
SWReGAP 2011

3.2 Geologic Resources

3.2.1 Affected Environment

The study area for geology includes the proposed ROWs and groundwater development areas and the broader geographical area referred to as the natural resources region of study (**Figure 3.0-2**).

QUICK REFERENCE

amsl – above mean sea level

FLPMA – Federal Land Policy and Management Act of 1976

GPS – global positioning system

InSAR – Interferometric Synthetic Aperture Radar

NBMG – Nevada Bureau of Mines and Geology

PGA – Peak Ground Acceleration

ROW – right-of-way

USGS – U.S. Geological Survey

3.2.1.1 Overview

Regional Geology

The study area is located in the Basin and Range physiographic province and the sub-province called the Great Basin (Eaton 1979). The Basin and Range province is characterized by generally north-south trending mountain ranges and valleys and encompasses portions of a number of states including Arizona, California, Idaho, Nevada, New Mexico, Oregon, Utah, and Texas.

In the study area, the mountains and valleys follow the Basin and Range north-south pattern and are about 5 to 15 miles wide and 20 to 100 miles long. Elevations range from less than 2,000 feet above mean sea level (amsl) in the valleys in the Las Vegas area to Wheeler Peak at 13,063 feet amsl, the second highest point in Nevada. Generally, the valley floors in the northern part of the study area are higher than in the southern areas with elevations ranging from 6,000 to 6,500 feet amsl. Elevations in the mountain ranges generally are from 7,500 to 10,000 feet with the higher peaks often above 11,000 feet amsl. The highest mountain ranges are in the northern part of the study area, with the Snake and Schell Creek ranges containing several peaks above 11,000 feet amsl.

The mountain ranges in the study area generally consist of volcanic and sedimentary rocks (Stewart and Carlson 1978), and intrusives are scattered in mountain ranges throughout the study area. Erosion has created rugged terrain in the mountains and some areas show evidence of past glaciation (Price 2004). The valleys contain valley-fill material eroded from the mountains. The valley fill can be thousands of feet thick with deposits consisting of poorly sorted alluvial fans adjacent to the mountain ranges and fine grained playa deposits and sand dunes in the valley floors. Most of the area is internally drained and surface runoff is confined to the basins. A few drainages in the southern part of the study area drain into the Virgin or Colorado rivers. See Section 3.3.1, Surface Water Resources, for information regarding surface water drainages.

Volcanic – Rocks formed from an opening in the crust that allows molten rock to reach the surface.

Sedimentary – Rocks formed by rocks accumulation and cementation of minerals transported by wind or water, or chemically precipitated.

Intrusives – Igneous rock bodies that have forced their way in a molten state into surrounding rock.

Alluvial – Water-deposited terrestrial.

Fans – sediment composed of sorted or unsorted sand, gravel, and clay.

Playa – Dry lake.

The region of study in the eastern Great Basin presents a complex geologic setting. Deformed Paleozoic and Mesozoic rock units were overlain by thick Tertiary volcanic ash-flow tuffs, intruded by igneous stocks of considerable size and depth, and then rifted apart during middle to late Cenozoic Basin and Range extensional faulting. See **Appendix F**, **Table F3.2-1** (Geologic History Summary), **Figure F3.2-2** (Geologic Map) and **Figures F3.2-1**, **F3.2-3**, **F3.2-4**, and **F3.2-5** (composite stratigraphic columns). Today the project area is dominated by alluvial basins with thick accumulations of clastic sediments separated by mountain ranges that contain some of the most complex geology on the North American continent. Most current groundwater sources come from wells developed in the aquifers that are contained within the alluvial sediments of the basins. However, the Paleozoic carbonate rocks found in the mountain ranges and in the bedrock beneath the alluvial basins are believed to constitute a major regional aquifer system that contains many different flow regimes. Groundwater flow in these rocks is controlled by secondary permeability created by faults and fractures.

Additional information regarding the potential effects of these structural features on groundwater flow is provided in Section 3.3.1.5, Hydrogeologic Conditions.

Paleontology

The study area for paleontological resources includes the proposed ROWs and groundwater development areas that would be directly disturbed by the Proposed Action and other alternatives (**Figure 3.0-1**). No additional region of study is relevant for paleontological resources because the indirect effect of groundwater drawdown is not an issue for this resource.

Paleontology – The study of prehistoric life, including organisms evolution and interactions with each other and their environments.

Pleistocene Deposits – Of or belonging to the geologic time, rock series, or sedimentary deposits of the earlier of the two epochs of the Quaternary Period (1.6 million to 10,000 years ago), characterized by the alternate appearance and recession of northern glaciation, the appearance and worldwide spread of hominids, and the extinction of numerous land mammals, such as the mammoths, mastodons, and saber-toothed tigers.

Paleontological resources or fossils are the imprints or remains of once-living plants and animals preserved in rocks and sediments. Paleontological resources on public lands are considered nonrenewable records of the history of life on earth; hence, they represent important and critical components of America's natural history. Once damaged, destroyed, or improperly collected, their scientific value could be greatly reduced or lost forever. Paleontological resources also can be used to provide information about interrelationships between biological and geological components of ecological systems over long periods of time.

The BLM manages paleontological resources under a number of federal laws including the Paleontological Resources Preservation Act of 2009, FLPMA Sections 302(b) and 310, which direct the BLM to manage public lands to protect the quality of scientific and other values. Management direction also is provided in 43 CFR 8365.1-5, which prohibits the willful disturbance, removal, and destruction of scientific resources or natural objects; and 43 CFR 3622, which regulates the amount of petrified wood that can be collected for personal, noncommercial purposes without a permit. In addition, the BLM provides management direction for the identification, evaluation, protection, and use of fossils in the Potential Fossil Yield Classification System for Paleontological Resources on Public Lands (BLM 2007). In addition to the BLM fossil classification system, the BLM Manual 8270 and BLM Handbook H-8270-1 provide guidance for managing paleontological resources on federally owned and managed lands.

Fossils occur in sedimentary rocks and also in deposits found in caves, lake bottoms, and older alluvial surfaces. The BLM Potential Fossil Yield Classification System for Paleontological Resources on Public Lands describes a classification system for ranking rock units according to their potential for scientifically important occurrences of fossils. The Potential Fossil Yield Classification System indicates unlikely occurrence of paleontological resources in areas with igneous and metamorphic rocks; extremely young alluvium, colluvium, or aeolian deposits; or deep soils. The classes listed below are assigned to rock units that have the potential to contain important paleontological resources:

- Class 3a (Moderate) – Units are known to contain vertebrate fossils or scientifically significant non-vertebrate fossils, but these occurrences are widely scattered. Common invertebrate and plant fossils may be found in the area.
- Class 4 (High) – Geologic units are known to contain a high occurrence of significant fossils. Vertebrate fossils or scientifically significant invertebrate or plant fossils are known to occur and have been documented, but may vary in occurrences and predictability.
- Class 5 (Very High) – Highly fossiliferous geologic units that consistently and predictably produce vertebrate fossils or scientifically significant invertebrate or plant fossils, and that are at risk of human-caused adverse impacts or natural degradation.

The BLM (1998; 2008) has not categorized specific geologic formations in the project area according to the Potential Fossil Yield Classification System. However, there are deposits and sedimentary rocks that have potential to contain important fossils. The following is a general list of formations or deposits that have a high sensitivity rating for fossil potential occurrence.

- Pleistocene deposits in caves or fissures have a potential to contain woodrat/packrat (*Neotoma* sp.) middens (i.e., concentrations of bone and fecal waste from woodrats [Scott 2003]). Material in these middens is partially fossilized and contains a wealth of data on climatic and faunal biogeographical changes over the past 40,000 years. Pleistocene deposits found in caves would be considered highly sensitive for paleontological resources.
- Tertiary formations that contain abundant vertebrate fossils. These formations, while not often yielding fossils of scientific importance, are given a high sensitivity rating because of the abundance of vertebrate fossil material. An example of a highly sensitive Tertiary formation is the Muddy Creek formation (Scott 2003).
- Cambrian-aged sedimentary rocks (for example, the Pioche Shale) may contain abundant trilobites, ancient segmented arthropods that lived 550 to 250 million years ago (Alles 2006). Trilobites are important fossils for documenting the profusion of life that occurred during the Cambrian Period. Areas where Cambrian rocks are exposed may be considered moderate to high sensitivity for paleontological resources.

An important information source for paleontological resources for the area was a literature review and records search conducted by the San Bernardino County Museum (Scott 2008). This study identified known records of paleontological resources within the project area, as well as areas considered to contain high potential for occurrence fossils. The study referenced a variety of paleontological surveys that have been conducted in the vicinity of the project area.

3.2.1.2 Right-of-way Areas and Groundwater Development Areas

Geologic Features and Hazards

Characterization of geologic hazards within the project area is described in terms of seismicity, landslides, subsidence, and karst topography. These hazards represent risks to pipeline and project facility integrity. Karst geology also is considered an important aspect of cave formation.

Seismicity

Nevada is a very seismically active state and ranks third behind Alaska and California in numbers of 7.0 magnitude earthquakes from 1789 to 2005 (Nevada Seismological Laboratory 2006). However, most of the earthquake events recorded in the state are concentrated in the western and central part of the state in two areas designated as the Central Nevada Seismic Belt and the Eastern California Seismic Belt (**Figure 3.2-1**). The project area in the central Great Basin has relatively few earthquakes in comparison to the rest of the state (Machette et al. 2004). The Central Nevada Seismic Belt and Eastern California Seismic Belt are characterized by numerous historic events (during last 150 years) where ground rupture has been documented along the faults. Seismic activity in Utah occurs along a line north to south in the center of the state from Salt Lake City to the southwest corner of the state (**Figure 3.2-1**). The line corresponds to the Wasatch Mountain front in the northern part of the state and along the hingeline that marks the boundary between the Great Basin and Colorado Plateau. This area of earthquake activity along the Wasatch Mountains is referred to as the Intermountain Seismic Belt (Machette et al. 2004).

There are numerous faults of Quaternary-age in the project area (**Figure 3.2-2**). The Quaternary Period represents the last 1.6 million years of geologic history. Quaternary faults have been classified according to age of movement (Nevada Earthquake Safety Council 1998):

- Historic Active Fault – a fault that has moved within the last 150 years;
- Holocene Active Fault – a fault that has moved within the last 15,000 years;
- Late Quaternary Active Fault – a fault that has moved within the last 130,000 years;
- Mid-Late Quaternary Active Fault – a fault that has moved within the last 750,000 years; and
- Quaternary Active Fault – a fault that has moved within the last 1.6 million years.

Figure 3.2-1 Regional Seismicity

Figure 3.2-2 Potentially Active Faults

Global positioning system (GPS) data indicate that extension is occurring along the aforementioned seismic belts. The central part of the Great Basin, which encompasses the project area, shows a much lower level of potential activity. Most of the faults in this area are late Quaternary (130 thousand years ago) or older. The project exploration areas would be located over an area of normal Holocene faults (activity less than 15,000 years ago) in central and southern Spring Valley, in the central Dry Lake Valley, and the west side of the Snake Valley. A several-mile discontinuous, generally north-south surface fissure is located in Dry Lake Valley (Swadley 1995). It is unknown whether this fissure was caused by subsidence or tectonics. Additional fissures are located in Delamar Valley oriented northeast, parallel to the Pahranagat shear zone, approximately north-south, or northwest (Swadley 1995). The latter directions are also parallel to known fault zones.

