Prepared for: Keystone Pipeline Project
TransCanada Keystone Pipeline, LP

Pipeline Risk Assessment and Environmental Consequence Analysis

ENSR Corporation
June 2006
Document No.: 10623-004

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1.0 Project Overview

TransCanada Keystone Pipeline, LP (Keystone) proposes to construct and operate a crude oil pipeline and related facilities from Hardisty, Alberta, Canada, to Patoka, Illinois, in the United States (U.S.). The project, known as the Keystone Pipeline Project or Keystone, initially will have the capacity to deliver 435,000 barrels per day (bpd) of crude oil from an oil supply hub near Hardisty to existing terminals in Salisbury, Missouri, and Wood River and Patoka, Illinois. If market conditions warrant expansion in the future, additional pumping capacity could be added to increase the average throughput to 591,000 bpd. Based on shipper interest, Keystone also is considering the construction of two pipeline extensions to take crude oil from terminals in Fort Saskatchewan, Alberta, and deliver to Cushing, Oklahoma.

In total, the Keystone Pipeline Project will consist of approximately 1,833 miles of pipeline, including about 760 miles in Canada and 1,073 miles within the U.S. (**Figure 1-1**). These distances will increase if either or both of two potential pipeline extensions to Fort Saskatchewan, Alberta, or Cushing, Oklahoma, are constructed as discussed below.

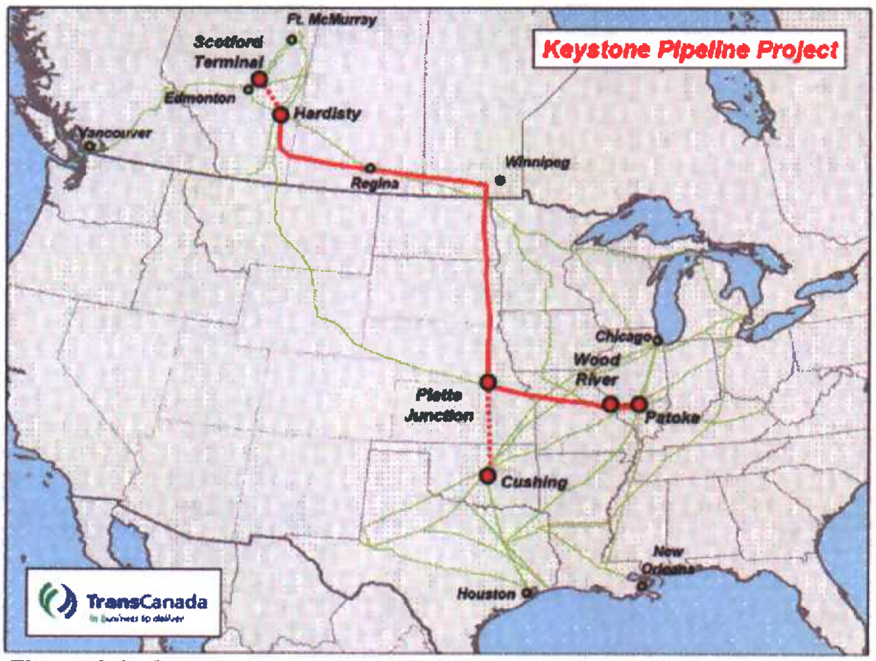

Figure 1-1 Overview Map of the Keystone Pipeline Project (Potential expansions represented by the dotted line)

In the U.S., Keystone will construct and operate a new 1,073-mile pipeline (Keystone Mainline) that will transport crude oil from the Canadian border to existing terminals in the Midwest. The proposed pipeline will consist of 1,018 miles of 30-inch pipe between the Canadian border and Wood River, Illinois and a 55-mile segment of 24-inch pipeline between Wood River and Patoka, Illinois. Depending on the results of an additional binding Open Season to be held later in 2006, Keystone also may construct a 291-mile 30-inch pipeline extension to Cushing, Oklahoma (Cushing Extension). Thus, there will be 1,365 total miles of new pipeline in the U.S. if the Cushing Extension is constructed. Unless specified, the remainder of this Supplemental Filing describes and evaluates the U.S. portion of the Keystone Pipeline Project, including both the Keystone Mainline and Cushing Extension, and the additional facilities required to increase capacity to 591,000 bpd.

