3.0 ENVIRONMENTAL ANALYSIS

The environmental consequences of constructing and operating the proposed Keystone Project would vary in duration and significance. Four levels of impact duration were considered: temporary, short term, long term, and permanent. Temporary impacts generally occur during construction, with the resources returning to pre-construction conditions almost immediately afterward. Short-term impacts could continue for approximately 3 years following construction. Impacts were considered long term if the resources would require more than 3 years to recover. Permanent impacts would occur as a result of activities that modify resources to the extent that they would not return to pre-construction conditions during the life of the proposed Keystone Project, such as with construction of aboveground structures. An impact resulting in a substantial adverse change in the environment would be considered significant.

This section discusses the affected environment, construction and operations impacts, and mitigation for each affected resource. Keystone has indicated that it would implement certain measures to reduce environmental impacts. These measures have been evaluated and additional measures that might be necessary to further reduce impacts are recommended. The recommended measures are shown as bulleted, boldface paragraphs in the text of the EIS.

Conclusions in this EIS are based on the analysis of environmental impacts and the following assumptions:

- Keystone would comply with all applicable laws and regulations,
- The proposed facilities would be constructed as described in Section 2.0 of this EIS, and
- Keystone would implement the mitigation measures identified in the Environmental Report (ENSR 2006a) and supplemental filings to the DOS.

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3.1 GEOLOGY

3.1.1 Physiography and Surface and Bedrock Geology

3.1.1.1 Affected Environment

The proposed Keystone Project ROW crosses the U.S./Canada border at the western edge of the Lake Agassiz Plain, and then ascends the Pembina Escarpment to the Northern Glaciated Plains (Bryce et al. 1998). The Lake Agassiz Plain is named for glacial Lake Agassiz, the most recent in a series of proglacial lakes that, during the Pleistocene, filled what is now the Red River Valley. The resulting plain is composed of lacustrine sediments underlain by glacial till; it is extremely flat except at its margins, where sandy former deltas and beach ridges mark the multiple shorelines of glacial Lake Agassiz. The Pembina Escarpment marks the northeastern boundary of the Northern Glaciated Plains, a flat to gently rolling region of fertile glacial drift dotted with temporary and seasonal wetlands. The proposed Keystone Project ROW traverses most of North Dakota and all of South Dakota within the Northern Glaciated Plains.

South of its Missouri River crossing at the South Dakota/Nebraska border, the proposed ROW crosses the Western Corn Belt Plains for 65 miles before entering the Central Great Plains near Columbus, Nebraska (Chapman et al. 2001). The proposed route continues south through the Central Great Plains to the Smoky Hills, north of the Kansas/Nebraska border, where the proposed Mainline Project ROW turns east-southeast and crosses Kansas within the Western Corn Belt Plains to another crossing of the Missouri River at the Kansas/Missouri border. The Western Corn Belt Plains are characterized by level to gently rolling plains formed in glacial till, locally interrupted by moraine hills and loess deposits. The Central Great Plains crossed by the proposed ROW include the rolling dissected Central Nebraska Loess Plains, the alluvial Platte River valley, and the Rainwater Basin Plains, flat to rolling loess plains with many closed watersheds that formerly supported natural wetlands. The proposed Cushing Extension branches off at the point where the proposed Mainline Project turns eastward.

Twenty miles into Missouri the proposed Mainline Project ROW crosses into the Central Irregular Plains, where it remains until it descends into the Interior River Valleys and Hills region, approaches the Mississippi River, and crosses into Illinois before reaching its terminus at Patoka, Illinois (Chapman et al. 2002, Woods et al. 2006). The Central Irregular Plains are a region of gentle irregularly-dissected topography built upon clayey glacial drift. Toward the eastern edge of the region, the topography is flatter—with streams that drain east toward the Mississippi, entering the Interior River Valleys and Hills region as they go. The Interior River Valleys and Hills region incorporates wide alluvial valleys and terraces, forested river bluffs and hills, and partially-dissected till plains, underlain by Paleozoic sedimentary rocks.

Because the geological surface traversed by the proposed Keystone Project has been formed by a series of continental glacial advances and retreats, much of the proposed ROW is underlain by thick Quaternary sediments where depth to bedrock is typically much greater than 5 feet. There are about 331 miles of the proposed alignment where soil types suggest the potential for zones of shallow bedrock. This bedrock-controlled terrain is located primarily within the Missouri and Mississippi River valleys and locally found along the more deeply incised stream valleys.

Mainline Project Route

North Dakota

Throughout North Dakota, the proposed Mainline Project ROW lies within the Dakota-Minnesota Drift and Lake-Bed Flats physiographic subdivision (Hammond 1965), an area of low-relief glacial moraines and lakebeds (Radbruch-Hall et al. 1982). The proposed ROW traverses seven EPA Level IV Ecoregions, each with a distinct physiography (Bryce et al. 1998). Regional physiographic characteristics are presented in detail in Table 3.1.1-1.

The proposed Mainline Project ROW crosses the U.S./Canada border in the Red River Valley, part of the Lake Agassiz Plain. After crossing the Pembina River at MP 7, the proposed ROW ascends the Pembina Escarpment, and then runs roughly parallel to the Pembina Hills above the western edge of the Red River Valley for the remainder of its path through North Dakota.

Elevations along the proposed route range between 950 and 1,550 feet above mean sea level (amsl). The greatest local relief is found where the proposed ROW crosses the Pembina and Sheyenne River valleys; elevation changes between river crossing and valley wall are on the order of 200–300 feet (ENSR 2006a).

Surface materials along most of the proposed Mainline Project route consist of unconsolidated alluvium, lake sediments, and glacial drift (Bluemle 1977), although bedrock consisting of Upper Cretaceous marine shale and limestone is exposed at outcrops along gullies and valleys in the Pembina Escarpment (Bluemle and Ashworth 2002). About 4 miles of potential shallow bedrock lie along the proposed Mainline Project ROW in North Dakota.

There are no known areas of karst along the proposed Mainline Project route in North Dakota.

South Dakota

The proposed Mainline Project ROW continues through South Dakota within the Dakota-Minnesota Drift and Lake-Bed Flats physiographic subdivision (Hammond 1965). It traverses five EPA Level IV Ecoregions (Bryce et al. 1998), physiographic characteristics of which are presented in detail in Table 3.1.1-2.

The proposed ROW enters South Dakota at MP 218 and proceeds southward along the James River Valley, a broad north-south trending valley of low relief situated between the Coteau du Prairies to the east and the Coteau du Missouri to the west (SDSGS 1964).

Elevations along the proposed route range between 1,300 and 1,150 feet amsl. Local relief is slight except where the ROW crosses the James River and also where it descends to the Missouri River Valley. Elevation changes at the James River crossing are about 140 feet and those at the edge of the Missouri River valley are about 100 feet (ENSR 2006a).