Landslides

Because of the infrequency of rainfall, precipitation events are characterized by brief heavy storm events that result in mainly debris flows rather than landslides (Radbruch-Hall et al. 1982). Debris flows are a major mode of deposition for alluvial fans. Landsides in the Great Basin are less frequent and occur more often in the higher latitudes at higher elevations where precipitation is more frequent. Shale and sediments derived from volcanic deposits are prevalent in landslides in the Basin and Range area. Massive carbonate rocks that have been sheared and fractured are also prone to landslides. Most of the project area has a low recorded landslide incidence and susceptibility, areas with less than 1.5 percent of the area involved (National Atlas 2008). However, a few areas of medium (1.5 to 15 percent of area involved) to high (greater than 15 percent of area involved) susceptibility and incidence are present in the southern Snake Range located north of the White Pine-Lincoln county line, and in the Schell Creek Range south of Ely, Nevada (**Figure 3.2-3**). In the Snake Range, large blocks of displaced Paleozoic rocks have been observed (Elliott et al. 2006; Whitebread 1969).

Subsidence

Subsidence is a decrease of surface elevation of the ground and may be caused by a variety of phenomena including, but not limited to, solution of subsurface strata, compaction, removal of groundwater, and earthquake ground motion. The surface expression from subsidence can range from localized precipitous collapses (sinkholes) to broad regional lowering of the earth's surface.

Subsidence in the Las Vegas Valley is well documented and has been primarily caused by withdrawal of groundwater (Bell 1981, 2003). Subsidence has been monitored since 1935 and localized depressions have developed where the changes in elevation range from 2.5 to 5 feet. One of the depressions is located just north of the McCarran Airport.

The Las Vegas Valley faults are preferred sites for fissuring to occur when the ground subsides (Bell 1981, 2003). Subsidence due to groundwater withdrawal has not been documented in other basins in the project area.

Karst Topography and Caves

Another potential cause of subsidence is the solution of carbonate rocks resulting in karst terrain (sinkholes and depressions). Some areas of karst potential are present in the project area (**Figure 3.2-4**) (National Atlas 2008). These areas of karst potential are broadly defined in areas that are shallowly underlain by carbonate rocks, but subsidence has not been documented. The greater the depth of fill over carbonate rocks, the lower the probability for surface effects occurring from subsurface voids created by solutions. Caves may form in thick layers of limestone where there is sufficient water to dissolve rock and create fissures, tubes, and caves. The Federal Cave Resources Protection Act of 1988 provided for the protection of cave resources on federally managed lands. Included in the act were provisions charging the DOI to issue regulations that define what constitutes significant caves, identify and list significant caves on federally managed lands. The legislation also defined prohibited acts and criminal penalties for violation of the law. All the caves in the GBNP would be considered significant caves. The primary areas where the pipeline crosses limestone outcrops where caves may potentially be present include the south end of Spring Valley and the divide between Cave and Dry Lake valleys. Lehman Caves and other known caves in the GBNP, and caves in Cave Valley are located in project hydrologic basins. Cave information generally is not publicized by the caving community or the land management agencies to prevent vandalism and disturbance of cave fauna, such as bats.

Figure 3.2-3 Landslide Susceptibility

Figure 3.2-4 Karsts

Erionite

Potential public exposure to airborne particles of erionite, a zeolite mineral that occurs in some volcanic tuff deposits may be a public health hazard if inhaled. Erionite deposits have been identified in Nevada and Utah, but the primary localities are in the western and central part of Nevada and are associated with upper Cenozoic tuffaceous rocks (Sheppard 1996). No erionite occurrences have been identified in the project area. Volcanic tuff is present south of Baker, Nevada, but erionite has not been identified in these deposits (Sweetkind 2009). In addition, the volcanic origin and depositional environment of the tuff deposits near Baker have not been characterized. This issue is addressed in this Geologic Resources section, since the risk of exposure must be evaluated before considering health hazards.

Paleontological Resources

Based on a records search by San Bernardino County Museum (Scott 2008), no paleontological resource locations were identified for the project ROWs. However, this study identified areas of high potential occurrence of paleontological resources along portions of the ROWs based on geological formations and previous paleontology studies (**Figure 3.2-5**). These high potential occurrence areas are located in Lincoln County. The following information provides a summary of geologic formations and their associated fossils.

- Paleozoic Rocks – The Guimette and Simonson Dolomite formations located north of the Limestone Hills and the western Schell Creek Range are known to contain marine invertebrate fossils. Caves also may be present in the limestone formations that could contain vertebrate fossils.
- Lacustrine (lake) Deposits in Valley Alluvium – Lacustrine deposits in Cave, Coyote Spring, Delamar, Dry Lake, and Spring valleys include abundant invertebrate fossils with lesser occurrence of vertebrates. These areas are considered ancient lakes such as Bristol or Dry Lake, Cave Lake, Lake Carpenter, Delamar Lake, and Spring Lake. Fluvial (river) and lacustrine sediments of late Pliocene and Pleistocene age have high potential to contain significant nonrenewable paleontological resources. Older alluvium and its associated sediments are not considered conducive to the preservation of vertebrate fossils, see **Table F3.2-1**.

The sedimentary basins in Eastern Nevada provide a variety of paleontological resources including large and small mammals. The Panaca and Muddy Creek formations contain vertebrate fossils and overlap portions of the ROW and groundwater exploratory areas (Reynolds and Lindsay 1999). Both formations were developed through a basin-fill depositional process. Based on information provided by Reynolds and Lindsay (1999), geological characteristics and known fossils are described below for each of these formations.

- Muddy Creek Formation – This geologic formation was deposited in a series of small basins that coalesced into a single large basin. It extends northward from the Henderson area to Mesquite, with scattered exposures around Moapa. Most of the fossil-bearing areas occur on sloped areas with outcroppings. The exception is the White Narrows member referenced below. The formation is considered to be Miocene Age. Fossils that have been observed in the Muddy Creek formation include carnivores (dog and bear), artiodactyls (camel, llama, and pronghorn), perissodactyls (horse), small mammals (e.g., bats), and microtines (e.g., shrews). Fish and invertebrate fossils associated with lacustrine sediments, carbonates, and fluvial sand also have been collected from the Marl of the White Narrows (Schmidt et al 1996).
- Specific fossil sites also have been identified at locations adjacent to the ROWs for the Proposed Action and Alternatives in Clark, Lincoln, and White Pine counties (**Table 3.2-1**). Wildcat Wash is within of the Muddy Creek formation, while the Snake Creek Indian Burial Site is located within late Pleistocene deposits. The closest known sites are Hidden Valley and Seven Oaks Springs (1 to 2 miles east of alternatives A through C), and the Snake Creek Indian Burial Site (1 to 2 miles west of Alternatives A through C).
- The highest potential for paleontological resources is lacustrine formations in valley alluvium in Delamar, Dry Lake, Cave, and southern Spring Valley. These deposits may contain invertebrate fossils and lesser occurrences of vertebrates (see ROWs above) (**Figure 3.2-5**).

Figure 3.2-5 Areas of Potential for Paleontological Resources

Table 3.2-1 Known Fossil Sites Near the Right-of-way/Groundwater Exploratory Areas

Site/Location	Description	Source of Information
Clark		
Wildcat Wash, eastern portion of Pahranagat Wash, approximately 4 miles east of the ROW for Alternatives A through E and Alignment Options 1 through 4	Collection site is part of Muddy Creek formation. Fossils occasionally are locally abundant but usually are infrequent and isolated fragments. Recovered fossils included fish, mammal, and rodent bones.	Scott (2003)
Joanna and Monte Cristo Limestone formation	Marine invertebrates.	Scott (2008)
Lincoln County		
Kane Springs Wash/Highway 93 in Coyote Spring Valley, 2 to 3 miles east of the ROW for Alternatives A through C and Alignment Option 3	Late Mississippian limestone outcrop coral fossils. Most of the fossil-bearing outcrops of early Permian and late Mississippian beds of limestone, dolomite, and sandstone are buried up to 33 feet in Quaternary alluvium.	Duncan and Gordon (no date) as cited in Tschanz and Pampeyan (1970).
Hidden Valley and Seven Oaks Springs approximately 1 to 2 miles east of the ROW for Alternatives A through C	Collection sites contain trilobites from the late Lower Cambrian and early Middle Cambrian periods.	Palmer (1998)
White Pine County		
Snake Creek Indian Burial Site, approximately 7 miles southeast of Baker, 1 to 2 miles west of the Snake Lateral ROW for Alternatives A through C	Pleistocene-aged camel, horse, rodent, and reptile fossils were recovered from a cave.	BLM (2008); Bell and Mead (1998); and Mead and Bell (1994)
Southern Schell Creek Range, limestone formations	Marine invertebrate fossils and vertebrate fossils in cave deposits.	Hose et al. (1976)

3.2.2 Environmental Consequences

3.2.2.1 Rights-of-Way

Issues

The following issues for paleontological resources and geological hazards are evaluated for ROW construction and maintenance.

Geological Hazards

- Risk of potential damage to pipelines and ancillary facilities from earthquake ground motion and permanent ground displacement along faults or ground fissures of undetermined origin.
- Risk of landslides or mass wasting (large movements of earth materials) to pose risks of damage to pipelines and related facilities.
- Areas underlain by carbonate formations may have the potential for ground subsidence due to karst features. Ground subsidence due to karst can create loss of support and damage to pipelines and related facilities.
- Potential health risks to workers and public due to exposure to erionite.

Caves

Unique geological features in the region are caves that have formed in bedrock carbonate formations. Caves provide habitat for flora and fauna as well as localities for scientifically important fossil resources. Caves may be adversely affected by ROW construction and maintenance activities.

Paleontological Resources

- Potential damage and loss of scientifically important fossils could occur from ROW clearing, grading, trench excavation, construction of other pipeline-related facilities, operational maintenance activities that would require disturbance of previously unaffected areas within the established ROW.
- Loss of scientifically valuable fossils also may occur because of vandalism or unauthorized collection.

Assumptions

The following assumptions were used in the impact analysis for geological and paleontological resources for ROW construction and maintenance.

