# Executive summary:

TransCanada Pipelines Limited is proposing the Keystone Pipeline Project to transport a nominal 435,000 bpd (591,000 bpd maximum) of crude oil from facilities near Hardisty, Alberta, to the vicinity of Patoka, Illinois, and to Cushing, Oklahoma.

DNV Consulting is assisting TransCanada with risk management and regulatory compliance for the Keystone Pipeline, specifically, assessing the U.S. portion of the Keystone Pipeline to quantify oil spill risk. The outputs will enable refinement of the ecological assessment being conducted for compliance with the National Environmental Policy Act. This report documents the frequency of potential spilled volumes from the Keystone Pipeline. The current design of Keystone was reviewed and the latest techniques in quantitative risk analysis were used to quantify the likelihood of realistic maximum spill volumes.

The pipeline spill frequency was estimated by adjusting historical pipeline failure frequencies using Keystone-specific modification factors. This study segmented the pipeline into lengths that each pose virtually constant spill frequency based on causes of failure. The relevant failure mechanisms specific to Keystone that could impact the frequency of leaks were identified.

The frequency of failure was estimated for three hole sizes for each cause of failure, for each segment. Overall, the likelihood of a leak greater than 50 barrels anywhere along the pipeline is estimated to be about 0.14 per year, or once every 7 years. The leak volume per mile for Keystone is approximately 0.37 bbl per mile per year. For purposes of comparison, pipelines in the U.S. had a leak frequency of 0.49 bbl per pipeline mile per year during the period 1992 to 2003 (OPS, 2006).

Approximately 53.5% of the spills would be from small holes (pinholes), 32.5% would be from medium sized holes (1 in), and 14% would be from large holes (10 in or greater). The most likely cause of a leak is estimated to be corrosion.

Realistic maximum spill volumes were calculated based on estimated leakrates for each segment and each hole size. Draindown procedures and line depressurization were not accounted for in the spill volume estimates, resulting in conservative estimations of potential maximum spill volumes.

Two throughput scenarios were evaluated, a 435,000 bpd throughput scenario (nominal case) and a 657,000 bpd throughput scenario (best available data to represent the 591,000 bpd case). Cumulative frequency-volume curves were developed, describing the likelihood of a spill of a given volume occurring from the Keystone Pipeline in its current design phase. These curves provide a visual illustration of the risk profile of Keystone.

These two scenarios bound this study of Keystone Pipeline. However, alone they do not provide an accurate picture of potential spills from Keystone. Evaluation of risk requires assessing frequency and consequence together rather than separately, because the worst risk scenario is often not the greatest volume release, because a large volume release often is associated with the smallest frequencies.



EXHIBIT
L. Anderson
21 d
12-5-07

MANAGING RISK DNV

Anderson Exhibit # 21d

Distribution of Hole Sizes for Each Cause

A specific distribution of small, medium and large sized holes was developed and applied for each spill cause (described further in Section 4.0). Note that hole size is not the same as spill volume. Some leaks from small holes could occur for a long period of time and result in a large spill volume because they would not be detected as quickly as some leaks from larger holes.

The estimation of frequency for a given spill volume is linked to hole size, because for any failure cause, one hole size is more or less likely than another. In assessing the distribution of hole sizes for each cause, the failure mechanism and pipe material properties were considered. The size of the hole is a function of many factors including stress levels and material properties such as ductility. For instance, corrosion is characterized by a failure mechanism of slow removal of metal, and therefore is generally prone to result in pinhole-type leaks rather than full bore failures. In contrast, outside forces such as vehicle impact on aboveground pipeline are more likely to cause larger holes.

Three sizes of leak were assessed for each cause:

- Small, equivalent to 0.1 inch diameter hole
- Medium, equivalent to 1 inch diameter hole
- Large, equivalent to 10 inch diameter hole and larger

The representative hole sizes were chosen to allow use of the best statistically significant set of data for pipelines. Further detail regarding the generic data sets used in this analysis is provided in Appendix I..

## 3.2 Segmentation

The pipeline was segmented for this assessment based on an offset of factors, all related to the physical and environmental characteristics that would create unique failure mechanisms for various lengths of pipe. These segments were used as the basis for calculating frequency of spill volumes. DNV defined each segment as the length of pipe over which none of the risk characterization parameters changes significantly.

An alternative approach would have been to define each segment by a static geographic distance; however, the current approach was deemed more suitable for any future spill risk studies incorporating consequence of a spill.

Table 3-3 lists the characterization parameters used as inputs to segmentation.

report the leak immediately, the detection/verification times would be different than if the leak detection system was the only means of identifying a spill.

For the purpose of discussion, a cause is called, "reported" if a person is expected to be present at the scene, and very likely to observe the leak and called it in within a short timeframe (regardless of whether the leak is detectable by the leak detection system). An example is excavation damage. Such an event would likely be observed at the time of the incident, and a phone call would be placed to report that a pipeline had been hit during excavation activities. The two reported causes are:

- Excavation damage
- Hydraulic (pressure surge) event

For reported causes, it is assumed that the leak is observed, reported, verified, and valves instructed to close in the times indicated in Table 5-1.

**Table 5-1 Time from Leak Start to Closure of RGVs for Reported Causes**

| Hole size | Detection | Valve closure |
|---|---|---|
| Small | 30 min | 2.5 min |
| Medium | 15 min | 2.5 min |
| Large | 9 min | 2.5 min |

Non-reported causes are expected to occur without any person present to witness and report the event; thus, the leak detection system and surveillance is assumed to be the only means of leak detection for these causes. For example, a corrosion leak is not normally related to the presence of people who might observe it, and would have to be detected via the Keystone systems designed for that purpose. The non-reported causes are:

- Mechanical defect
- Corrosion (external or internal)
- Flange, seal, and fitting leak
- Washout

The estimated times to detect, verify, initiate valve closure, and complete valve closure (isolation) for non-reported causes are provided in Table 5-2. For large leaks, the time for detection system response is independent of whether the leak is above or below ground. Small leaks below ground (necessarily detected by surveillance) may take significantly longer to detect than small leaks above ground.

Table 5-2 Time from Leak Start to Closure of RGVs for Non-Reported Causes

| Leak Rate | Detection and Verification | | Isolation |
|---|---|---|---|
| | Below Ground Pipe | Above Ground Pipe | Time for RGV to Close |
| Less than 1.5% | 90 days | 14 days | 2.5 min |
| 1.5% | 138 min | 138 min | 2.5 min |
| 15% | 18 min | 18 min | 2.5 min |
| 50% | 9 min | 9 min | 2.5 min |