This presentation details how the Technical Standards and Safety Authority (TSSA), a provincial regulator of safety standards in the province of Ontario, has used the outcomes of a quantitative risk assessment in order to inform policy geared towards safeguarding the interests of the public and the environment.

The TSSA is an Ontario-based regulatory body which enforces safety standards across various areas: elevating and amusement devices, ski lifts, escalators and moving walks, upholstered and stuffed articles, boilers and pressure vessels, operating engineers and fuels safety. Similar organisations include the British Columbia Safety Authority (BCSA), the Alberta Boilers Safety Association (ABSA) and Régie du Bâtiment de Québec (RBQ).

Our Fuels regulations span the utilization, storage & dispensing and transmission, distribution & transportation life cycle of various types of fuels including propane, compressed gas, fuel oil, gaseous fuels, liquid fuels and oil & gas pipeline systems.
Akin to similar organisations with enforcement components, the TSSA receives a number of occurrence reports on an annual basis. The TSSA receives approximately 3000 occurrence reports on average, related to fuels safety across various types of locations and fuels types.

Approximately 20% of all fuel-related occurrences reported to the TSSA over the past 8 years resulted from fuel oil leak releases into the environment. More than 80% of these occurrences took place in residential locations (i.e., private dwellings, multi-unit residences [condominiums, apartments]). Of particular interest and concern to the TSSA were those occurrences that related to single-wall above ground fuel oil storage tanks. Leaks from these types of tanks have historically resulted in high environmental impacts and property damages.

The excerpt from the 2011 CBC news article (included in the above slide) highlights the significant financial burden and the implications sustained by homeowners have had these tanks on their properties. In particular, some homeowners have lost their homes and/or their life savings to pay for the clean-up costs associated with these leaks.
In response to several of these occurrences, the TSSA conducted a risk assessment to better understand the failure mechanism involved in these tank failures.

**Aboveground Storage Tank Risk Assessment – Background**

- Ageing in conjunction with time dependent failure mechanisms causing failures of fuel oil above ground storage tanks
- Accelerated degradation due to microbiologically influenced corrosion (MIC)
- Visual inspections cannot assess internal condition of a tank
- No prescribed age at which the tank must be replaced
Objective

- Establish replacement interval for single wall fuel oil aboveground storage tanks using risk-informed approach

- Original risk assessment study expressed risk in terms of time-dependent failure probabilities due to corrosion
  - Established how tank replacement intervals would be calculated as a function of tank age at the time of failure
The data available in our safety database was mined and analysed in order to generate a data set which could be used for analysis and modeling purposes. As suggested by the background information, the criteria for what would constitute a ‘valid’ occurrence, which would be eligible for this study, has been included above (please see ‘Valid Occurrences’).

Additionally, several assumptions, also included in the above slide) were made as part of the risk assessment. In particular, with respect to tank corrosion rate data, literature review suggests that there is a high degree of uncertainty associated with corrosion rates because of spatial and temporal variability. Moreover, the literature review suggests that the traditional deterministic approach, which uses single failure rates, has generally been seen as being insufficient in modelling the typically random propagation of corrosion over time.
The conceptual model was developed by Dr. Muddassir Nazir formerly with TSSA. Key inputs to this model are:
1) the Mean Corrosion Rate
2) Variability in the Corrosion Rate
The valid occurrences from the TSSA database which met the 3 criteria points (mentioned in slide 5) were fed into the gamma stochastic model to yield the above lifetime distribution at the Lower Confidence Level (LCL - blue), the Mean average (red) and the Upper Confidence Level (UCL - green).

The above distribution portrays the probability of failure of the tank (due to corrosion) as a function of time (in tank age). The probability of failure (Pf) represents the probability of 2mm thickness loss being reached. For a given Pf value, one can interpolate to determine the tank age at the time of failure.
To facilitate decision making, 3 data points from the mean lifetime distribution on slide 7 (i.e., the red line) have been selected to display the spectrum and range in tank failure ages.

### Safety Issue Analysis – Results

- The probability of failure for mean lifetime distributions were used to determine at which tank ages the chance of thickness loss reaching 2mm due to corrosion

**Expected Age at which 2 mm thickness loss is reached**

<table>
<thead>
<tr>
<th>Pf for mean (%)</th>
<th>TSSA Incidents (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.4</td>
</tr>
<tr>
<td>50</td>
<td>12.5</td>
</tr>
<tr>
<td>90</td>
<td>29.6</td>
</tr>
</tbody>
</table>

- Margin of Error: 9.1%
- Confidence Level: 95%
Safety Issue Analysis – Results (cont’d)

- The recommended sample size to establish a corrosion failure rate is at least 96*, based on the margin of sampling error being tolerated up to 10% at a 95% confidence level

- Based on the minimum recommended sample sizes, the 115 incidents on record thus far are sufficient in ascertaining a service life

One of the outcomes of the risk assessment was an amendment to a Fuel Oil Code Adoption Document (CAD).

CADs are a regulatory instrument used by the TSSA in order to change or modify TSSA-specific requirements. This is the TSSA’s default regulatory instrument for mandatory requirements of general application, such as the adoption of codes and standards. Additions and exclusions may be applied to make the code suitable for Ontario purposes.

As part of the amendment to the CAD, the TSSA has addressed requirements pertaining to new installations and leak detection (please see above for details).
Conclusions and Recommendations

- Evaluating effectiveness of Fuel Oil Code Adoption Document (CAD) Amendment (FS-202-12)

- Establishing replacement intervals for currently used single-wall residential ASTs
  - Using computed failure probabilities
  - Consider grandfathering of those tanks demonstrated by owner to have material integrity and no other issues
Acknowledgements

- John Marshall, Statutory Director of Fuels Safety Program (TSSA) for supporting the initiative

- Christine Ho, Kavitha Ravindran (TSSA) for analytical and editing support at various stages of the project

- Dr. Muddassin Nazir (Morton Jagodich Incorporated and formerly with TSSA) for designing the conceptual prediction model

- Raphael Sumabat (TSSA) and for expert advice
Questions