Geological Hazards

- The location of active faults is based on information available from the USGS and Nevada Bureau of Mines and Geology (NBMG) (2006). The ground motion estimate is based on recent updates of the USGS seismic hazard mapping by the USGS (2010). There are numerous Quaternary faults in the project area which may rupture at any time, however, only those faults with movement documented by the USGS and Nevada Mines and Geology (2006) in the last 15,000 years are considered to be active.
- Movement across ground fissures in the Dry Lake and Delamar valleys may result in ground deformation similar to that caused by movement on active faults.
- Landslide risk information is based on data provided in the National Atlas (2008). The data for landslide incident and susceptibility areas is based on Radbruch-Hall et al. (1982), Landslide Overview map of the Contiguous U.S. Because of the scale of the map, it overstates the landslide risk in the southern Snake Range. Landslide risk was assessed using large-scale mapping, where available, that showed mapped landslides in relation to proposed project elements (NPS 2009).
- Nevada does not have a state-wide database for sinkholes (NBMG 2010), therefore potential karst areas were identified by review of the national karst hazards mapping by Davies et al. (1984) which used for the karst layer in the National Atlas (2008). As with the national landslide risk mapping, the karst hazards map of the U.S. at a

1:7,500,000 scale may overstate the potential for karst development. However, the presence of caves in areas underlain by limestone may indicate the potential presence for other karst features.

- The greatest exposure risk to Erionite would occur during active ground disturbance and excavation.

Caves

- In the analysis of ROW construction and maintenance effects, caves are considered to be unique geological features.

Paleontological Resources

- Areas of medium to high potential for valuable fossil resources were defined on the basis of literature review and assessment conducted by the San Bernardino Museum (Scott 2008). No field surveys were conducted. The fossil yield potential areas identified for this analysis were used to define areas where detailed on-site surveys would be needed.

Methodology for Analysis

The methodology for impact analysis for geological and paleontological resources for ROW construction and maintenance:

Geologic Hazards

- Seismicity and Active Faults. Based on seismic hazard mapping and Quaternary fault maps (USGS 2010; USGS and NBMG 2006), assess the risk of the proposed pipeline and related facilities being affected by permanent ground displacement resulting from movement on faults or fissures and potential ground motion. Pipelines can be susceptible to two major types of seismic hazards: permanent ground deformation and wave propagation hazards (O'Rourke and Liu 1999). Permanent ground deformation hazards include displacement of ground across a fault, soil liquefaction, and landslides. Wave propagation hazards result from the ground waves that are set in motion from an earthquake event. The ground waves can cause stress on pipe, resulting in rupture. There is potential for permanent displacement of the ground across active faults (O'Rourke and Liu 1999). A pipeline crossing an active fault is susceptible to bending or rupture if ground displacement is severe. An earthquake generates waves of energy that cause the ground to shake. Surface structures are susceptible to ground motion, but buried pipelines also may be at risk (Pelmulder 1995). Soil liquefaction occurs when ground shaking from an earthquake causes soil to lose its ability to support a load. Soils that are especially susceptible to liquefaction are saturated unconsolidated sand and sandy soil. Liquefaction causes the soil to compact and settle allowing buried pipelines to become buoyant. Liquefaction on a slope may cause earth materials to flow downhill. Lateral spreading is another liquefaction hazard in which blocks of competent soil are displaced horizontally over liquefied strata (Pelmulder 1995). Earthquake induced liquefaction can cause loss of pipeline support resulting in bending or rupture. Soil liquefaction has been documented in valley areas in the Mojave Desert in California (Wills 2001). Liquefaction may occur where soil and shallow groundwater create susceptibility. The mass movement of ground because of seismic energy can cause bending or rupture of buried pipelines due to loss of support or movement of pipe.

Seismicity – The world-wide and local distribution of earthquakes in space and time; a general term for the number of earthquakes in a unit of time.

Subsidence – The movement or sinking of the land surface.

Karst – Landscape shaped by the dissolving of soluble bedrock (usually limestone or dolomite).

- Landslides. Through the use of available geological information and landslide incidence and susceptibility maps, qualitatively estimate the risk of landslide movement affecting the construction zone via destabilization of existing active landslides or creation of instability based on undercutting of slopes. Landslides can occur in a number of different ways in different geological settings. Large masses of earth become unstable and by gravity begin to move downhill. Another form of mass wasting, debris flows, are common where mountain drainages cross onto mountain pediments formed by alluvial fans. Debris flows occur during heavy precipitation events and are slurries of materials that may consist of large boulders to clay-size particles (USGS 2004). Because debris flows have high water content, they can be very destructive. However, the power of debris flows is rapidly reduced as flows discharge over the upper reaches of the alluvial fans.

- Karst. Based on available geological information and karst potential maps, qualitatively estimate the risk of installing project components over shallow caves and potential sinkholes in karst terrain.
- Erionite. The potential for the occurrence of eronite-containing surficial materials in areas to be disturbed and excavated was evaluated to assess the risks of inhalation of erionite by construction workers and the public.

Caves

- Based on available geological information (geologic maps and karst potential maps), assess the risk of construction and maintenance of the project on caves and cave resources.

Paleontological Resources

Conduct an analysis using the available paleontological information from publically available sources and information provided by the Scott (2008) to determine the potential for the existence of scientifically important paleontological resources. Based on review of the information, provide an estimate of risk and identify measures that would be used to protect the resources.

3.2.2.2 Proposed Action, Alternatives A through C

Construction and Facility Maintenance

Geologic Hazards

Seismicity and Active Faults. During construction activities, potential effects due to seismicity and permanent ground displacement are not expected to pose a concern. Seismicity and active fault hazards present risks to long-term maintenance of the proposed pipeline and facilities. Permanent ground deformation across faults or fissures could result in damage to pipelines and facilities. There are two active fault zones (last movement demonstrated to be less than 15,000 years ago) that are present in the proposed in ROW areas: the Southern Spring Valley and Snake Valley fault zones (**Figure 3.2-2**) (Sawyer and Redsteer 2000; Black et al. 2005). The Southern Spring Valley fault zone is a series of scarps along the west side of the southern Spring Valley. The proposed ROW in the Spring Valley crosses two mapped faults in the fault zone. The south end of the Snake Valley fault zone parallel the groundwater development area along the Utah-Nevada state line. There are also fissures that have been described in Dry Lake and Delamar valleys of undetermined origin, but are possibly seismic (Swadley 1995). The proposed ROW crosses fissures in the north end of Dry Lake Valley and southern Delamar Valley.

Ground motions from a maximum earthquake in the project area are expected to range from 10 to 27 percent of the acceleration of gravity (g = 9.80 meters per second squared), with a 2 percent probability of exceedance in 50 years (USGS 2010). The highest ground accelerations would be expected to occur in central Lincoln County and the least in southeastern White Pine County. Ground accelerations of 27 percent of g may result in slight damage to well-built structures, but damage may be considerable in poorly built or badly designed structures. Such ground accelerations would probably not affect high-grade steel pipe in good condition (McDonough 1995; Wald et al. 1999). Ground motion risk will be lessened by design and construction of the proposed ROW facilities according to applicable and appropriate seismic standards.

Soil liquefaction has the greatest probability of occurring along the edges of alluvial fans where the deposits are saturated at shallow depths (Wills 2001). However, the overall potential for liquefaction would be low because of the expected low-magnitude of ground motions in the project area from a maximum earthquake.

Earthquake induced landslides do not appear to present to a risk to the project since the project ROWs are located in areas of low to medium landslide risk and susceptibility (see landslide discussion below).

The Ely and Las Vegas RMPs (BLM 2008, 1998) provide no management direction or BMPs regarding the siting of facilities with regard to active faults. Therefore if active faults or fissures cannot be avoided, then the ACMs (**Appendix E**) provide for the following protection measures for active faults and fissures:

- ACM A.3.1: If fault crossings of the pipeline are identified during detailed geotechnical investigations, additional design features will be added to ensure pipeline integrity (e.g., flexible couplings, increased pipe wall thickness, pipe sleeves).
- ACM A.3.2: In the "fissures" area of Dry Lake Valley, in addition to design features, over-excavation of existing soils and replacement with engineered fill, grouting of fissures, and/or use of geo-textile fabric will be utilized as needed to ensure pipeline stability.

Landslides. Hazards of concern from landslides during construction of the pipeline would be from unintentional undercutting of slopes or construction on steep slopes resulting in instability that would lead to landslides. When selecting the final pipeline route, steep slopes crossed by the pipeline should be kept to a minimum.

Landslide is a term used for various processes involving the movement of earth material down slopes (USGS 2004).

In the project vicinity, there is an area of high landslide susceptibility and incidence in the southern Snake Range, southwest of Baker. This area of landslide risk is restricted to the slopes of the range. Since the project ROW in that area is located on the valley areas east and south sides of the range, where landslide risk is low to moderate, landslides are not expected to be a concern for facility maintenance. Other portions of the proposed ROWs are located in areas of low landslide incidence and susceptibility and therefore landslides would pose low-risk to the proposed project.

During facility maintenance, debris flows have the potential to damage pipelines, roads, and associated facilities. The power of debris flows is such that backfill could be eroded and the pipeline exposed and damaged. Also culverts and roads are commonly washed away during heavy precipitation events.

The Ely and Las Vegas RMPs (BLM 2008, 1998) provide no management direction or BMPs regarding the siting of facilities with regard to landslides and debris flows. To reduce the risk of debris flows, ROW facilities should be located as far as practically allowable from the mouths of drainages at the mountain range-alluvial fan interface. Additional measures are included in the ACMs (**Appendix E**):

- ACM A.1.67: Desert washes and ephemeral drainages will be restored to pre-existing conditions. Soils will be compacted, and additional stabilization measures such as rip-rap may be required to protect the facilities and prevent increased erosion in the wash.

Karst. Although there is potential for karst development in the project area (National Atlas 2008), karst terrain has not been documented along ROWs. While the inferred presence of caves and other karst features from **Figure 3.2-5** has not been conclusively documented in many areas, it also doesn't preclude the existence of karst potential and hazards related to sinkhole subsidence during construction and maintenance of ROW facilities. Erionite is not likely to pose a concern because no erionite deposits have been identified in the project area.

Caves. No caves have been identified in ROW areas. Construction and maintenance of pipelines ROW facilities are not likely to pose risks to caves and their unique habitats.

Conclusion. Geologic hazards are not likely to pose risks during construction of ROW facilities. During facility maintenance, seismic hazards, active faults, fissures, and debris flows pose the greatest concern. The proposed pipeline and facilities are not likely to be at risk from expected ground motion and karst. There is a low potential for disturbance or damage to caves from construction activities and cave resources would not be affected by maintenance of the facilities.

Proposed mitigation measures:

None.

Residual impacts include:

- A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement and seismicity.

Paleontological Resources

Figure 3.2-5 displays project elements with respect to paleontological resource sensitivity. ROWs in the Coyote Springs, Delamar, Dry Lake, Cave, Lake, and Snake valleys cross deposits that have high potential for important fossils. Potential impacts to fossil localities during construction would be both direct and indirect. Direct impacts to or destruction of fossils would occur from trenching or facility construction activities conducted through important fossil beds. Indirect impacts during construction would include erosion of fossil beds due to slope re-grading and vegetation clearing or the unauthorized collection of scientifically important fossils by construction workers or the public due to increased access to fossil localities along the ROW.