Surface deposits consist of glacial till, loess, and alluvium (Martin et al. 2004). For the most part the underlying bedrock is similar to that described for North Dakota, consisting of shale, limestone, and sandstone of the Pierre Shale, Niobrara Formation, Carlile Shale, and Greenhorn Formation (Martin et al. 2004). Dakota Formation sandstone and shale may be present in places, and in Hanson County (MP 365–378) some bedrock consists of Precambrian quartzite (ENSR 2006a). Outcrops are occasionally present along road cuts and streams in South Dakota, but the proposed Mainline Project ROW does not cross any areas of known potential shallow bedrock.

TABLE 3.1.1-1
Physiographic Characteristics of Ecoregions Crossed in North Dakota by the Keystone Mainline Project

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Lake Agassiz Plain—Glacial Lake Agassiz Basin [a]					
0–6	Extremely flat glacial lake plain. Streams and rivers sluggish, meandering, and highly turbid with large sediment loads. Ditching and channelization common.	790–1,200	1–50	150–300 feet of glacial drift overlain by up to 95-foot silt/clay lake deposits	Cretaceous shales and sandstones, Ordovician and Precambrian basement
Lake Agassiz Plain—Sand Deltas and Beach Ridges [a]					
6–16	Parallel ridges up to several miles wide composed of medium sand to medium gravel. Deltas comprised of lenses of fine to coarse sands. Thickest sand deposits windblown into dunes. Stream substrates, sand or gravel riffles contrast with clay- and silt-bottom streams elsewhere in Red River Valley.	900–1,200	40–250	Stratified sand and gravel beach deposits interlayered with lacustrine silts and sandy deltaic lenses	Cretaceous shales and sandstones, Ordovician and Precambrian basement
Northern Glaciated Plains—Pembina Escarpment [a]					
16–43	Glaciated. Steep, dissected escarpment. High-gradient perennial streams.	1,225–1,580	100–400	Glacial till	Tertiary sandstone and shale
Northern Glaciated Plains—Drift Plains [a]					
43–111, 134–197, 199–207	Glaciated. Generally flat, with occasional "washboard" undulations. High concentrations of temporary and seasonal wetlands. Simple drainage pattern.	1,080–2,000	0–200	Glacial till	Cretaceous Pierre Shale and Fox Hills Formations
Northern Glaciated Plains—End Moraine Complex [a]					
111–134	Glaciated. A diverse area of hummocky stagnation moraine; parallel end moraine ridges; and other glacial features such as eskers, kames, and thrust ridges.	1,450–1,790	20–179	Glacial till and outwash	--

TABLE 3.1.1-1
(Continued)

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Northern Glaciated Plains—Glacial Outwash [a]					
207–211	Glaciated. Flat to slightly rolling. Ancient channel depressions, relict lakes.	1,300–1,550	0–50	Sand and plane-bedded gravel, sediments of glacial meltwater rivers	--
Northern Glaciated Plains—Glacial Lake Deltas [a]					
211–218	Glaciated. Flat sheets of sand and gravel or rolling sand dunes. Paucity of stream channels.	1,290–1,595	6–85	Sand and gravel deposits over lacustrine sediments	--

-- = Not available.

[a] EPA Level III-IV Ecoregion name.

Sources: Bryce et al. 1998; mile posts taken from TransCanada 2007d.

TABLE 3.1.1-2
Physiographic Characteristics of Ecoregions Crossed in South Dakota by the Keystone Mainline Project

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Northern Glaciated Plains – Glacial Lake Deltas [a]					
218–223, 228–232	*See Table 3.1.1-1.*				
Northern Glaciated Plains–Glacial Lake Basins [a]					
223–228, 232–247	Glaciated. Very level glacial lake floors. Low wetland density.	1,300–1,585	0–30	Glacial lacustrine silts and clays	NA
Northern Glaciated Plains–Drift Plains [a]					
247–265	*See Table 3.1.1-1.*				
Northern Glaciated Plains–Prairie Coteau [a]					
265–273	Glaciated. Platform of hummocky, rolling terrain raised above surrounding drift plains. Stream network lacking. High concentration of large lakes and wetlands.	1,500–2,010	50–150	Glacial till	Cretaceous shales
Northern Glaciated Plains–James River Lowland [a]					
307–436	Glaciated. Level to slightly rolling plain composed of glacial drift. Dense concentrations of temporary and seasonal wetlands.	1,200–1,850	10–150	Glacial till	Cretaceous Pierre Shale and Niobrara sandstone
Western Corn Belt Plains – Missouri Alluvial Plains [a]					
436–438	Smooth to irregular alluvial plain. Channelized streams.	600–1,100	0–50	Alluvium	Pennsylvanian and Cretaceous shale, sandstone, and limestone

NA = Not applicable.

[a] EPA Level III-IV Ecoregion name.

Sources: Bryce et al. 1998; mile posts taken from TransCanada 2007d.

In the southern half of the state, karst may be present from MP 353 to the border with Nebraska; karst features are found in southern portions of Miner County, northern Hanson County, southern Hutchinson County, and all of Yankton County (ENSR 2006a), where carbonate rocks of the Niobrara Formation can form fissures up to 1,000 feet long and 100 feet deep, spaced at intervals of 1,000 feet or more (Tobin and Weary 2005). Where fissures are likely to occur, however, 50 feet or more of Quaternary sediments cover the carbonate rocks.

Nebraska

The proposed Mainline Project ROW crosses Nebraska within the Middle Western Upland Plain and West-Central Rolling Hills physiographic subdivisions (Hammond 1965). It traverses six EPA Level IV Ecoregions (Chapman et al. 2001), physiographic characteristics of which are presented in detail in Table 3.1.1-3.

The proposed ROW enters Nebraska at MP 438 and proceeds southward across the Western Corn Belt Plains to the Platte River Valley. It then continues south across the Central Great Plains to the Smoky Hills, a few miles north of the Kansas/Nebraska border, where it turns to the east-southeast and crosses into Kansas.

Elevations along the proposed route range between 1,150 and 1,800 feet amsl. Significant local relief is found near the Missouri and Elkhorn Rivers; elevation changes along the Elkhorn River crossing are about 140 feet, those at the edge of the Missouri River valley are about 100 feet (ENSR 2006a).

Surface deposits consist of glacial till, loess, and alluvium. Underlying bedrock consists of shale, limestone, and sandstone of the Pierre Shale, Niobrara Formation, Carlisle Shale, Greenhorn Formation, and Graneros Shale (Bennison and Chenowith 1984). Dakota Formation sandstone and shale underlie the proposed route from Butler County to the Kansas border. There are about 3 miles of potential shallow bedrock along the proposed route in Nebraska.

Karst features exist between MP 436 and 520 in Cedar and Wayne Counties (Tobin and Weary 2005) where the proposed ROW is underlain by carbonate rocks of the Niobrara Formation (Burchett 1986).

Kansas

The proposed Mainline Project ROW crosses Kansas within the West-Central Rolling Hills physiographic province (Hammond 1965). It traverses three EPA Level IV Ecoregions (Chapman et al. 2001), physiographic characteristics of which are presented in detail in Table 3.1.1-4.

The proposed ROW enters Kansas at MP 652 and then proceeds east-southeast across the Western Corn Belt Plains to the Missouri River Valley.