The Keystone Pipeline Project will require the issuance of a Presidential Permit by the U.S. Department of State to cross the U.S./Canadian border. Issuance of the Presidential Permit is considered a federal action and is subject to environmental review pursuant to the National Environmental Policy Act (NEPA) (42 United States Code § 4321 et seq.). Keystone filed a Presidential Permit Application and Environmental Report (ER) on April 19, 2006. The ER was intended to provide the Department of State and other involved agencies with adequate information to commence review of the Keystone Pipeline Project under NEPA. The ER includes an objective disclosure of beneficial and adverse environmental impacts resulting from the Keystone Pipeline Project, as well as a set of reasonable alternatives. Keystone has stated that it will supplement the environmental information provided in the ER with the results of its field studies and pipeline risk assessment as they are completed.

2.0 Introduction

This portion of the supplemental filing represents Keystone's initial evaluation of the risk of a pipeline disruption and its potential environmental consequences. This section focuses on the potential for spills during operations and the subsequent potential effects on sensitive resources and humans associated with major spills. Additional effects on public health and safety that could occur during project construction are discussed under other resource sections (e.g., air quality, water resources, transportation, land use, and aesthetics) within the Keystone Pipeline Project's ER, which was submitted to the Department of State on April 19, 2006.

General information on pipeline safety and historical spills as documented in the U.S. Department of Transportation (USDOT) incident database were previously presented in Section 3.12 of the ER. Section 3.12 of the ER also summarized the location and extent of natural hazards and sensitive natural and human resources near the Keystone Pipeline Project.

This report builds upon the baseline information presented in the ER. The report presents the results of a pipeline oil spill frequency and spill analysis based on Keystone's current project-specific design and operations criteria and applies the resulting risk probabilities to an environmental consequence analysis that incorporates project-specific environmental data. Specifically, this report evaluates the risk of crude oil spills during pipeline operations, including contribution of natural hazards to spill risk, and the subsequent potential effects on humans and other sensitive resources, called high consequence areas (HCAs), that include populated areas, drinking water areas, and/or ecologically sensitive areas.

As Keystone collects additional information to support the risk assessment through ongoing design work and environmental field surveys, this risk assessment and its supporting reference documents will continue to evolve. The risk assessment process is an iterative procedure in which information is continually updated and refined in an effort to improve the specificity of the assessment. Keystone anticipates submitting an updated consequence analysis in November 2006 that incorporates the additional design and environmental data into the assessment.

3.0 Spill Frequency-Volume Study

A project-specific oil spill frequency and volume study for the Keystone Pipeline Project was conducted by DNV Consulting and is provided in **Appendix A**. DNV Consulting assessed the U.S. portion of the Keystone Pipeline in terms of frequency and volume of potential spills to quantify the likelihood of realistic maximum spill volumes. The study estimated the frequency and volume of releases for each defined pipeline segment for three postulated hole sizes and six distinct and independent failure causes, and developed a frequency-volume curve for the pipeline as a whole.

The study is a quantitative assessment of spill potential for the entire pipeline system and of individual segments of the pipeline. The Keystone Pipeline system was partitioned into 1,317 segments based on similar design, operational, terrain, and other potential risk parameters, each with a virtually consistent risk profile. Spill frequency was estimated for each segment along with potential spill volumes, based on small holes (<0.1-inch diameter), medium holes (1-inch diameter), and large holes (>10-inch diameter).

Two throughput scenarios were evaluated, a 435,000 bpd and a 591,000 bpd throughput case (nominal and maximum throughput). For the assessment, a leak detection capability of 1.5 percent in 138 minutes and a 15 percent leak detected within 18 minutes was assumed. Because Keystone is currently engineering the pipeline system, a detailed hydraulic profile and leak detection systems are not currently available. As the engineering and design progresses, the information will be integrated into the study and revised spill frequency and spill volumes will be estimated.