Any potential effects to fossils from facility maintenance (non-pumping) activities would be isolated due to the probable dispersed nature of maintenance activities. Also, potential impact during maintenance would be minimal since activity would generally occur on previously disturbed ROW. Routine operation of the proposed pipeline and related facilities would not disturb paleontological resources. Maintenance activities that would result in surface disturbance typically would occur within the ROW that was previously disturbed during construction. Since new disturbances would not be anticipated from routine maintenance activities (i.e., maintenance activities would occur within the ROW), impacts to paleontological resources would be negligible. If maintenance or new construction requires disturbance of previously undisturbed areas, the protection measures as described in **Appendix E** would be implemented.

To provide protection for potential paleontological resources, protection measures would be followed as provided in **Appendix E** would be implemented.

- ACM A.6.1: A field survey will be conducted of areas within the ROWs identified as having a high potential for paleontological resources, based upon a paleontological records search using the Potential Fossil Yield Classification System. The field surveys will identify if there are surface exposures containing visible fossils and if there is a potential for buried fossils within the construction footprint. If any important fossils or middens are found during the field survey, a program will be developed and implemented to remove any exposed fossils prior to construction.
- ACM A.6.2: Areas identified as having a high potential for buried paleontological resources based upon the field survey will be monitored by a qualified paleontologist during construction activities involving ground disturbance, including grading, excavation, and trenching.
- ACM A.6.3: Any fossils recovered during the field survey or construction monitoring will be prepared in accordance with standard professional paleontological techniques. The fossils will be curated in a BLM-approved facility. A report on the findings and significance of the salvage program, including a list of the recovered fossils, will be prepared following completion of the program. A copy of this report will accompany the fossils, and a copy will be submitted to the Nevada State Museum.

Ely RMP (BLM 2008) provides management direction for protection of paleontological resources including BMPs for wind energy development and stipulations and notices for fluid minerals leasing. The ACMs listed for paleontological resources below are in conformance with those BMPs and stipulations. The Las Vegas RMP (BLM 1988) does not provide management direction or BMPs with regard to paleontological resources.

Conclusion. Portions of proposed ROWs may contain areas of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources.

Proposed mitigation measures:

None.

Residual impacts include:

- Even if construction monitoring is implemented, some scientifically valuable fossils may be disturbed and lost during excavation and ROW grading over thousands of acres. As a consequence, there would be a small incremental loss of fossil material that would be offset by the material that is recovered, and curated for scientific study purposes. Since public access to the ROW and surrounding areas would not be prohibited by the BLM, the risk of unauthorized collection of fossil material would remain.

3.2.2.3 Alternative D

Construction and Facility Maintenance

Geological Hazards

Hazards due to fault movement seismic-induced ground motion are not expected to pose a risk during construction of the facilities. Seismicity and active fault hazards present risks to long-term maintenance of the proposed pipeline and facilities. No active faults zones are crossed by the proposed ROWs in Alternative D. However, the proposed ROWs cross fissures of unknown origin in Dry Lake and Delamar valleys. ACM A3.2 would be used to lessen the risk from movement along faults or fissures. Ground motion is not expected to pose a risk to proposed pipelines and facilities. Landslides due to slope failure may present concerns during construction, but not during maintenance. Debris flows pose a concern for facilities adjacent to mountain fronts. ACM A1.67 provides for special construction methods to lessen the risk of damage to facilities from high runoff events or debris flows.

Subsidence from karst is not expected to have impacts on operational and maintenance activities in ROW areas.

Erionite is not likely to pose a concern because erionite-containing deposits have not been identified in the project area.

Caves

Caves would not be affected during construction or maintenance of ROW facilities.

Conclusion. Geologic hazards are not likely to pose risks during construction of ROW facilities. During facility maintenance, seismic hazards, active faults, fissures, and debris flows pose the greatest concern. The proposed pipeline and facilities are not likely to be at risk from expected ground motion and karst. There is a low potential for disturbance or damage to caves from construction activities and cave resources would not be affected by maintenance of the facilities.

Proposed mitigation measures:

None.

Residual impacts include:

- A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement and seismicity.

Paleontological Resources

Potential impacts to fossil resource during construction would be both direct and indirect. Direct impacts to or destruction of fossils would occur from trenching or facility construction activities conducted through important fossil beds. Indirect impacts during construction would include erosion of fossil beds due to slope re-grading and vegetation clearing or the unauthorized collection of scientifically important fossils by construction workers or the public due to increased access to fossil localities along the ROW. Routine facility maintenance of the proposed pipeline and related facilities would not disturb paleontological resources. Maintenance activities that would result in surface disturbance typically would occur within the ROW that was previously disturbed during construction. Since new disturbances would not be anticipated from routine maintenance activities (i.e., maintenance activities would occur within the ROW), impacts to paleontological resources would be negligible.

<u>Conclusion</u>. Portions of proposed ROWs may contain areas of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources.

Proposed mitigation measures:

None.

Residual impacts include:

- Paleontological Resources – Some paleontological resources may be disturbed or lost during excavation of the pipeline ROW. There could be a small incremental loss of fossil material that would be offset by recovered material and curated for scientific study. There is a risk of unauthorized collection of fossil materials.
- Geologic Hazards – There is a small risk of facility damage after implementation of geological studies and design measures for fault movement and seismicity.

3.2.2.4 Alternative E

Construction and Facility Maintenance

Geological Hazards

Hazards due to fault movement seismic-induced ground motion are not expected to pose a risk during construction of the facilities. Seismicity and active fault hazards present risks to long-term maintenance of the proposed pipeline and facilities. There is 1 active fault zone (last movement demonstrated to be less than 15,000 years ago) that is present in the proposed in ROW areas: the Southern Spring Valley fault zone (**Figures 3.2-2** and **3.2-3**) (Sawyer and Redsteer 2000). The Southern Spring Valley fault zone is a series of scarps along the west side of the southern Spring Valley. The proposed ROWs cross fissures of unknown origin in Dry Lake and Delamar valleys (Swadley 1995). ACM A3.2 would be used to lessen the risk from movement along faults or fissures. Ground motion is not expected to pose a risk to proposed pipelines and facilities. Landslides due to slope failure may present concerns during construction, but not during maintenance. Debris flows pose a concern for facilities adjacent to mountain fronts. ACM A1.67 provides for special construction methods to lessen the risk of damage to facilities from high runoff events or debris flows.

Subsidence from karst is not expected to have impacts on operational and maintenance activities in the ROW areas and caves would not be affected during construction or maintenance of the ROW facilities.

Erionite is not likely to pose a concern because erionite-containing deposits have not been identified in the project area.

Caves

Caves would not be affected during construction or maintenance of the ROW facilities.

Conclusion. Geologic hazards are not likely to pose risks during construction of the ROW facilities. During facility maintenance, seismic hazards, active faults, fissures, and debris flows pose the greatest concern. The proposed pipeline and facilities are not likely to be at risk from expected ground motion and karst. There is a low potential for disturbance or damage to caves from construction activities and cave resources would not be affected by maintenance of the facilities.

Proposed mitigation measures:

None.

Residual impacts include:

- A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement and seismicity.

Paleontological Resources

Potential impacts to fossil resource during construction would be both direct and indirect. Direct impacts to or destruction of fossils would occur from trenching or facility construction activities conducted through important fossil beds. Indirect impacts during construction would include erosion of fossil beds due to slope re-grading and vegetation clearing or the unauthorized collection of scientifically important fossils by construction workers or the public due to increased access to fossil localities along the ROW. Routine facility maintenance of the proposed pipeline and related facilities would not disturb paleontological resources. Maintenance activities that would result in surface disturbance typically would occur within the ROW that was previously disturbed during construction. Since new disturbances would not be anticipated from routine maintenance activities (i.e., maintenance activities would occur within the ROW), impacts to paleontological resources would be negligible.

Conclusion. Portions of the proposed ROWs may contain areas of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources.

Proposed mitigation measures:

None.

Residual impacts include:

- Paleontological Resources – Some paleontological resources may be disturbed or lost during excavation of the pipeline ROW. There could be a small incremental loss of fossil material that would be offset by recovered material and curated for scientific study. There is a risk of unauthorized collection of fossil materials.

3.2.2.5 Alignment Options 1 through 4

Table 3.2-2 presents impacts for the Alignment Options (1 through 4) in relation to the relevant underground or aboveground facility segment(s) of the Proposed Action.

Table 3.2-2 Paleontological and Geological Resources Impact Summary for Alignment Options 1 through 4 as Compared to Proposed Action

Option	Analysis
Alignment Option 1 (The potential effects on paleontological and geological resources of changing the locations of a portion of the 230 kV power line from Gonder Substation near Ely to Spring Valley)	Alignment Option 1 would result in no changes in potential impacts to paleontological resources and geological hazards compared to the relevant segment of the Proposed Action.
Alignment Option 2 (The potential effects on paleontological and geological resources of changing the locations of portions of the mainline pipeline and electrical transmission line in north Lake Valley)	Alignment Option 2 would result in no changes in potential impacts to paleontological resources and geological hazards compared to the relevant segment of the Proposed Action.
Alignment Option 3 (The potential effects on paleontological and geological resources of eliminating the Gonder to Spring Valley transmission line, and constructing a substation with an interconnection with an interstate, high voltage power line in Muleshoe Valley).	Alignment Option 3 would result in no changes in potential impacts to paleontological resources and geological hazards compared to the relevant segment of the Proposed Action.
Alignment Option 4 (The potential effects on paleontological and geological resources of changing the location of a short section of mainline pipeline in Delamar Valley to follow an existing transmission line).	Alignment Option 4 would result in no changes in potential impacts to paleontological resources and geological hazards compared to the relevant segment of the Proposed Action.

3.2.2.6 No Action

If the proposed project did not occur, then there would be no impacts to paleontological resources and geological hazards. No project-related surface disturbance would occur. Paleontological and geological resources would continue to be affected by natural events such as wildfires and land use activities such as mining.

3.2.2.7 Comparison of Alternatives

Table 3.2-3 summarizes the major differences between the alternatives.

Table 3.2-3 Comparison of Alternatives

Parameter	Proposed Action, Alternatives A through C	Alternative D	Alternative E
Active Faults	There are two active fault zones present in proposed project areas: the Southern Spring Valley and Snake Valley fault zones. The proposed ROWs cross fissures of unknown origin in Dry Lake Valley.	No active fault zones are crossed, but ROWs do cross fissures in Dry Lake Valley.	There is one active fault zone present in proposed project areas: the Southern Spring Valley fault zone. The proposed ROWs cross fissures of unknown origin in Dry Lake Valley.

3.2.2.8 Groundwater Development and Groundwater Pumping

Issues

Groundwater Development Construction and Facility Maintenance

The following issues for paleontological resources and geological hazards are evaluated for groundwater development construction and facility maintenance.

Geological Hazards

- Risk of potential damage to groundwater development facilities from earthquake ground motion and permanent ground displacement along faults or ground fissures of undetermined origin.
- Areas underlain by carbonate formations may have the potential for ground subsidence due to karst features (see Caves below). Ground subsidence due to karst can create loss of support and damage to groundwater development facilities.
- Potential health risks to workers and public due to exposure to erionite.