Elevations along the proposed route range between 790 and 1,500 feet amsl. The greatest relief is found at the edge of the Missouri River valley, where the proposed route descends about 220 feet from the bluffs to the floodplain. Relatively high local relief—on the order of 100 to 130 feet—is also found where the proposed route crosses the Big Blue and Nemaha Rivers (ENSR 2006a).

TABLE 3.1.1-3
Physiographic Characteristics of Ecoregions Crossed in Nebraska by the Keystone Mainline Project

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Western Corn Belt Plains–Northeastern Nebraska Loess Hills [a]					
438–501	Glaciated. Rolling low hills. Perennial streams.	1,100–1,900	100–300	Deep calcareous loess	Cretaceous shale, sandstone, and limestone, Oglalla Formation
Western Corn Belt Plains–Transitional Sandy Plains [a]					
501–506	Level to rolling plains.	1,400–2,000	5–150	Alluvial sand and gravel, lacustrine silt	Miocene sandstone of the Oglalla Formation
Central Great Plains–Platte River Valley [a]					
532–547	Flat, wide alluvial valley. Shallow, interlacing streams on a sandy bed.	1,300–2,900	2–75	Alluvial sand, silt, clay and gravel	Quaternary and Tertiary unconsolidated sand and gravel
Central Great Plains–Rainwater Basin Plains [a]					
547–634	Flat to gently rolling loess-covered plains. Historically, extensive rainwater basins, and wetlands.	1,300–2,400	5–100	Quaternary loess and sandy alluvium	Tertiary Oglalla sandstone, Cretaceous Niobrara, Carlisle limestone and shale
Central Great Plains–Smoky Hills [a]					
634–652	Undulating to hilly dissected plain. Broad belt of low hills formed by mature dissection of Cretaceous rock layers.	1,200–1,800	100–250	Local thin loess, loamy colluvium	Chalky limestone, Cretaceous sandstone of the Dakota Formation

[a] EPA Level III-IV Ecoregion name.

Sources: Chapman et al. 2001; mile posts taken from TransCanada 2007d.

TABLE 3.1.1-4
Physiographic Characteristics of Ecoregions Crossed in Kansas by the Keystone Mainline Project

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Central Great Plains – Smoky Hills [a]					
652–658	*See Table 3.1.1-3.*				
Western Corn Belt Plains –Glacial Drift Hills [a]					
658–729	Glaciated. Rolling low hills. Perennial streams.	1,000–1,600	40–250	Loess and clay-loam calcareous till	Pennsylvanian shale, sandstone, limestone, Permian shale, limestone
Western Corn Belt Plains–Nebraska-Kansas Loess Hills [a]					
729–751	Glaciated. Deep, rolling loess-covered hills. Perennial streams.	1,000–1,500	100–300	Loess over calcareous till	Pennsylvanian shale, sandstone, limestone

[a] EPA Level III-IV Ecoregion name.

Sources: Chapman et al. 2001; mile posts taken from TransCanada 2007d.

Surface materials consist of glacial drift—till, lake deposits, and loess—with alluvium in river valleys and smaller drainages (SGSK 1964). Glacial deposits are generally not continuous or thick, and bedrock units are exposed along some valleys; but loess deposits can be more than 100 feet deep. Underlying bedrock consists of Pennsylvanian limestone, shale, and localized sandstones of the Shawnee and Wabaunsee Groups and Permian limestone and shale of the Admire, Council Grove, Chase, and Sumner Groups. Permian rocks are found in Marshall, Nemaha, and western Brown Counties, while the Pennsylvanian rocks are found in eastern Brown and Doniphan Counties (SGSK 1964). There are about 4 miles of potential shallow bedrock along the proposed route in Kansas.

There are no known areas of karst along the proposed Mainline Project route in Kansas.

Missouri

The proposed Mainline Project ROW crosses Missouri within the West-Central Rolling Hills, Mid-continent Plains and Escarpments, and Middle Western Upland Plain physiographic provinces (Hammond 1965). It traverses five EPA Level IV Ecoregions (Chapman et al. 2002), physiographic characteristics of which are presented in detail in Table 3.1.1-5.

The proposed ROW enters Missouri at MP 751 and proceeds across irregular plains and low hills until it drops down into the Upper Mississippi Alluvial Plain and crosses into Illinois at approximately MP 1025.

Elevations along the proposed route range from between 790 and 1,165 feet amsl in northwestern Missouri to 400 feet amsl at the Mississippi River (ENSR 2006a). Relief is generally low to moderate, with rolling hills and dissected drainages (Chapman et al. 2002). Areas of steep relief are found adjacent to the major river valleys. The greatest elevation change is in northwest Missouri, where the elevation change at the edge of the Missouri River floodplain is about 250 feet.

Surface deposits consist of alluvium and glacial drift composed of till and loess. Most of northern Missouri is covered with a mantle of glacial drift. Alluvium is present in the river valleys and is especially thick in the flood plains of the Mississippi and Missouri Rivers. Underlying bedrock consists of Pennsylvanian sandstone, limestone, shale, and coal (Oetking et al. 1966) in the northwest corner of the state and for a small distance west of the Mississippi River north of St. Louis, and Mississippian cherty limestone with minor amounts of shale and sandstone from Montgomery County to the Mississippi River. There are about 31 miles of potential shallow bedrock along the Mainline Project route in Missouri.

Karst features are found along the Mainline Project route in Lincoln and St. Charles Counties. Bedrock with karst potential is found from MP 735 through 811 (but karst features are exceptionally rare, if not completely absent) and between MP 946 and the Illinois border. The potential karst has been characterized as fissures, tubes, and caves usually less than 1,000 feet long and less than 50 feet deep (Tobin and Weary 2005).

Illinois

The proposed Mainline Project ROW crosses Illinois within the Middle Western Upland Plain physiographic subdivision (Hammond 1965). It traverses three EPA Level IV Ecoregions (Woods et al. 2006), physiographic characteristics of which are presented in detail in Table 3.1.1-6.

The proposed ROW enters Illinois at MP 1025 and proceeds across the Mississippi Alluvial Plain for approximately 60 miles before climbing the River Hills up to Patoka.

