportunities within that population

**Population of interest:** Covered vessels in a geographic area during a time period

**Occurrences:** Number of groundings in that area, during that time period

**Opportunities:** Number of transits in that area, during that time period
Establishing a Probability – Standard Method

1) Find a population of interest
   • A time period with similar trends as today
   • An geographic area with similar trends as the study area

2) Count occurrences
   • Representative examples
   • Must be of sufficient number

3) Count opportunities
   • Need an exposure variable
   • The unit of measure for the probability denominator
Establishing a Probability – Standard Method

**Challenges**

- No easy way to identify the right population of interest
- Relatively small number of occurrences
- Database challenges
Establishing a Probability – Alternative Method

Zero-Failure Approaches

• Estimates probability with few to no occurrences
• A wide variety of ways to do this
• Lots of uncertainty in the different approaches

How?

• Estimate based on number of opportunities
• The number of opportunities could be larger or smaller, depending on your approach
Establishing a Probability – Expert Elicitation

**An alternative to data: expert elicitation**
- Other risk analysis projects have used expert elicitation as a way to produce quantifiable information on human error or other factors with sparse data available

**Many challenges with this approach**
- Complex process aimed at eliminating biases from the expert’s interest in the value of the parameter
- Extremely difficult to provide a probability with a meaningful level of precision
How will we calculate a probability?

When there are occurrences, the probability is the number of occurrences divided by the number of opportunities.

When there are no occurrences, the probability is a function of the number of opportunities.

\[
\hat{p} = \begin{cases} 
  f(n), & \text{when } x = 0 \\
  \frac{x}{n}, & \text{when } x > 0 
\end{cases}
\]
There are strengths and weaknesses to every approach

- No one way is identifiably the best

Proposed path forward

- Multiple methodologies for calculating probabilities
- Each methodology is a comprehensive, standalone approach to calculating probabilities
- Model will produce unique outputs for each methodology
- Model results will be characterized as a range based on the different outputs
Multiple probability approach

**Helps communicate uncertainty**
- Different methods yield different results

**Improves model transparency**
- How much difference do different accident probabilities make?

**Allows multiple viewpoints to be included**
- A more inclusive approach may help us find common ground
Multiple probability approach

One potential structure for this approach:

<table>
<thead>
<tr>
<th></th>
<th>Probability Set A</th>
<th>Probability Set B</th>
<th>Probability Set C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic Area</td>
<td>Narrow</td>
<td>Medium</td>
<td>Broad</td>
</tr>
<tr>
<td>Time Period</td>
<td>Shorter</td>
<td>Medium</td>
<td>Longer</td>
</tr>
</tbody>
</table>

The narrower our scope:
- More likely to end up using the zero failure method
- Less likely to be able to identify factors that influence probabilities

The broader our scope:
- Higher potential that we are capturing trends that don’t match trends in study area
- Less able to use AIS information for calculation of exposure variables
Consideration for Parameters

For each Probability Set, we need
• A temporal scope – how far back in time?
• A geographic scope – how wide an area?
Temporal Scope

**We want a time period that mirrors today**

**What factors might drive changes in accident trends?**
- Regulatory changes
- Industry practices
- Other factors

**Other considerations**
- Reporting practices – formal and informal
- Database quality/changes over time
Geographic Scope

We want a geographic area that mirrors our study area

What factors might drive geographic differences in accident trends?

• Different rules and regulations
• Waterway characteristics
• Traffic separation schemes
• Vessel Traffic Services
• Pilotage

Other considerations

• Reporting practices – formal and informal
• Database quality/changes between jurisdictions
Next Steps for Vessel Accident Module

Mechanistic models
• Drift and momentum model
• Anchor dragging model
• Loss of steering model
• Discuss at next accident module webinar

Probability sets
• Work on parameters (geographic scope, temporal scope, etc)
• Discuss at public technical discussion sessions
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

- Sep
- Nov
- Feb
- Mar
- May
- Aug
- Sep
- Oct
Upcoming events

June 30\textsuperscript{th}, 2021 -- 1 pm to 3 pm
- Model 101 review session

July 14\textsuperscript{th}, 2021 -- 1 pm to 3 pm
- Technical Discussion Session: Modeling vessels and anchorages

July 28\textsuperscript{th}, 2021 -- 1 pm to 3 pm
- Technical Discussion Session: Probability
Upcoming events

August 18th, 2021 -- 1 pm to 3 pm
- Vessel Accident Module Outstanding Topics and Follow Up
Today’s discussion topics

• Our proposed multiple probability approach

• Your initial thoughts on probability parameters
  • What factors do you feel are most important?
Discussion logistics
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