3.1 Spill Frequency

Spill frequencies were estimated from historical data and modified by project-specific factors to estimate spill frequencies for the Keystone Pipeline system. Based on the available information, the study produced an overall frequency for spills or leaks greater than 50 barrels of 0.14 spills per year for a throughput of 435,000 bpd over the entire pipeline system, equivalent to one spill every 7 years. **Table 3-1** shows the number of spills that might occur along the Keystone Pipeline system during the next 10 years.

Table 3-1 Spill Occurrence Interval Associated with the Proposed Keystone Project over 10 Years

	Spills[1]
Keystone Mainline (1,073 miles)	1.1
Cushing Extension (291 miles)	0.3
Total Keystone Project (1,365 miles)	1.4

[1]Calculated based on project-specific analysis of spill probabilities for 435,000 bpd (**Appendix A**).

While future events cannot be known with absolute certainty, spill frequencies can be used to estimate the number of events that might occur. Actual frequency may differ from the predicted values of this analysis. Notably, with the implementation of USDOT's Integrity Management Rule, the number of spills is expected to decline from historical levels observed on other pipelines. Incident frequencies have been steadily decreasing and are five times lower in recent years compared with thirty years ago (EGIG 2005).

3.2 Spill Volume

Estimated spill volumes were based on leak rate and time to isolate for throughputs of 435,000 and 591,000 bpd along the Keystone Pipeline system. The study currently assumes complete drain down within the affected segment, recognizing that actual spill volumes are expected to be significantly less. Actual incident data from the *Hazardous Liquid Pipeline Risk Assessment* (California State Fire Marshal 1993) indicate that spill volumes are significantly less than the potential drain down volume. For example, in 50 percent of the cases, the actual spill volume represented less than 0.75 percent of the maximum potential drain down volume. In 75 percent of the cases, the actual spill volume represented less than 4.6 percent of the maximum drain down volume. Procedures to reduce spill volume, such as depressurization and drain down, may significantly reduce the predicted spill volumes estimated for the Keystone Pipeline, bringing the spill volume distribution more in line with USDOT historical data. Spill volume estimates, revised to account for drain down and depressurization, will be included in Keystone's November 2006 Supplemental filing.

Of the postulated 1.4 spills along the Keystone Pipeline system during a 10-year period, the study's findings suggest that approximately 0.2 would be 50 barrels or less; 0.8 would consist of between 50 and 1,000 barrels; 0.3 would consist of between 1,000 and 10,000 barrels; and 0.2 would contain more than 10,000 barrels[1] (**Appendix A**). The spill volume frequency distribution likely underestimates the proportion of spill volumes under 50 barrels due to reliance upon the greater than 50 barrel reporting criteria within the USDOT incident database. The current analysis tends to overemphasize larger spills and underreport the small spills, making the assessment conservative.

Based on probabilities generated from the study, the estimated occurrence intervals for a spill of 50 barrels or less occurring anywhere along the entire pipeline system is once every 65 years, a spill between 50 and 1,000 barrels might occur once in 12 years; a spill of 1,000 and 10,000 barrels might occur once in 39 years; and a spill containing more than 10,000 barrels might occur once in 50 years. Applying these statistics to a 1-mile section, the chances of a large spill (greater than 10,000 barrels) would be less than once every 67,000 years. The results of the study are incorporated into the environmental consequence analysis presented in Section 4.0 below.

3.3 Contribution of Natural Hazards to Spill Potential

As part of its National Pipeline Mapping System (NPMS) program, the USDOT has compiled data from a variety of sources to identify areas of high geologic hazard potential for pipelines (USDOT-NPMS 2005). The Integrity Management Rule (2002) states that segments of pipeline with a high geologic risk and the potential to impact HCAs must implement protective measures. HCAs are specific locales and areas where a release could have the most significant adverse consequences. Examples of protective measures may include: enhanced damage prevention programs, reduced inspection intervals, corrosion control program improvements, leak detection system enhancements, installation of Emergency Flow Restricting Devices (EFRDs), and emergency preparedness improvements. **Table 3-2** provides a summary of the geologic hazards and pipeline miles identified with HCAs.