TABLE 3.1.1-5
Physiographic Characteristics of Ecoregions Crossed in Missouri by the Keystone Mainline Project

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Western Corn Belt Plains – Missouri Alluvial Plain [a]					
751–753, 841–846	*See Table 3.1.1-3.*				
Western Corn Belt Plains–Rolling Loess Prairies [a]					
753–768	Irregular plains to open low hills. Intermittent and perennial streams, many channelized.	700–1,300	100–200	Moderate to thick loess, generally less than 25 feet, over clay loam till	Pennsylvanian and Cretaceous shale, sandstone, and limestone
Central Irregular Plains–Loess Flats and Till Plains [a]					
768–841	Glaciated. Low hills and smooth plains. Perennial streams with many channelized.	600–1,200	100–300	Moderate loess over loamy till and clay loam till	Pennsylvanian sandstone, limestone, and shale
Central Irregular Plains–Claypan Prairie [a]					
846–939, 944–947	Glaciated. Smooth plains. Perennial streams with many channelized.	700–1,000	50–100	Loamy till and clay loam till, well developed claypan	Pennsylvanian sandstone, limestone, and shale
Interior River Valleys and Hills–River Hills [a]					
939–944, 947–984	Bluffs, valleys, and low hills. Areas of karst features. Perennial streams. Missouri River channelized.	400–810	50–300	Thin cherty clay and silty to sandy clay solution residuum; areas of clay loam till along the northern boundary along the Missouri River and eastern boundary of the upper Mississippi River; thin loess, 5 to 13 feet, on uplands along bluffs; alluvium along the Missouri and Mississippi Rivers	Ordovician, Mississippian, and Pennsylvanian limestones, sandstones, and shales with considerable bedrock exposures throughout the region

TABLE 3.1.1-5 (continued)

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Interior River Valleys and Hills – Upper Mississippi Alluvial Plain [a]					
984–1001	Broad floodplains and low terraces of the Mississippi River (and its major tributaries) upstream of the confluence with the Missouri River. Levees, oxbow lakes, islands, disjunct sand sheets, and scattered dunes.	420–600	< 50	Quaternary alluvium, outwash deposits, and slackwater deposits	Paleozoic sedimentary rock; bedrock is deeply covered by Quaternary sediments
Interior River Valleys and Hills–Middle Mississippi Alluvial Plain [a]					
1001–1025	Broad floodplains and low terraces, levees, oxbow lakes, islands, spring-fed swamps, sand sheets and scattered dunes.	350–420	< 50	Deep Quaternary alluvial, outwash, and slackwater sediments	Paleozoic sedimentary rocks

[a] EPA Level III-IV Ecoregion name.

Sources: Chapman et al. 2002; mile posts taken from TransCanada 2007d.

TABLE 3.1.1-6
Physiographic Characteristics of Ecoregions Crossed in Illinois by the Keystone Mainline Project

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Interior River Valleys and Hills–Middle Mississippi Alluvial Plain [a]					
1025–1026	Broad floodplains and low terraces, levees, oxbow lakes, islands, spring-fed swamps, sand sheets and scattered dunes.	350–420	< 50	Deep Quaternary alluvial, outwash, and slackwater sediments	Paleozoic sedimentary rocks
Interior River Valleys and Hills–River Hills [a]					
1026–1082	Formerly glaciated rugged hills, bluffs, cliffs, and ravines. Some karst caves and sinkhole ponds.	425–800	50–375	Quaternary loess > 60 inches deep, glacial till	Paleozoic sedimentary rocks, limestone, and sandstone

[a] EPA Level III-IV Ecoregion name.

Sources: Woods et al. 2006; mile posts taken from TransCanada 2007d.

Elevations along the proposed route range between 500 and 600 feet amsl. Local relief is slight along the entire route until it reaches the till plains east of Edwardsville, where it occasionally crosses larger incised drainages with local relief of up to 100 feet (ENSR 2006a).

Surface materials consist of glacial deposits and alluvium. The Mississippi River valley is composed of alluvial sand, silt, and clay, while the uplands to the east are composed of glacial tills between 50 and 200 feet thick (Lineback 1979). Underlying bedrock consists of Mississippian limestone, sandstone, and shale grading eastward to Pennsylvanian sandstone, shale, and coal (Willman et al. 1967). There is less than 1 mile of potential shallow bedrock along the Mainline Project route in Illinois.

Karst features—including numerous sink holes and collapse structures—are present along the western edge of Illinois along the Mississippi River (ISGS 2003). Although the entire Mainline Project route in Illinois is underlain by karst-prone bedrock, no karst features have been identified along the proposed ROW (Tobin and Weary 2005, ENSR 2006a).

Cushing Extension

Nebraska

The proposed Cushing Extension separates from the Mainline Project ROW in the Smoky Hills, then proceeds 2.5 miles south to the Nebraska/Kansas border. Physiographic characteristics of the Smoky Hills are presented in detail in Table 3.1.1-7.

Surface deposits consist of thin loess and loamy colluvium. Underlying bedrock consists of Dakota Formation sandstone and shale (ENSR 2006a). There is less than 0.5 mile of potential shallow bedrock along the proposed Cushing Extension in Nebraska.

No karst features are found along the proposed Cushing Extension route in Nebraska (Tobin and Weary 2005).

Kansas

The proposed Cushing Extension ROW in Kansas traverses three EPA Level IV Ecoregions (Chapman et al. 2001), physiographic characteristics of which are presented in detail in Table 3.1.1-8.

The proposed ROW enters Kansas at MP 3 and then proceeds east-southeast through the Smoky Hills to the Flint Hills and on into the Wellington-McPherson Lowland. At MP 213, it crosses into the Prairie Tableland region of Oklahoma.

Elevations along the proposed route range between 1,070 and over 1,400 feet amsl. Local relief at major drainages along the proposed route is on the order of 100 feet, but slopes are typically not steep (ENSR 2006a).

Surface materials consist of glacial till, loess, alluvium, and colluvium. In upland areas of the Flint Hills region, the colluvium consists of cherty gravels. Underlying bedrock consists of Dakota Formation sandstone and shale in the north, and Permian Council Grove, Chase, and Sumner limestones and shales from southern Washington County to the border with Oklahoma (SGSK 1964). There are about 10 miles of potential shallow bedrock or consolidated sediments along the proposed Cushing Extension route in Kansas.

TABLE 3.1.1-7
Physiographic Characteristics of Ecoregions Crossed in Nebraska by the Keystone Cushing Extension

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Central Great Plains – Smoky Hills [a]					
0–3	Undulating to hilly dissected plain. Broad belt of low hills formed by mature dissection of Cretaceous rock layers.	1,200–1,800	100–250	Local thin loess, loamy colluvium	Chalky limestone, Cretaceous sandstone of the Dakota Formation

[a] EPA Level III-IV Ecoregion name.

Sources: Chapman et al. 2001; mile posts taken from TransCanada 2007d.

TABLE 3.1.1-8
Physiographic Characteristics of Ecoregions Crossed in Kansas by the Keystone Cushing Extension

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Central Great Plains–Smoky Hills [a]					
3–52, 54–82	*See Table 3.1.1-7.*				
Flint Hills [a]					
52–54, 82–157	Undulating to rolling hills, cuestas, cherty limestone, and shale outcrops. Perennial streams and springs common.	1,000–1,600	50–400	Cherty and clayey residuum, some limited glacial drift in the northeast corner of region	Interbedded cherty Permian limestone and shale
Central Great Plains–Wellington-McPherson Lowland [a]					
157–213	Flat alluvial lowlands. Perennial streams and numerous springs.	1,000–1,800	2–75	Loess and silty, sandy, and clayey alluvium	Permian sandstone, shale, and salt deposits (Wellington Formation)

[a] EPA Level III-IV Ecoregion name.

Sources: Chapman et al. 2001; mile posts taken from TransCanada 2007d.