Caves

- Unique geological features in the region are caves that have formed in bedrock carbonate formations. Caves provide habitat for flora and fauna as well as localities for scientifically important fossil resources. Caves may be adversely affected by groundwater development and maintenance activities.
- Caves are the natural result of dissolution processes on susceptible rock layers. Caves and naturally-occurring voids that have not manifested to the surface also present hazards. Also, the caves themselves constitute unique geological features that are potentially at risk. However, there are other concerns related to caves with regard to groundwater hydrology, wildlife, and cultural resources. Concerns related to those resources are discussed in the appropriate sections of this document.

Paleontological Resources

- Potential damage and loss of scientifically important fossils could occur during groundwater development including clearing, grading, trench excavation, construction of other pipeline-related facilities, development of production well sites, and operational maintenance activities that would require disturbance of previously unaffected areas. Loss of scientifically valuable fossils also may occur because of vandalism or unauthorized collection.

Groundwater Pumping

Geological Hazards

- The major geologic hazard associated with groundwater pumping would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits.
- Landslides and seismic hazards are not considered for analysis under groundwater pumping.
- Erionite is not a concern with groundwater pumping.

Caves

- Data do not exist to provide a connection of area caves to groundwater; therefore, caves are not anticipated to be affected by groundwater pumping.

Paleontological Resources

- Groundwater pumping is not expected to have effects on paleontological resources. Therefore there are no issues concerning potential impacts to paleontological resources with regard to groundwater pumping.

Assumptions

Groundwater Development Construction and Facility Maintenance

The following assumptions were used in the impact analysis for geological and paleontological resources for groundwater development construction and facility maintenance:

Geological Hazards

- The location of active faults is based on information available from the USGS and NBMG (2006). The ground motion estimate is based on recent updates of the USGS seismic hazard mapping by the USGS (2010). There are numerous Quaternary faults in the project area which may rupture at any time, however, only those faults with movement documented by the USGS and NBMG (2006) in the last 15,000 years are considered to be active.
- Movement across ground fissures in the Dry Lake and Delamar Valleys may result in ground deformation similar to that caused by movement on active faults.
- Landslide risk information is based on data provided in the National Atlas (2008). The data for landslide incident and susceptibility areas is based on Radbruch-Hall et al. (1982), Landslide Overview map of the Conterminous U.S. Because of the scale of the map, it overstates the landslide risk in the southern Snake Range. Landslide risk was assessed using large-scale mapping, where available, that showed mapped landslides in relation to proposed project elements (NPS 2009).
- Nevada does not a have a state-wide database for sinkholes (Nevada Mines and Geology 2010), therefore potential karst areas were identified by review of the national karst hazards mapping by Davies et al. (1984) which used for the karst layer in the National Atlas (2008). As with the national landslide risk mapping, the karst hazards map of the U.S. at a 1:7,500,000 scale may overstate the potential for karst development. However, the presence of caves in areas underlain by limestone may indicate the potential presence for other karst features such as sinkholes.
- The greatest exposure risk to erionite would occur during active ground disturbance and excavation.

Caves

- In the analysis of ROW construction and maintenance effects, caves are considered to be unique geological features.
- Underground voids derived from natural processes could be present, but have yet to be manifested on the surface, posing hazards to activities on the surface.

Paleontological Resources

- Areas of medium to high potential for valuable fossil resources were defined on the basis of literature review and assessment conducted by the San Bernardino Museum (Scott 2008). No field surveys were conducted. The fossil yield potential areas identified for this analysis were used to define areas where detailed on-site surveys would be needed.

Groundwater Pumping

The following assumptions were used in the impact analysis for geological hazards and cave resources for groundwater pumping.

Geological Hazards

- Hazards from seismicity, active faults, landslides, karst, and erionite are not considered risks associated with groundwater pumping. Rather, the geologic hazard of subsidence due to withdrawal of subsurface fluids result is the only geologic hazard considered in analyzing groundwater pumping effects.
- Drawdown of potentiometric heads from groundwater pumping may cause subsidence of unconsolidated valley fill materials.
- The fissures identified in the Delamar and Dry Lake valleys have the potential to be affected by groundwater pumping.
- In the absence of modeling it is assumed that 20 feet of drawdown could result in 1 foot of subsidence (Bell 1981).

- The magnitude of potential subsidence coincides with the magnitude of groundwater drawdown, but actual subsidence also is highly dependent on other conditions such as composition and physical properties of the aquifers that would be pumped. Pumping from well-cemented or solid grain-supported rocks is not likely to cause subsidence; whereas pumping from unconsolidated deposits with a high proportion of fine-grained materials would be more prone to compaction from fluid withdrawal that would result in subsidence. The analysis of subsidence assumes that aquifer materials would be prone to a degree of compaction because of groundwater withdrawal.
- Assumptions about the potential changes in future groundwater availability from groundwater pumping do not incorporate additional assumptions about the effects of climate change because specific long-term effects of climate change are not presently known, and the incremental contribution of climate change effects to project effects cannot be reasonably estimated. A general discussion of climate change effects is provided in Section 3.1.3.2, Climate Change Effects to All Other Resources.

Caves

- Some caves in the area have been nominated as “Significant Caves” under the Federal Cave Resources Protection Act of 1988 based on several resource values. It is assumed that there are identified caves and other caves yet to be discovered that have the potential to be nominated and listed.

Methodology for Analysis

Groundwater Development Construction and Facility Maintenance

The methodology for impact analysis for geological and paleontological resources for groundwater development construction and facility maintenance is the same as that described for ROWs:

Groundwater Pumping

The impact analysis methodology for geological hazards for groundwater pumping are listed below.

Geological Hazards

- Provide a relative magnitude of subsidence that could occur due to the proposed groundwater pumping by looking at subsidence due to groundwater withdrawal in analogous basins that are similar in character to the basins proposed for extraction.
- Use documented subsidence from groundwater withdrawal in other Great Basin or southwestern U.S. valleys as analogs to provide a qualitative estimate of drawdown risk of subsidence from the proposed groundwater pumping scenarios.

3.2.2.9 Proposed Action

Groundwater Development Area

Geologic Hazards

Seismicity and Active Faults. During construction activities, potential effects due to seismicity and permanent ground displacement are not expected to pose a concern. Seismicity and active fault hazards present risks to long-term maintenance of the proposed pipeline and facilities. Permanent ground deformation across faults or fissures could result in damage to pipelines and facilities. There are two potentially active fault zones (last movement demonstrated to be less than 15,000 years ago) present in the proposed in groundwater development areas: the Southern Spring Valley fault zone and the West Dry Lake fault zone (**Figure 3.2-2**) (Anderson 1999; Sawyer and Redsteer 2000). The Southern Spring Valley fault zone is a series of scarps along the west side of Southern Spring Valley. The West Dry Lake Valley fault zone is marked by a series of northeast trending scarps in the central part of the valley. There are also fissures that have been described in Dry Lake and Delamar valleys of undetermined origin, but are possibly seismic (Swadley 1995). Fissures are present in proposed groundwater development areas in the center and east side of Dry Lake Valley.

Ground motion from a maximum earthquake in the project area are expected to range from 10 to 27 percent of the acceleration of gravity (gravity = 9.80 meters per second squared), with a 2 percent probability of exceedance in 50 years (USGS 2010). The highest ground accelerations would be expected to occur in central Lincoln County and the least in southeastern White Pine County. Ground accelerations of 27 percent of g may result in slight damage to well-built structures, but damage may be considerable in poorly built or badly designed structures. Such ground accelerations would probably not affect high-grade steel pipe in good condition (McDonough 1995; Wald et al. 1999). Ground motion risk will be lessened by design and construction of the proposed groundwater development facilities according to applicable and appropriate seismic standards.

Soil liquefaction has the greatest probability of occurring along the edges of alluvial fans where the deposits are saturated at shallow depths (Wills 2001). However, the overall potential for liquefaction would be low because of the expected ground motions in the project area from a maximum earthquake.

Earthquake induced landslides do not appear to present risks since the groundwater development areas are located where there is low landslide risk and susceptibility (see landslide discussion below).

Landslides. During the construction phase, there is a very low risk of landslides in the groundwater development areas since the development areas are located where there is low to medium risk and susceptibility for landslides (National Atlas 2008). An area of high landslide susceptibility and incidence is indicted in the southern Snake Range, southwest of Baker. This area of landslide risk is restricted to the slopes of the range (NPS 2009). Since the groundwater development areas are on the west and east sides of the Snake Range in the valley floors, landslides are not expected to be a concern for construction or facility maintenance.

During facility maintenance, debris flows have the potential to damage groundwater development facilities. The power of debris flows is such that backfill could be eroded and the pipelines exposed and damaged and culverts and roads can be washed away during heavy precipitation events.

Karst. Although there is potential for karst development in the groundwater development areas (National Atlas 2008), karst terrain has not been documented. However, the circumstantial presence of nearby caves may be indicative of the existence of karst potential and hazards related to sinkhole subsidence during construction and maintenance of groundwater development areas. Other hazards in karst terrain would include lost circulation of drilling fluids and potential groundwater contamination.

Erionite. Erionite is not likely to pose a concern because no erionite deposits have been identified in the in areas of proposed disturbance.

The Ely and Las Vegas RMPs (BLM 2008, 1998) provide no management direction or BMPs regarding the siting of facilities with regard to active faults. Therefore, if active faults or fissures cannot be avoided, then the ACMs (**Appendix E**) provide for the following protection measures for active faults and fissures:

- ACM A.3.1: If fault crossings of the pipeline are identified during detailed geotechnical investigations, additional design features will be added to ensure pipeline integrity (e.g., flexible couplings, increased pipe wall thickness, pipe sleeves).
- ACM A.3.2: In the “fissures” area of Dry Lake Valley, in addition to design features, over-excavation of existing soils and replacement with engineered fill, grouting of fissures, and/or use of geo-textile fabric will be utilized as needed to ensure pipeline stability.

The Ely and Las Vegas RMPs (BLM 2008, 1998) provide no management direction or BMPs regarding the siting of facilities with regard landslides and debris flows. To reduce risk due to debris flows, ROW facilities should be located as far as practically allowable from the mouths of drainages at the mountain range-alluvial fan interface. Additional measures are included in the ACMs (**Appendix E**):

- ACM A.1.67: Desert washes and ephemeral drainages will be restored to pre-existing conditions. Soils will be compacted, and additional stabilization measures such as rip rap may be required to protect the facilities and prevent increased erosion in the wash.

Conclusion. Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. See discussion on caves below for analysis of potential hazards from karst since caves and karst are related topics. During facility maintenance, active faults, fissures, and karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from earthquake ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures.

Proposed mitigation measures:

None.

Caves

Caves have been identified in areas close to, but not within groundwater development areas. The development areas are located in Cave Valley and Snake Valley. The presence of caves may be indicative of karst systems that cover larger areas than the caves themselves, but are not obvious on the surface. Construction and maintenance activities in groundwater development areas are likely to pose risks to caves and their unique habitats:

- Increased opportunity for unauthorized entry and disturbance or damage to cave resources.
- Drilling into cave/karst features and providing a pathway for contamination of groundwater.
- Blasting may cause cave instability and collapse.