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[1] Total does not sum to 1.4 spills due to rounding.

Table 3-2 Summary of Geological Hazard HCAs Identified Along the Keystone Pipeline Project

	Potential Geological Hazards (miles of pipeline)		
	Earthquake	**Flood**	**Landslide**
Keystone Mainline			
North Dakota	0.0	3.0	0.0
South Dakota	0.0	21.9	7.7
Nebraska	0.0	21.9	13.1
Kansas	0.0	10.9	0.0
Missouri	0.0	99.5	30.1
Illinois	0.0	12.8	6.9
Keystone Mainline subtotal	*0.0*	*170.1*	*57.8*
Cushing Extension			
Nebraska	0.0	2.5	2.5
Kansas	0.0	107.2	7.0
Oklahoma	0.0	27.8	0.0
Cushing Extension Subtotal	*0.0*	*137.4*	*9.5*
Project Total	**0.0**	**307.5**	**67.3**

Seismicity and Faults. Seismic damage to buried pipelines is due to the combination of seismic wave propagation and permanent ground displacement. Strong ground shaking also can cause water-saturated soils to become liquified (liquifaction). Earthquakes tend to cause more damage to segmented pipelines than to continuous pipelines that have joints consisting of full penetration welded steel. The Keystone Pipeline will be a continuous pipeline. Buckling and pinhole leaks (typically at previously weakened areas of corrosion) are the most common types of pipeline damage caused by seismic events.

Nationwide, earthquakes (and other natural hazards) are responsible for less than 3 percent of all pipeline incidents each year. Moreover, O'Rourke and Palmer (1996) studied earthquake performance data for steel transmission and distribution pipelines over a 61-year period. Their review of the data found that post-1945 electric arc-welded transmission pipelines in good repair have performed very well in earthquakes.

Keystone will construct all new facilities to current Uniform Building Code standards. Additional engineering measures to account for seismic activity are not expected to be required due to relatively low seismic activity in the region crossed by the Keystone Pipeline Project.

Federal regulations (49 CFR 195) require Keystone to conduct an internal inspection if an earthquake, landslide, or soil liquefaction is suspected of having caused abnormal movement of the pipeline. Consequently, damage to the pipeline would be detected quickly and spills would be averted or minimized. The likelihood of earthquake damage to the Keystone Pipeline is low, as the entire Keystone Pipeline Project falls outside of the USDOT-defined high earthquake hazard areas.

Landslides. Three segments of the Keystone Pipeline Project cross areas identified by the NPMS as having high landslide potential (**Table 3-2**). These areas are located at 1) the Missouri River crossing near Yankton, South Dakota; 2) the Nebraska-Kansas border at Silver Hills; and 3) the Missouri and Mississippi River crossings. These areas will be field verified and evaluated for recent landslide activity and determination of whether HCAs could be impacted. Overall, landslides are considered a low hazard to the Keystone Pipeline system.

Subsidence. Subsidence of the ground surface can result in damage due to loss of support and the transfer of stresses in the ground to structures and facilities. Subsidence can be caused by several factors, but the cause of subsidence considered here is the dissolution of subsurface strata. Limestone, dolomite, gypsum or other susceptible rock is susceptible to water solution. The dissolution may cause surface effects such as sinkholes or depressions of the ground surface, caves, sinking streams, springs and seeps, and valleys with closed drainage (Kastning and Kastning 1999). The surface effects of dissolution are referred to as karst terrain.

Several areas of potential karst hazards were identified along the proposed route based on the map produced by Davies et al. (1984). In South Dakota and Nebraska, Upper Cretaceous Niobrara Formation and equivalents are identified as strata that could be involved in the formation of karst. Areas in northeast Kansas and Missouri are underlain by limestones in Pennsylvanian and Permian-age strata. The solution features are characterized as irregularly spaced (1,000 feet or more) small fissures (less than 1,000 feet long and 50 feet deep) with 50 feet or more overburden. Overall, subsidence is a low hazard to the Keystone Pipeline System.