There are 84 miles of potential karst terrain along the proposed Cushing Extension route in Kansas. Where present, karst is likely to consist of fissures, tubes, and caves generally less than 1,000 feet long; 50 feet or less in vertical extent; in gently dipping to flat-lying beds of carbonate rock (Tobin and Weary 2005).

Oklahoma

The Cushing Extension ROW crosses Oklahoma in the Mid-continent Plains and Escarpments physiographic subdivision (Hammond 1965). The terrain is characterized by low- to moderate-relief escarpments formed in gently west-dipping bedrock, similar to the Flint Hills. It traverses two EPA Level IV Ecoregions (Woods et al. 2005), physiographic characteristics of which are presented in detail in Table 3.1.1-9.

The proposed ROW enters Oklahoma at MP 213 and proceeds across the level to slightly rolling plains of the Wellington-McPherson Lowland until approximate MP 254, where it crosses into the rough, broken plains of the Cross-Timbers Transition region. The proposed route terminates at Cushing, Oklahoma, at MP 296.

Between the Kansas/Oklahoma border and the Cimarron River, elevations along the proposed route range between 900 and 1,150 feet amsl. At the Cimarron crossing relief is on the order of 140 to 180 feet. South of the Cimarron River crossing, elevations range between 860 and 1,070 feet amsl (ENSR 2006a)

Surface deposits consist of relatively fine-grained alluvium and terrace deposits. Underlying bedrock consists of Lower Permian Wellington Formation sandstone and limestone from the Kansas/Oklahoma border to the terminus at Cushing (Miser 1954). Upper Pennsylvanian rocks also outcrop at the edge of the Salt Fork Arkansas River floodplain (ENSR 2006a). There is less than 1mile of potential shallow bedrock along the proposed Cushing Extension in Oklahoma.

Karst terrain similar to that described above for Kansas may be found along 4 miles of the proposed Cushing Extension route in Oklahoma (ENSR 2006a).

3.1.1.2 Potential Impacts and Mitigation

Construction Impacts

The proposed Keystone Project does not involve substantial long- or short-term alteration of topography, and no disturbance of geological features that have received state or federal protection. Most of the proposed route is within areas where bedrock is deeply buried by Pleistocene and Holocene sediments. Consequently, impacts to bedrock are expected to be minimal, and limited to areas where bedrock is within 8 feet of the surface. Potential impacts to surface sediments and topography due to accelerated erosion or soil compaction are described in Section 3.2.

During construction, blasting may be required at locations where shallow bedrock is present. In addition to temporary effects, including generation of dust, noise, and vibration, blasting will permanently alter the bedrock surface. Appendix E lists by milepost locations where shallow bedrock may be found, the type of bedrock likely to be found, and whether ripping or blasting is expected to be used at the identified locations. Tables 3.1.1-10 and 3.1.1-11 summarize the approximate locations of expected blasting and ripping operations respectively, by state, county, and approximate milepost.

TABLE 3.1.1-9
Physiographic Characteristics of Ecoregions Crossed in Oklahoma by the Keystone Cushing Extension

Milepost Range	Physiographic Description	Elevation Range (feet above mean sea level)	Local Relief (feet)	Surface Geology	Bedrock Geology
Central Great Plains–Prairie Tableland [a]					
213–254	Level to slightly rolling plains with broad, flat interfluves and low-gradient broad, shallow, and sand- or silt-choked channels; uncommon short reaches with gravel, cobble, or bedrock substrates occur. Streams usually flow strongly after rains, have high suspended sediment concentrations, and go dry in late summer.	850–1,650	10–125	Quaternary alluvium, terrace deposits, and decomposition residuum of clay loam, fine sandy loam, and sandy clay loam	Permian-age red shale, sandstone, and siltstone with some Pennsylvanian-age limestone in northeastern-most areas
Central Great Plains–Cross Timbers Transition [a]					
254–296	Rough plains that are sometimes broken. Incised streams occur and have rocky or muddy substrates.	750–1,950	30–300	Quaternary alluvium; terrace deposits; and decomposition residuum of fine sandy loam, clayey silt, sandy clay loam, silty clay, and clayey loam	Permian- and Pennsylvanian-age sandstone and shale, as well as some limestone and mudstone conglomerate

[a] EPA Level III-IV Ecoregion name.

Sources: Woods et al. 2005; mile posts taken from TransCanada 2007d.

TABLE 3.1.1-10
Potential Blasting Locations
for the Keystone Project

MP Range	State	County	Length (miles)
Mainline Project			
635.4 – 636.2	Nebraska	Jefferson	0.33
747.0 – 747.8	Kansas	Doniphan	0.26
766.9 – 766.9	Missouri	Buchanan	0.02
799.4 – 813.9		Caldwell	1.24
848.7 – 871.4		Chariton	2.07
918.4 – 919.5		Audrain	0.24
948.6 – 953.7		Montgomery	0.71
957.2 – 979.0		Lincoln	1.63
Mainline Project subtotal			6.5
Cushing Extension			
0.5 – 0.7	Nebraska	Jefferson	0.15
14.9 – 15.9	Kansas	Washington	0.15
39.8 – 42.3		Clay	1.11
116.2 – 116.5		Marion	0.38
Cushing Extension subtotal			1.79
Keystone Project total			**8.3**

Source: TransCanada 2007b.

TABLE 3.1.1-11
Potential Ripping Locations
for the Keystone Project

MP Range	State	County	Length (miles)
Mainline Project			
33.0 – 54.6	North Dakota	Walsh	1.90
63.0 – 84.8		Nelson	0.41
104.2 – 109.6		Steele	2.01
439.3 – 449.0	Nebraska	Cedar	1.44
635.6 – 639.8		Jefferson	1.53
658.2 – 662.2	Kansas	Marshall	0.39
685.4 – 685.4		Nemaha	0.03
704.1 – 728.0		Brown	3.18
728.5 – 740.5		Doniphan	0.36
754.3 – 764.8	Missouri	Buchanan	1.13
798.2 – 814.4		Caldwell	1.63
814.5 – 838.3		Carroll	4.68
843.2 – 857.0		Chariton	0.58
876.1 – 890.8		Randolph	4.74
898.6 – 932.8		Audrain	6.55
932.8 – 953.8		Montgomery	3.73
953.8 – 972.1		Lincoln	2.29
1045.5 – 1046.0	Illinois	Madison	0.11
Mainline Project subtotal			6.5
Cushing Extension			
15.0 - 26.0	Kansas	Washington	0.47
44.1 - 61.0		Clay	1.89
67.7 - 98.1		Dickinson	1.01
101.9 - 120.5		Marion	5.46
261.2 - 264.6	Oklahoma	Noble	0.22
280.5 - 287.8		Payne	0.45
Cushing Extension subtotal			1.79
Keystone Project total			**8.3**

Source: TransCanada 2007b.