In addition to the potential impacts listed above, the cave openings and undiscovered underground voids pose risks to health and safety, roads, structures, and runoff.

The Ely and Las Vegas RMPs (BLM 1998; 2008) do not provide general management direction for protection of cave resources; however, there are instances of ACEC and lease stipulations that provide for cave protection in specific locations. The RMPs do not provide management direction for dealing with karst hazards.

<u>Conclusion</u>. There is a potential for disturbance or damage to caves from construction and drilling activities. Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities.

Proposed mitigation measures:

GW-G-1: Cave Protection. Prior to ground disturbing or drilling activities in areas close to identified cave resources, the conditions of approval will require appropriate site specific measures for the protection of caves that may be at risk such as, but not limited to, the following:

- Reasonable and appropriate setbacks and buffers around caves.
- Limitations on blasting.
- Requirements for the storage and handling of hazardous materials such as fuels.
- Other measures that may be appropriate for wells including procedures when encountering subsurface voids while drilling, closed drilling fluid (mud) systems (no earthen mud pits), use of freshwater mud, directional drilling, and special casing programs.

<u>Effectiveness</u>: This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves. <u>Effects on other resources</u>: Effects on other resources would be minimal.

GW-G-2: Underground Voids. If underground voids are unexpectedly encountered during facility construction or drilling, the following measures would apply:

- Work will be halted and the BLM will be notified immediately.
- The BLM, in consultation with the permittee, shall assess the risk of further drilling or siting of surface facilities in the area where the voids are encountered.
- Risk assessment may require the use of appropriate geotechnical methods to gather relevant data on the extent of karst features.

Effectiveness: This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves. Effects on other resources: Effects on other resources would be minimal.

Summary of Impacts Groundwater Development Proposed Action

A summary of impact information including ACMs (where applicable) and mitigation recommendations is provided for the Proposed Action in **Table 3.2-4**. This same tabular presentation is used for Alternatives A through E in groundwater development effects (**Tables 3.2-8**, **3.2-10**, **3.2-12**, **3.2-14**, and **3.2-16**) and in subsequent pumping effects analyses (**Tables 3.2-7**, **3.2-9**, **3.2-11**, **3.2-13**, **3.2-15**, and **3.2-17**).

Paleontological Resources

Figure 3.2-5 displays project elements with respect to paleontological resource sensitivity. Proposed groundwater development areas in the Coyote Springs, Delamar, Dry Lake, Cave, Lake, and Snake valleys are located in areas with deposits that have high potential for important fossils. Potential impacts to fossil localities during construction would be both direct and indirect. Direct impacts to or destruction of fossils would occur from trenching or facility construction activities conducted through important fossil beds. Indirect impacts during construction would include erosion of fossil beds due to slope re-grading and vegetation clearing or the unauthorized collection of scientifically important fossils by construction workers or the public due to increased access to fossil localities in the proposed groundwater development areas.

Any potential effects to fossils from facility maintenance (non-pumping) activities would be isolated due to the probable dispersed nature of maintenance activities. Also, potential impact during operations and maintenance would be minimal since activity would generally occur in previously disturbed areas. Routine operation of the proposed pipeline and related facilities would not disturb paleontological resources. Maintenance activities that would result in surface disturbance typically would occur within areas previously disturbed during construction. Since new disturbances would not be anticipated from routine maintenance activities, impacts to paleontological resources would be negligible. If maintenance or new construction requires disturbance of previously undisturbed areas, the protection measures as described in **Appendix E** would be implemented.

Ely RMP (BLM 2008) provides management direction for dealing with paleontological resources including BMPs for wind energy development and stipulations and notices for fluid minerals leasing. The ACMs listed for paleontological resources below are in conformance with those BMPs and stipulations

To provide protection for potential paleontological resources, protection measures would be followed as provided in **Appendix E**. The protection measures are applicable to ROWs and groundwater development areas. These protection measures include the following:

- ACM A.6.1: A field survey will be conducted of areas within the ROWs identified as having a high potential for paleontological resources, based upon a paleontological records search using the Potential Fossil Yield Classification System. The field surveys will identify if there are surface exposures containing visible fossils and if there is a potential for buried fossils within the construction footprint. If any important fossils or middens are found during the field survey, a program will be developed and implemented to remove any exposed fossils prior to construction.

- ACM A.6.2: Areas identified as having a high potential for buried paleontological resources based upon the field survey will be monitored by a qualified paleontologist during construction activities involving ground disturbance, including grading, excavation, and trenching.
- ACM A.6.3: Any fossils recovered during the field survey or construction monitoring will be prepared in accordance with standard professional paleontological techniques. The fossils will be curated in a BLM-approved facility. A report on the findings and significance of the salvage program, including a list of the recovered fossils, will be prepared following completion of the program. A copy of this report will accompany the fossils, and a copy will be submitted to the Nevada State Museum.

Conclusion. Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources.

Proposed mitigation measures:

None.

Residual impacts include:

- Even if construction monitoring is implemented, some scientifically valuable fossils would be disturbed and lost during excavation and grading over underdetermined distances. As a consequence, there would be a small incremental loss of fossil material that would be offset by the material that is recovered, and curated for scientific study purposes.
- Since public access to the groundwater development and surrounding areas would not be prohibited by the BLM, the risk of unauthorized collection of fossil material would remain.

Table 3.2-4 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Proposed Action Groundwater Development

Effects/Conclusion

- Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures. Proposed mitigation measures would lessen the risk of karst hazards.
- Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities.
- Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. Facility maintenance is not expected to pose risks to paleontological resources.

ACMs

- ACM A.6.1: A field survey will be conducted of areas within the ROWs identified as having a high potential for paleontological resources, based upon a paleontological records search using the Potential Fossil Yield Classification System. The field surveys will identify if there are surface exposures containing visible fossils and if there is a potential for buried fossils within the construction footprint. If any important fossils or middens are found during the field survey, a program will be developed and implemented to remove any exposed fossils prior to construction.
- ACM A.6.2: Areas identified as having a high potential for buried paleontological resources based upon the field survey will be monitored by a qualified paleontologist during construction activities involving ground disturbance, including grading, excavation, and trenching.
- ACM A.6.3: Any fossils recovered during the field survey or construction monitoring will be prepared in accordance with standard professional paleontological techniques. The fossils will be curated in a BLM-approved facility. A report on the findings and significance of the salvage program, including a list of the recovered fossils, will be prepared following completion of the program. A copy of this report will accompany the fossils, and a copy will be submitted to the Nevada State Museum.

Table 3.2-4 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Proposed Action Groundwater Development (Continued)

Proposed Mitigation

GW-G-1: Prior to ground disturbing or drilling activities in areas close to identified cave resources, the conditions of approval will require appropriate site specific measures for the protection of caves that may be at risk such as , but not limited to, the following:

- Reasonable and appropriate setbacks and buffers around caves.
- Limitations on blasting.
- Requirements for the storage and handling of hazardous materials such as fuels.
- Other measures that may be appropriate for wells including procedures when encountering subsurface voids while drilling, closed drilling fluid (mud) systems (no earthen mud pits), use of freshwater mud, directional drilling, and special casing programs.

This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.

GW-G-2: If underground voids are unexpectedly encountered during facility construction or drilling, the following measures would apply:

- Work will be halted and the BLM will be notified immediately.
- The BLM, in consultation with the permittee, shall assess the risk of further drilling or siting of surface facilities in the area where the voids are encountered.
- Risk assessment may require the use of appropriate geotechnical methods to gather relevant data on the extent of karst features.

This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.

Residual Impacts

- Even if construction monitoring is implemented, some scientifically valuable fossils would be disturbed and lost during excavation and grading over underdetermined distances. As a consequence, there would be a small incremental loss of fossil material that would be offset by the material that is recovered, and curated for scientific study purposes.
- Since public access to the groundwater development and surrounding areas would not be prohibited by the BLM, the risk of unauthorized collection of fossil material would remain.
- A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement, seismicity, and karst.

Groundwater Pumping

The following issues for paleontological resources and geological hazards are evaluated for groundwater pumping.

Geological Hazards

The major geologic hazard associated with groundwater pumping would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits. The subsidence due to groundwater withdrawal is a very different phenomenon from subsidence resulting from dissolution of subsurface strata as in karst environments discussed in the ROW and groundwater development impact sections.

There are many variables in this process and no one aquifer is going to react in the same way as other aquifers. Instead of modeling the potential subsidence that might occur due to the withdrawal of groundwater, the purpose here is to provide a relative magnitude of subsidence that could occur due to the proposed action by looking at subsidence due to groundwater withdrawal in analogous basins that are similar in character to the basins proposed for extraction.

Subsidence caused by groundwater withdrawal occurs as a result of a decrease in pore volume of the aquifer as fluids are removed (Holzer and Galloway 2005). The compaction of beds within the aquifer can result in the lowering of the ground surface around the point or points of withdrawal (wells). The subsidence can be from less than a foot to tens of feet depending on the amount of fluid withdrawal and the composition of the aquifer. Finer-grained materials are more susceptible to compaction than coarse-grained materials. Subsidence due to groundwater withdrawal may include the following effects: damage to well casings, roads, structures, utilities, and pipelines. In addition, subsidence would also affect surface drainage flow resulting in undesirable diversion and impoundment of water. Permanent irreversible subsurface compaction causing subsidence could result in decreased well productivity over the lifetime of the well.

If materials prone to compaction are encountered, there is a high likelihood that subsidence would occur. The crucial questions are how much would occur and what are the consequences. There are two simple ways to estimate the amount of subsidence that would occur. One way is to look at documented subsidence rates in similar basins and assign a reasonably comparable rate of subsidence regardless of amount of water withdrawal and extrapolate that rate over time. Another way is to use documented data from an analogous basin and compare the amount of ground subsidence to have occurred for an estimated amount of decline in *potentiometric head* or water table.

For the first case, **Table 3.2-5** provides data on documented subsidence rates and water table declines for similar basins located mainly in the southwestern U.S.

Table 3.2-5 Rates of Subsidence and Water Table Declines for Selected Southwestern U.S. Basins

Location	Maximum Subsidence (feet)	Dates	Subsidence Rate (feet per year)	Maximum Water Table Decline (feet)	Ratio of Subsidence to Water Table (Head) Decline
Central Arizona[1]	9	1915-1971	0.16	374	1:42
Tulare-Wasco, California[1]	14	1926-1970	0.32	100	1:7
Antelope Valley, California[2]	6	1930-1992	0.10	150	1:25
Las Vegas, Nevada[3]	5	1935-2000	0.08	300	1:61
			Average 0.17		Average 1:34

[1] Holzer 1976,p. 425.

[2] Sneed and Galloway 2000, p. 19.

[3] Bell et al. 2002.