Flooding. Scattered portions of the Keystone Pipeline Project cross areas that are ranked as high flood hazard areas by the NPMS (**Table 3-2**). These areas are more prevalent along the southern portion of the route and are generally collocated with major river systems, such as the Missouri, Platte, Kansas, Arkansas, and Mississippi Rivers. These areas will be field verified and cross-checked with Federal Emergency Management Agency flood maps. If the area is highly susceptible to flooding, then the portion of pipeline within the affected area will be cross-referenced for presence of HCAs and, if present, protective measures will be taken, as per 49 CFR Part 195. Additionally, if aboveground facilities are located within potential floodplains, Keystone will evaluate the potential for relocating these facilities and/or measures to reduce damage to aboveground facilities should flooding occur.

4.0 Consequences of a Spill

4.1 Human Consequences

The risk associated with the Keystone Pipeline system can be compared with the general risk to the population encountered in everyday life. Proposed actions that result in negligible additional risk are generally acceptable. The National Center for Health Statistics (CDC 2003) age-adjusted average annual death rate in the U.S. is approximately 830 per 100,000. The USDOT reports the historical average risk to the general population per year associated with hazardous liquids transmission pipelines, such as Keystone, is 1 in 27,708,096 (USDOT 2002). Therefore, the predicted risk of fatality to the public from incidents associated with the Keystone Pipeline over and above the normal U.S. death rate is negligible (<1 percent).

4.2 Environmental Consequences

The environmental risk posed by a crude oil pipeline is a function of 1) the probability of an accidental release, 2) the probability of a release reaching an environmental receptor (e.g., waterbody, fish), 3) the concentration of the contamination once it reaches the receptor, and 4) the hazard posed by that concentration of crude oil to the receptor. Based on spill probabilities and estimated spill volumes, this environmental assessment determines the probability of exposure to environmental receptors and the probable impacts based on a range of potential concentrations.

4.2.1 Environmental Fate of Crude Oil Spills

4.2.1.1 Crude Oil Composition

The composition of crude oil varies widely, depending on the source and processing. Crude oils are complex mixtures of hundreds of organic (and a few inorganic) compounds. These compounds differ in their solubility, toxicity, persistence, and other properties that profoundly affect their impact on the environment. The effects of a specific crude oil cannot be thoroughly understood without taking its composition into account.

Crude oil transported by the Keystone Pipeline Project is derived from the Alberta oil sands region. The oil extracted from the sands is called bitumen, a black and thick oil. In order for the bitumen to be transported by pipeline, an upgrading technology is applied to convert the bitumen to synthetic crude oil. The precise composition of synthetic crude will vary by shipper and is considered proprietary information.

The primary classes of compounds found in crude oil are alkanes (hydrocarbon chains), cycloalkanes (hydrocarbons containing saturated carbon rings), and aromatics (hydrocarbons with unsaturated carbon rings). Most crude oils are more than 95 percent carbon and hydrogen, with small amounts of sulfur, nitrogen, oxygen, and traces of other elements. Crude oils contain lightweight straight-chained alkanes (e.g., hexane, heptane), cycloalkanes (e.g., cyclyohexane), aromatics (e.g., benzene, toluene), cycloalkanes, and heavy aromatic hydrocarbons (e.g., polycyclic aromatic hydrocarbons [PAHs], asphaltines). Straight-chained alkanes are more easily degraded in the environment than branched alkanes. Cycloalkanes are extremely resistant to biodegradation. Aromatics (i.e., benzene, toluene, ethylbenzene, xylenes [BTEX compounds]) pose the most potential for environmental concern. Because of their lower molecular weight they are more soluble in water than alkanes and cycloalkanes.

4.2.1.2 Environmental Fate and Transport

Accidental releases of crude oil can occur during transport by pipeline. Once released into the environment, the crude oil will pool in low-lying areas. Some lighter volatile constituents of the crude oil will evaporate into air, while other constituents will bind or leach into soils, or dissolve into water. Hydrocarbons that volatilize into