In its CMR Plan (Appendix B), Keystone has committed to complying with all laws and regulations governing explosives, notifying nearby residents, using blasting mats or subsoil to prevent fly-rock, clearing and cleaning all blasting locations before and after blasting operations, and performing all blasting during regular daylight working hours. In addition, Keystone would prepare a blasting plan for any locations where blasting would be necessary. Prior to construction, Keystone would file required blasting plans with applicable state or local jurisdictions. Required post-blasting testing procedures for surface water resources will be incorporated in these plans.

Operations Impacts

Routine pipeline operation and maintenance activities are not expected to affect physiography or surface or bedrock geology. Potential impacts to surface sediments and topography due to accelerated erosion or soil compaction are described in Section 3.2.

3.1.2 Paleontological Resources

3.1.2.1 Affected Environment

Although no areas of known sensitive paleontological resources would be crossed, surficial materials along the proposed ROW may contain Quaternary vertebrate fossils. Glacial deposits in particular may contain fossils of mastodon, mammoth, horses and other Pleistocene large vertebrates (Paleontology Portal). Vertebrate fossils are relatively rare, and locations containing vertebrate fossils are more likely to be scientifically significant than those containing invertebrate or plant fossils. Where exposed, bedrock may contain Cretaceous and earlier marine fossils. Upper Cretaceous bedrock outcrops may contain fossils of marine organisms, including turtles, fish, ammonites, and various invertebrates. Pennsylvanian bedrock outcrops may contain fossils of marine invertebrates, including mussels, echinoids, bryozoans, crinoids, snails, corals, and trilobites. Pennsylvanian rocks in Illinois may contain plant fossils. Permian outcrops may contain fish and shark fossils. Along the Cushing Extension route in Noble County, Oklahoma, the Wellington Formation has yielded non-mammal vertebrate, invertebrate, and plant fossils (Paleontology Portal).

3.1.2.2 Potential Impacts and Mitigation

Construction Impacts

Potential impacts to paleontological resources during construction include damage to or destruction of fossils resulting from excavation activities, erosion of fossil beds resulting from grading, and unauthorized collection of fossils by construction personnel or the public.

Pleistocene-age mammal fossils may be discovered during construction in areas where the proposed route crosses glacial and glacial-derived surface deposits, which includes the entire length of the proposed Mainline Project, except for bedrock outcrop areas. Keystone does not propose to recover or study any such fossils that may be uncovered during excavation. However, Keystone would consult with the appropriate regulatory agencies in each state on the applicability and requirements for Paleontological Resource Protection Plans. Keystone would prepare and file plans addressing vertebrate fossils with any respective states, as may be required.

Where necessary, blasting and bedrock ripping are likely to destroy any fossils that might be found in shallow bedrock. Because these fossils are unlikely to be of particular scientific importance, Keystone does not propose to log or recover fossils from shallow bedrock locations. If a location that is likely to contain valuable fossils is encountered during blasting, required protection plans would be implemented to identify and protect significant fossil resources.

Table 3.1.1-10 summarizes likely blasting areas. Table 3.1.1-11 summarizes areas where consolidated materials are within 7 feet of the surface, but ripping is likely to be sufficient. More precise location information for blasting and ripping areas is presented in Appendix E. The estimates of blasting and ripping locations were obtained from Keystone's review of depth to bedrock, as recorded in NRCS soils data. Locations where depth to bedrock is shallower than 80 inches are considered as likely to require blasting if the bedrock is indurated, well-cemented, or lithic, and potentially rippable otherwise (TransCanada 2007b). Approximately 37 miles of the proposed Mainline Project route may require ripping, and approximately 7 miles may require blasting. If blasting and ripping are required, Keystone would follow the procedures described in Section 2.2.

Operations Impacts

Routine pipeline operations and maintenance activities are not expected to affect paleontological resources. Although maintenance activities may result in surface disturbance, this would typically occur in areas previously disturbed by construction. Therefore, operational impacts to paleontological resources would be negligible.

3.1.3 Mineral and Fossil Fuel Resources

3.1.3.1 Affected Environment

The proposed route does not cross any active surface mines or quarries, but potentially valuable sand, gravel, clay, and stone resources may lie within the proposed Mainline Project ROW for the approximately 800 miles that traverse glacial deposits. Sand, gravel, crushed stone, and dimensional limestone are also present along the Kansas portion of the Cushing Extension ROW (ENSR 2006a).

The proposed Mainline Project route does not cross the well-pads of any active or proposed oil or gas wells (ENSR 2006a). The proposed Cushing Extension ROW in Kansas crosses or passes near several oil and gas fields. In addition to four abandoned oil-fields in Clay County, the proposed route passes near the active El Dorado oil field (Brooks et al. 1975, in ENSR 2006a). In Oklahoma, numerous oil and gas fields are in the vicinity of the proposed Cushing Extension route. Cushing, the destination of the extension, has been a major crude oil refining and pipeline transportation hub since the early part of the 20^{th} century. Table 3.1.3-1 identifies oil and gas fields that would be crossed by the Mainline Project and Cushing Extension ROWs.

In Kansas, coal beds are present in Pennsylvanian rocks underlying the proposed route; they are too deep to mine, although coal bed methane production is a possibility (Charpentier and Rice 1995). The proposed route crosses approximately 40 miles of underlying coal seams between Wood River and Patoka, Illinois, where coal is mined with underground methods (USGS 2004, ENSR 2006a). Table 3.1.3-2 identifies coal fields that would be crossed by the Mainline Project. No coal fields would be crossed by the Cushing Extension.

TABLE 3.1.3-1 Identified Oil and Gas Fields Crossed by the Keystone Project			
State	Starting Milepost	Ending Milepost	Type of Field
Mainline Project			
Kansas	701.2	701.6	Oil
	1021.3	1024.7	Oil*
	1021.4	1027.7	Oil*
Illinois	1027.7	1038.8	Oil*
	1038.8	1039.9	Oil*
	1039.9	1040.8	Oil*
	1040.8	1041..4	Oil*
	1041.4	1070.1	Oil*
	1070.1	1072.1	Oil*
	1072.1	1072.6	Oil*
	1072.6	1077.9	Oil*
Cushing Extension			
Kansas	118.8	120.8	Inactive
	131.3	133.6	Oil
	133.6	134.4	Oil
	136.4	136.9	Oil
	136.9	137.4	Oil
	137.4	142.6	Oil
	142.6	143.1	Oil
	146.2	146.7	Oil
	148.8	149.3	Oil
	152.3	154.9	Oil
	154.9	156.0	Oil
	156.0	157.0	Oil
	168.6	169.1	Oil
	176.0	178	Oil
	186.6	187.1	Oil
	189.7	190.7	Oil
	199.5	201.5	Oil and gas
	204.2	205.9	Oil and gas
	207.1	208.9	Oil and gas
	209.1	209.5	Oil and gas
	209.5	209.8	Oil and gas
	209.8	210.1	Oil and gas
	210.1	213.3	Oil and gas
Oklahoma	267.3	267.8	Gas
	292.6	292.9	Gas
	296.1	298.5	Gas
	217.8	233.5	Oil and gas
	235.2	236.1	Oil and gas
	289.5	289.8	Oil and gas

TABLE 3.1.3-1 (Continued)			
State	**Starting Milepost**	**Ending Milepost**	**Type of Field**
Mainline Project (continued)			
Oklahoma (continued)			
	290.6	292.2	Oil and gas
	215.8	218.1	Oil
	226.4	227.6	Oil
	228.4	229.4	Oil
	237.0	245.3	Oil
	259.3	259.9	Oil
	270.5	271.1	Oil
	277.8	278.9	Oil
	280.0	280.7	Oil
	281.2	281.5	Oil
	282.5	283.9	Oil
	284.4	286.3	Oil
	286.6	287.0	Oil
	287.8	288.9	Oil
	293.6	295.9	Oil

*Information obtained from oilfields database; however, the field might also produce gas.