Using the average subsidence rate of 0.17 feet per year, for 200 years of pumping, the maximum subsidence would be 34 feet. However, to assume a linear relationship between subsidence and pumping time may overstate the amount of subsidence because of complex interactions of the aquifer materials and rates of recharge in response to groundwater withdrawal (Poland 1984).

Under the second approach, if it is assumed that the maximum drawdown over 200 years would be an estimated 100 feet, then the amount of subsidence based on the average ratio of subsidence to drawdown as shown in **Table 3.2-5** would be approximately 3 feet based on a ratio of 1 foot of subsidence to 34 feet of drawdown. However, this may underestimate the amount of subsidence that may occur. According to Bell (1981), a ratio of 1:20 may be "the most representative value for areas underlain by fine-grained deposits." Areas underlain by coarse materials may have subsidence-to-drawdown ratios of 1:40 to 1:60 because the coarser materials would undergo less compaction than fine-grained materials (Mindling 1974 as cited by Bell 1981). Moreover, observations in the Las Vegas Valley from 1939 to 1962 indicated that the subsidence to drawdown ratio varied over time at a bench mark measuring station from 1:8 to 1:30, but the cause for change in ratio was not explained (Malmberg 1964). Because the subsidence-to-drawdown ratio appears to vary over time and type of subsurface materials, the 1:20 ratio was chosen as a reasonable factor to use for potential subsidence analysis.

From the above data, it is worth noting that pumping in the Las Vegas Valley over the period of 1953 to 1978 was about 61,000 afy (Bell 1981, p.27). Also, to use as a comparison, peak water withdrawal from the Antelope Valley in California ranged from 350,000 to 400,000 afy and has declined since then to about 75,000 afy by 1999 (Sneed and Galloway 2000). Pumping in the Tulare-Wasco area from 1950 to 1962 averaged over 1,036,000 afy (Lofgren and Klausing 1969).

A measure of potential subsidence was estimated based on the assumption that every 20 feet of drawdown would result in 1 foot of surface subsidence. Using the drawdown values calculated in the groundwater withdrawal model, the amount of subsidence over the withdrawal areas can be estimated by using the drawdown contour maps. For example, **Figure 3.3.2-5** depicts the drawdown for the Proposed Action at full build out plus 200 years. The groundwater drawdown contours of 10 feet, 50 feet, 100 feet, and 200 feet enclose areas potentially subject to varying degrees of subsidence. **Table 3.2-6** lists the areas by basin that may be subjected to subsidence for the Proposed Action at full build out plus 200 years. The drawdown and associated potential subsidence magnitude categories shown on **Table 3.2-6** generally follow the drawdown contour intervals so that the regions of varying drawdown on the map correlate with the data in the table, but the acreages on the **Table 3.2-6** and tables in subsequent sections have been adjusted to exclude bedrock areas that are within the influence of drawdown, but would not be subject to compaction subsidence as would valley fill deposits. As can be seen on **Table 3.2-6**, about 525 square miles may be at risk for 5 feet of subsidence of greater. It is assumed that subsidence would occur within the defined drawdown areas.

Table 3.2-6 Potential Subsidence, Proposed Action at Full Build Out Plus 200 Years

Drawdown (feet)	**10 to 20**	**20-50**	**50 to 100**	**100 to 200**	**>200**
Potential Subsidence (feet)	**<1 to 1**	**1 to 2.5**	**2.5 to 5**	**5 to 10**	**>10**
Subsidence Area (square miles)					
Cave Valley	16	22	14	40	59
Coyote Spring Valley	2	<1	0	0	0
Delamar Valley	<1	22	109	86	<1
Dry Lake Valley	52	143	361	<1	0
Hamlin Valley	62	112	166	<1	0
Kane Springs Valley	5	<1	0	0	0
Lake Valley	193	70	2	0	0
Lower Meadow Valley Wash	8	<1	3	0	0
Pahranagat Valley	11	33	5	0	0
Pahroc Valley	10	14	<1	0	0
Panaca Valley	18	3	0	0	0
Patterson Valley	7	0	0	0	0
Pine Valley (Sld)	0	<1	0	0	0
Snake Valley	102	148	187	110	0
Spring Valley (Mvw)	0	0	0	0	0
Spring Valley (Sld)	96	319	223	230	0
Steptoe Valley	14	16	0	0	0
Tippett Valley	49	<1	0	0	0
White River Valley	4	1	0	0	0
Total	**647**	**905**	**1,071**	**465**	**60**

On **Table 3.2-6** it can be seen that the areas at highest risk for subsidence greater than 5 feet are Spring Valley, Snake Valley, Dry Lake Valley, Delamar Valley, and Cave Valley basins.

The groundwater development valleys with predicted drawdown effects are located in sparsely populated areas in comparison to the Las Vegas Valley. Subsidence could damage roads, buried utilities (including the proposed project utilities), and isolated structures where subsidence fissures become manifest. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.

Caves

The unique geological features in the region are caves that have formed in bedrock carbonate formations. Caves provide habitat for flora and fauna. Caves also provide places for unusual and fragile mineral formations. However, there are limited data concerning the sources of water that feed cave systems. Recent research has determined, for instance, that the source of water of the Cave Springs in GBNP may not be linked hydrogeologically with aquifers that would be pumped in Snake Valley (Prudic and Glancy 2009). These springs are fed by meteoric water (largely winter precipitation) and may not be susceptible to drawdown effects. A sample of water taken from the permanent pool at Lehman Caves indicated that water in the pool is sourced from local precipitation and the pool is above the water table. The research by Prudic and Glancy (2009) indicates that caves and cave systems in mountain ranges may also be similarly sourced and not subject to drawdown effects. Many of the caves and cave systems are located at higher elevations in the mountain ranges and are not likely to be in hydrogeologic continuity with basin aquifers. However, because of the lack of data on water sources and hydrogeologic linkages of cave system to basin aquifers, it would be premature to generalize about overall cave susceptibility to drawdown effects.

Conclusion. Insufficient hydrogeologic data exist to estimate drawdown effects to cave water sources.

Monitoring Recommendations:

GW-G-3: Subsidence Monitoring. Subsidence monitoring is recommended in current and proposed water withdrawal areas in order to provide baseline data before build out begins. As groundwater extraction occurs in full production, monitoring would be needed to assess the magnitude and extent of subsidence in order to take actions that would mitigate subsidence where necessary.

The following is a conceptual subsidence monitoring plan. The purpose is to provide a general framework for a subsidence monitoring plan and is not intended to be rigorous in scope. Geotechnical engineering design and best practices will provide the details of a monitoring plan that will be sufficient to assess the development of subsidence to aid in planning and mitigation of potential subsidence impacts.

Baseline Data Acquisition. Baseline data should be collected in the groundwater development areas prior to development. There may already be effects from pumping that, without proper documentation, could be attributed to the proposed groundwater development program. Baseline information would include surveys to precisely determine present elevations in the development areas and collection of evidence of existing subsidence (fissures, displacement of surface features such as roads, structures, and water well damage). If subsidence is already present, then an attempt should be made to estimate how much has occurred up to the present time.

Areas such as the Dry Lake and Delamar valleys have documented fissures and faults (Swadley 1995). Although the origin of these features is not well understood, they could be readily activated by groundwater pumping and provide zones of weakness allowing for preferential development of subsidence along fissures, even if they are presently inactive. If groundwater development is contemplated in any area with known faults regardless of age in valley fill sediments, then accurate baseline data are of critical importance.

Initial Subsidence Modeling, Exploratory Phase. Prior to the drilling of development wells, subsidence models should be developed in groundwater development areas with data taken from exploratory wells. Such an effort may provide sufficient information on subsurface conditions and well productivity that would allow for predictive modeling of subsidence. As wells are drilled and constructed, subsurface and well test information would be obtained that would allow preparation of predictive models. Such information would include subsurface boring logs, core descriptions, geotechnical test results on core materials, and extended pump tests of sufficient volume and duration to provide accurate estimates of potential drawdown and storage coefficients.

Monitoring During Pumping. During the operational phase, subsidence monitoring would be conducted by the following activities.

- Construction of subsidence monitoring monuments along transects or arrays in groundwater development areas to accurately survey changes in land surface with the use of GPS technology. The exact layout of monument transects or arrays would be determined when the location of pumping wells is known, but also should be located to provide information along major roads (e.g., State Highway [SH] 93), county roads, residences, and utilities. Monitoring transects may also be placed across faults in valley fill. In addition to survey monuments and GPS, Interferometric Synthetic Aperture Radar, a remote sensing technique, could be used to monitor changes in ground elevation (Haynes 2009).

- Monitor and document drawdown or declines in head according to best management practices for water production wells. Monitoring during pumping will be carried out in conjunction with stipulated agreements and other adaptive management plans.

Establish a periodic and systematic inspection of water development areas to observe the development and documentation of ground fissures that may develop. The inspection would include observation and documentation of damage to surface structures, roads, utilities, and wells.

Residual impacts include:

- Residual impacts may occur due to subsidence effects, which may continue as long as pumping occurs. Subsidence of the ground surface is likely to be permanent.

Paleontological Resources

Groundwater pumping is not expected to have effects on paleontological resources.

Summary of Impacts, Proposed Action Pumping

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for the Proposed Action, groundwater pumping, in **Table 3.2-7**.

Table 3.2-7 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Proposed Action Pumping

Effects/Conclusion			
• Areas within the 100-foot drawdown contour are at risk over the lifetime of the project for greater than 5 feet of subsidence and include areas in Spring Valley, Snake Valley, Cave Valley, Dry Lake Valley, and Delamar Valley basins. A risk of lesser subsidence could occur outside the 100-foot contour to the 10-foot contour (from 0.5 to 5 feet). The effects of subsidence may be permanent even if pumping ceases. Potential subsidence effects include damage to roads, buried utilities (including the proposed project utilities), and isolated structures. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible. • Groundwater pumping effects on caves cannot be estimated from available information. • Groundwater pumping is not expected to have effects on paleontological resources.			
Impact Indicators By Model Timeframe	**Full Build Out**	**Full Build Out Plus 75 Years**	**Full Build Out Plus 200 Years**
Subsidence greater than 5 feet (square miles)	<1	147	525
ACMs			
• None.			
Monitoring Recommendations			
GW-G-3. Subsidence monitoring is recommended in current and proposed water withdrawal areas in order to provide baseline data before build out begins. As groundwater extraction occurs in full production, monitoring would be needed to assess the magnitude and extent of subsidence in order to take actions that would mitigate subsidence where necessary. Subsidence Monitoring to include: • Baseline Subsidence Monitoring. • Initial Subsidence Modeling, Exploratory Phase. • Monitoring During Pumping. • Establish a periodic and systematic inspection of water development areas to observe the development and documentation of ground fissures that may develop.			

Table 3.2-7 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Proposed Action Pumping (Continued)

Mitigation Recommendations
• Mitigation measures as appropriate for subsidence and caves would be developed through adaptive management as described in **Appendix A**.
Residual Impacts
• Subsidence effects could occur as long as pumping continues. Subsidence of the ground surface is likely to be permanent.