Source: TransCanada 2007c.

TABLE 3.1.3-2 Identified Coal Fields Crossed by the Keystone Mainline Project			
State	**Starting Milepost**	**Ending Milepost**	**Type of Coal**
Nebraska	669.2	692.0	Medium and high volatile bituminous/other uses
	692.0	719.2	Medium and high volatile bituminous/other uses
Kansas	719.2	948.0	Medium and high volatile bituminous/potentially minable
Illinois	1026.9	1027.7	Medium and high volatile bituminous/potentially minable
	1027.7	1070.1	Medium and high volatile bituminous/potentially minable
	1070.1	1077.9	Medium and high volatile bituminous/potentially minable

Source: TransCanada 2007c.

3.1.3.2 Potential Impacts and Mitigation

Although the proposed route does not cross any active surface mines or quarries, construction and operation of the Keystone Project would limit access to sand, gravel, clay, and stone resources that are within the width of the permanent pipeline ROW for the approximately 800 miles of proposed pipeline that traverses glacial deposits. In Kansas, Missouri, and Illinois, the proposed route lies in or directly adjacent to an existing pipeline ROW; therefore, no additional restriction on mineral resources would result from the Keystone Project. In North Dakota, South Dakota, and Nebraska, the proposed route would cross deposits of sand, gravel, clay, and stone, but the acreage of deposits covered by the proposed ROW is insignificant compared to the total acreage of deposits present in each state.

The proposed route crosses approximately 40 miles of underlying coal seams between Wood River and Patoka, Illinois, where coal is mined with underground methods (ENSR 2006a). If surface mining was proposed for this area in the future, the pipeline might serve as an impediment. The effect of this impediment is likely to be minimal, however, as the proposed route follows existing pipelines in this area.

The proposed route does not cross the well-pads of any active oil and gas wells. Extraction of oil and gas resources would not be affected by routing operations because any new wells would be located outside of the pipeline ROW.

3.1.4 Geologic Hazards

3.1.4.1 Affected Environment

The proposed Keystone pipeline would be located entirely within the relatively flat and stable continental interior. Consequently, the potential for impacts from geologic hazards is lower than for facilities located in active mountain belts or coastal areas. Nonetheless, at some locations along the proposed route, seismic hazards, landsliding, subsidence, or flooding may occur. Table 3.1.4-1 summarizes by state the miles of proposed pipeline that cross areas of potential geologic hazard.

TABLE 3.1.4-1
Summary of Geological Hazard Areas for the Keystone Project (miles)

State	High Seismic Hazard[a]	Flood	Landslide	Subsidence
North Dakota	0.0	3.0	0.0	0.0
South Dakota	0.0	21.9	7.7	0.0
Nebraska	0.0	21.9	13.1	0.0
Kansas	0.0	10.9	0.0	0.0
Missouri	0.0	99.5	30.1	0.0
Illinois	0.0	12.8	6.9	0.0
Keystone Project total	**0.0**	**170.0**	**57.8**	**0.0**

[a] Peak ground acceleration with 2 percent probability of exceedance in 50 years >0.5 g.

Source: ENSR 2006a.

Seismic Hazards

Based on a comprehensive review of the fault activity east of the Rocky Mountains (Crone and Wheeler 2000), Keystone concluded that the proposed pipeline would not cross active faults (defined as movement along the fault within the last 10,000 years). Earthquake hazards can occur at a distance from actual faults as a result of earthquake-induced ground motion. The earthquake hazard rank map (Figure 3.1.4-1) shows earthquake hazard risk along the proposed Keystone Project route. There is low seismic hazard in Kansas, Oklahoma, Missouri, and Illinois. Hazard increases to an intermediate level in the Mississippi

Valley and in southern Illinois. This hazard is due to unconsolidated sediments that have the potential of being affected by New Madrid fault motion. The proposed Keystone Project is approximately 120 miles from the nearest active faulting in the New Madrid Seismic Zone (TransCanada 2007b).

As part of its National Pipeline Mapping System (NPMS) program, the DOT has compiled data from a variety of sources to identify areas of high geologic hazard potential for pipelines (DOT 1996). The Integrity Management Rule of 2002 states that segments of pipeline with a high geologic risk and the potential to affect HCAs must implement protective measures. HCAs are specific locales and areas where a release could result in more significant adverse consequences. No earthquake HCAs have been identified along the Keystone Project route.

Landslides

Landslides typically occur on steep or convergent terrain during conditions of partial or total soil saturation. Most of the proposed Keystone Project route is not located in landslide-prone terrain, but the proposed route does cross areas of high landslide potential as described by the NPMS at the Yankton and Mississippi crossings, as shown in Table 3.1.4-2. The areas listed with high landslide potential are based on high-level assessments for the NPMS and tend to overestimate the surficial extent of the hazard; actual areas of potential instability tend to be much smaller and discontinuous within the indicated zone (ENSR 2006a). Keystone has considered landslide potential in its routing work and has selected crossings of these areas where the landslide potential is considered minimal.

TABLE 3.1.4-2
Areas with High Landslide Potential Crossed by the Keystone Project

Area	Start (MP)	End (MP)	Length (miles)
Mainline Project			
Yankton Crossing	428.1	442.9	14.8
	454.0	454.3	0.3
	635.9	641.6	5.7
Mississippi Crossing	979.6	987.7	8.1
	999.4	1,021.1	21.7
	1,023.0	1,027.7	4.7
	1,027.7	1,029.9	2.2
Mainline Project subtotal			*57.5*
Cushing Extension			
Silver Hills	0.0	9.3	9.3
Cushing Extension subtotal	*0.0*	*9.3*	*9.3*
Keystone Project total			**66.8**

Source: ENSR 2006a.

During scoping meetings, issues were raised concerning the potential for rock slope instability in the vicinity of the Whitewater River crossing in Kansas. If required, Keystone would complete a site-specific crossing plan for the Whitewater River. In general, Keystone would complete site-specific crossing plans for water bodies as required by the applicable regulatory agencies, as well as for those water bodies required by federal and state permitting processes.

Subsidence

Although a potential result of soil liquefaction during seismic events, subsidence hazard along the proposed Keystone pipeline corridor would most likely be associated with the presence of karst features, such as sinkholes and fissures and in some areas potential underground coal mine works. Keystone reviewed national karst maps (Tobin and Weary 2005) to determine areas of potential karst terrain (i.e., areas where limestone bedrock is near the surface) along the proposed pipeline route. These areas are summarized in Table 3.1.4-3 and represented in the Karst map shown in Figure 3.1.4-2. Because national-scale karst maps may not incorporate the most recent field data or be of sufficient resolution to determine local subsidence risk due to karst features, prior to construction, Keystone would consult with the respective state geological survey departments to identify the most up-to-date sources of data on karst-related subsidence hazards along the proposed route.

TABLE 3.1.4-3
Karst Areas Crossed by the Keystone Project

Location	Start (MP)	End (MP)	Length (miles)
Mainline Project [a]			
South Dakota, Nebraska	353	520	167
Missouri	735	811	76
Missouri, Illinois	946	1,028	82
Cushing Extension [b]			
Kansas	65	83	18
	118	134	16
	150	200	50
Oklahoma	244	248	4
Keystone Project total			**413**

[a] Type: Fissures, tubes and caves generally less than 1,000 feet (300 meters long; 50 feet (15 meters) or less vertical extent; in gently dipping to flat-lying beds of carbonate rock beneath an overburden of noncarbonate material 10 to 200 feet (3 to 60 meters) thick.

[b] Type: Fissures, tubes, and caves generally less than 1,000 feet (300 meters) long, 50 feet (15 meters) or less vertical extent, in gently dipping to flat-lying beds of carbonate rock.

Source: ENSR 2006a.

Deep (generally 50 feet or more) glacial drift deposits overlie karst terrain in South Dakota, Nebraska, and Kansas. This deep and interbedded glacial material matrix limits the potential for sinkholes to cause fractures and soil displacement at the surface. The overall subsidence hazard risk from sinkholes that form in karst terrain along the proposed route is low. This conclusion is based on Keystone's review of the sinkhole data base for the segment of the route in Missouri where limestone bedrock is at or near the surface. The Missouri Environmental Geology Atlas indicates that the Keystone pipeline alignment would avoid all known sinkhole zones within the state (Missouri Division of Geology and Land Survey

2007, in TransCanada 2007b). Relative to hazards associated with underground coal mine works, no such works are known to underlie the proposed Keystone corridor.

Floods

Floods can cause lateral and vertical scour that can expose the pipeline to damage, particularly in active channel crossings. Keystone has committed to reviewing scour potential at all river crossings using qualified scientific or engineering professionals. River crossing designs would need to be reviewed and accepted by USACE personnel prior to issuing required permits. Keystone has committed to using HDD at major river crossings and to bury the pipeline under at least 5 feet of cover for at least 15 feet on either side of the bank-full width of all rivers, creeks, streams, ditches, and drains. An assessment of hazards and potential environmental impacts related to Keystone's proposed stream crossing procedures can be found in Section 3.3.

3.1.4.2 Potential Impacts and Mitigation

Seismic

Construction and operation of the proposed Keystone Project would not increase the likelihood of earthquakes. Given the assessment of potential seismicity along the proposed corridor, the risk of pipeline rupture from earthquake ground motion is considered to be minimal. The proposed route does not cross any active faults and would be located outside of known zones of high seismic hazard. In addition, no earthquake-induced ruptures in post-1945 electric-arc-welded transmission pipelines in good repair (the type proposed by Keystone) were observed to have resulted from large southern California earthquakes with reported surface wave magnitudes of up to 7.7 (O'Rourke and Palmer 1996). The New Madrid Seismic Zone is unlikely to produce an earthquake with a magnitude greater than 7.7 (NAHB 2003). In accordance with federal regulations (49 CFR 195), Keystone would conduct an internal inspection of the pipeline if an earthquake, landslide, or soil liquefaction event were suspected of causing abnormal pipeline movement. Thus, any damage to the pipeline would quickly be detected and repaired.

Landslides

During construction, landslide risk may be increased due to vegetation clearing and alteration of surface-drainage. Measures to reduce the risk of erosion during construction (described in Section 2.2) also would reduce the likelihood of construction-triggered landslides. Keystone has committed to revegetating areas disturbed by construction along the pipeline corridor. Revegetation would reduce the risk of landslides during the operational phase of the project. The proposed Keystone Project would be designed and constructed in accordance with 49 CFR, Parts 192 and 193. These specifications ensure that pipeline facilities are designed and constructed in a manner to provide adequate protection from washouts, floods, unstable soils, landslides, or other hazards that may cause the pipeline facilities to move or sustain abnormal loads. Proposed pipeline installation techniques, especially padding and use of rock-free backfill, are designed to effectively insulate the pipeline from minor earth movements.

Keystone plans to reduce landslide risk by preserving or improving the contour of native slopes; preserving or improving drainage patterns; and, in some circumstances, using light-weight granular material surrounding the pipe to insulate it from small ground movements. Keystone has proposed erosion and sediment control and reclamation procedures in its CMR Plan that are expected to limit the potential for erosion and enable slopes to remain in a stable configuration following construction. The potential for landslide activity would be monitored during operations through aerial and ground patrols and through landowner awareness programs, which are designed to encourage reporting from local landowners of events that may suggest instability or other threats to the integrity of the pipeline.

Keystone would implement TransCanada's Integrated Public Awareness (IPA) Plan. TransCanada's IPA Plan is consistent with the recommendations of API RP-1162 (Public Awareness Programs for Pipeline Operators). The plan includes the distribution of educational materials to inform landowners of potential threats and information on how to identify threats to the pipeline. TransCanada has a toll-free telephone number (1-888-982-7222) in place for landowners to report potential threats to the integrity of the pipeline and other emergencies.

Subsidence

There is a risk of subsidence where the proposed route crosses karst formations. Table 3.1.4-3 shows the locations by milepost where karst may be found. Where karst terrain is present or suspected to be near the surface, Keystone has proposed to conduct site-specific studies as necessary to characterize the karst features, and will evaluate and modify construction techniques as necessary. Because the karst formations that may be present along the proposed route tend to be deeply covered, karst formations likely would be encountered only where deep HDD is proposed, as described in Section 3.3.2.2. The overall risk to the Keystone Project and environment from karst-related subsidence is expected to be minimal.

In Missouri and in Illinois the proposed route runs through regions that may contain small shafts and adits associated with underground coal mining. Although no known shafts or adits underlie the proposed corridor, there is a small risk of encountering mine-related works that could represent a subsidence hazard. Near surface workings would likely be noticed during construction and the potential hazard eliminated through filling or avoidance. Deeper workings that might .underlie the pipeline invert are unlikely to pose a high risk to pipeline operations, Potential impacts from minor subsidence associated with soil settling in the ROW and recommended mitigation are discussed in Section 3.2.2.2.

Floods

There is a risk of pipeline exposure due to lateral or vertical scour at water crossings. Keystone's CMR Plan (Appendix B), its commitment to review river crossing design with qualified scientific or engineering personnel, and the necessity for USACE permits prior to water crossing construction reduce the risk to the proposed pipeline from potential flooding events. More detail on environmental risk associated with flooding is presented in Section 3.3.

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