3.2.2.10 Alternative A

Groundwater Development Area

Geological Hazards

Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion.

Caves

There is a potential for disturbance or damage to caves from construction and drilling activities. Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities.

Paleontological Resources

Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources.

Summary of Impacts, Alternative A Groundwater Development

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative A, groundwater development, in **Table 3.2-8**.

Table 3.2-8 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative A Groundwater Development

Effects/Conclusion
• Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures. Proposed mitigation measures would lessen the risk of karst hazards. • Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities. • Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. Facility maintenance is not expected to pose risks to paleontological resources.

Table 3.2-8 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative A Groundwater Development (Continued)

ACMs
• ACM A.6.1: A field survey will be conducted of areas within the ROWs identified as having a high potential for paleontological resources, based upon a paleontological records search using the Potential Fossil Yield Classification System. The field surveys will identify if there are surface exposures containing visible fossils and if there is a potential for buried fossils within the construction footprint. If any important fossils or middens are found during the field survey, a program will be developed and implemented to remove any exposed fossils prior to construction. • ACM A.6.2: Areas identified as having a high potential for buried paleontological resources based upon the field survey will be monitored by a qualified paleontologist during construction activities involving ground disturbance, including grading, excavation, and trenching. • ACM A.6.3: Any fossils recovered during the field survey or construction monitoring will be prepared in accordance with standard professional paleontological techniques. The fossils will be curated in a BLM-approved facility. A report on the findings and significance of the salvage program, including a list of the recovered fossils, will be prepared following completion of the program. A copy of this report will accompany the fossils, and a copy will be submitted to the Nevada State Museum.
Proposed Mitigation
GW-G-1: Prior to ground disturbing or drilling activities in areas close to identified cave resources, the conditions of approval will require appropriate site specific measures for the protection of caves that may be at risk such as , but not limited to, the following: • Reasonable and appropriate setbacks and buffers around caves. • Limitations on blasting. • Requirements for the storage and handling of hazardous materials such as fuels. • Other measures that may be appropriate for wells including procedures when encountering subsurface voids while drilling, closed drilling fluid (mud) systems (no earthen mud pits), use of freshwater mud, directional drilling, and special casing programs. This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves. **GW-G-2**: If underground voids are unexpectedly encountered during facility construction or drilling, the following measures would apply: • Work will be halted and the BLM will be notified immediately. • The BLM, in consultation with the permittee, shall assess the risk of further drilling or siting of surface facilities in the area where the voids are encountered. • Risk assessment may require the use of appropriate geotechnical methods to gather relevant data on the extent of karst features. This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.
Residual Impacts
• Even if construction monitoring is implemented, some scientifically valuable fossils would be disturbed and lost during excavation and grading over underdetermined distances. As a consequence, there would be a small incremental loss of fossil material that would be offset by the material that is recovered, and curated for scientific study purposes. • Since public access to the groundwater development and surrounding areas would not be prohibited by the BLM, the risk of unauthorized collection of fossil material would remain. • A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement, seismicity, and karst.

Groundwater Pumping

Geological Hazards

The major geologic hazard associated with groundwater pumping would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits. The areas at highest risk for subsidence greater than 5 feet are Spring Valley and Cave Valley basins. Potential subsidence effects include impacts to roads, buried utilities (including the proposed project utilities), and isolated structures where subsidence fissures become manifest. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.

Caves

Conclusion. Insufficient hydrogeologic data exist to estimate drawdown effects to cave water sources.

Summary of Impacts Alternative A Pumping

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative A, groundwater pumping, in **Table 3.2-9**.

Paleontological Resources

Groundwater pumping is not expected to have effects on paleontological resources.

Table 3.2-9 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative A Pumping

<table>
<tr><td colspan="4">Effects/Conclusion
• The areas at highest risk for subsidence greater than 5 feet are Spring Valley and Cave Valley basins. A risk of lesser subsidence could occur outside the 100-foot contour to the 10-foot contour (from 0.5 to 5 feet). The effects of subsidence may be permanent even if pumping ceases. Potential subsidence effects include damage to roads, buried utilities (including the proposed project utilities), and isolated structures. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.
• Groundwater pumping effects on caves cannot be estimated from available information.
• Groundwater pumping is not expected to have effects on paleontological resources.</td></tr>
<tr><th>Impact Indicators By Model Timeframe</th><th>Full Build Out</th><th>Full Build Out Plus 75 Years</th><th>Full Build Out Plus 200 Years</th></tr>
<tr><td>Subsidence greater than 5 feet (square miles)</td><td>0</td><td>5</td><td>159</td></tr>
<tr><td colspan="4">ACMs</td></tr>
<tr><td colspan="4">• None.</td></tr>
<tr><td colspan="4">Monitoring Recommendations</td></tr>
<tr><td colspan="4">GW-G-3. Subsidence monitoring is recommended in current and proposed water withdrawal areas in order to provide baseline data before build out begins. As groundwater extraction occurs in full production, monitoring would be needed to assess the magnitude and extent of subsidence in order to take actions that would mitigate subsidence where necessary. Subsidence Monitoring to include:
• Baseline Subsidence Monitoring.
• Initial Subsidence Modeling, Exploratory Phase.
• Monitoring During Pumping.
• Establish a periodic and systematic inspection of water development areas to observe the development and documentation of ground fissures that may develop.</td></tr>
<tr><td colspan="4">Mitigation Recommendations</td></tr>
<tr><td colspan="4">• Mitigation measures as appropriate for subsidence and caves would be developed through adaptive management as described in Appendix A.</td></tr>
<tr><td colspan="4">Residual Impacts</td></tr>
<tr><td colspan="4">• Subsidence effects could occur as long as pumping continues. Subsidence of the ground surface is likely to be permanent.</td></tr>
</table>

3.2.2.11 Alternative B

Groundwater Development Area

Geological Hazards

Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures.

Caves

There is a potential for disturbance or damage to caves from construction and drilling activities. Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities.

Paleontological Resources

Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources.

Summary of Impacts Alternative B Groundwater Development

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative B, groundwater development, in **Table 3.2-10**.

Table 3.2-10 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative B Groundwater Development

Effects/Conclusion
• Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures. Proposed mitigation measures would lessen the risk of karst hazards. • Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities. • Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. Facility maintenance is not expected to pose risks to paleontological resources.
ACMs
• ACM A.6.1: A field survey will be conducted of areas within the ROWs identified as having a high potential for paleontological resources, based upon a paleontological records search using the Potential Fossil Yield Classification System. The field surveys will identify if there are surface exposures containing visible fossils and if there is a potential for buried fossils within the construction footprint. If any important fossils or middens are found during the field survey, a program will be developed and implemented to remove any exposed fossils prior to construction. • ACM A.6.2: Areas identified as having a high potential for buried paleontological resources based upon the field survey will be monitored by a qualified paleontologist during construction activities involving ground disturbance, including grading, excavation, and trenching. • ACM A.6.3: Any fossils recovered during the field survey or construction monitoring will be prepared in accordance with standard professional paleontological techniques. The fossils will be curated in a BLM-approved facility. A report on the findings and significance of the salvage program, including a list of the recovered fossils, will be prepared following completion of the program. A copy of this report will accompany the fossils, and a copy will be submitted to the Nevada State Museum.

Table 3.2-10 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative B Groundwater Development (Continued)

Proposed Mitigation
GW-G-1: Prior to ground disturbing or drilling activities in areas close to identified cave resources, the conditions of approval will require appropriate site specific measures for the protection of caves that may be at risk such as, but not limited to, the following: • Reasonable and appropriate setbacks and buffers around caves. • Limitations on blasting. • Requirements for the storage and handling of hazardous materials such as fuels. • Other measures that may be appropriate for wells including procedures when encountering subsurface voids while drilling, closed drilling fluid (mud) systems (no earthen mud pits), use of freshwater mud, directional drilling, and special casing programs. This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves. **GW-G-2**: If underground voids are unexpectedly encountered during facility construction or drilling, the following measures would apply: • Work will be halted and the BLM will be notified immediately. • The BLM, in consultation with the permittee, shall assess the risk of further drilling or siting of surface facilities in the area where the voids are encountered. • Risk assessment may require the use of appropriate geotechnical methods to gather relevant data on the extent of karst features. This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.
Residual Impacts
• Even if construction monitoring is implemented, some scientifically valuable fossils would be disturbed and lost during excavation and grading over underdetermined distances. As a consequence, there would be a small incremental loss of fossil material that would be offset by the material that is recovered, and curated for scientific study purposes. • Since public access to the groundwater development and surrounding areas would not be prohibited by the BLM, the risk of unauthorized collection of fossil material would remain. • A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement, seismicity, and karst.

Groundwater Pumping

Geological Hazards

The major geologic hazard associated with groundwater pumping would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits. Simply stated, subsidence occurs in unconsolidated aquifers when compaction occurs in response to withdrawal of water. **Figure 3.3.2-18** depicts the drawdown for Alternative B full build out plus 200 years. The groundwater drawdown contours of 10 feet, 50 feet, 100 feet, and 200 feet enclose areas potentially subject to varying degrees of subsidence. For Alternative B at full build out plus 200 years, it is estimated that about 669 square miles would be at high risk for subsidence greater than 5 feet.

The areas at highest risk for subsidence greater than 5 feet are Dry Lake Valley, Delamar Valley, Lake Valley, Snake Valley, Spring Valley, and Cave Valley basins. Potential subsidence effects include impacts to roads, buried utilities (including the proposed project utilities), and isolated structures where subsidence fissures become manifest. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.

Caves

Conclusion. Insufficient hydrogeologic data exist to estimate drawdown effects to cave water sources.

Paleontological Resources

Groundwater pumping is not expected to have effects on paleontological resources.

Summary of Impacts Alternative B Pumping

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative B, groundwater pumping, in **Table 3.2-11**.

Table 3.2-11 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative B Pumping

Effects/Conclusion

- The areas at highest risk for subsidence greater than 5 feet are Dry Lake Valley, Delamar Valley, Lake Valley, Snake Valley, Spring Valley and Cave Valley basins. A risk of lesser subsidence could occur outside the 100-foot contour to the 10-foot contour (from 0.5 to 5 feet). The effects of subsidence may be permanent even if pumping ceases. Potential subsidence effects includes damage to roads, buried utilities (including the proposed project utilities), and isolated structures. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.
- Groundwater pumping effects on caves cannot be estimated from available information.
- Groundwater pumping is not expected to have effects on paleontological resources.

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	3	172	669

ACMs

- None.

Monitoring Recommendations

GW-G-3. Subsidence monitoring is recommended in current and proposed water withdrawal areas in order to provide baseline data before build out begins. As groundwater extraction occurs in full production, monitoring would be needed to assess the magnitude and extent of subsidence in order to take actions that would mitigate subsidence where necessary. Subsidence Monitoring to include:

- Baseline Subsidence Monitoring.
- Initial Subsidence Modeling, Exploratory Phase.
- Monitoring During Pumping.
- Establish a periodic and systematic inspection of water development areas to observe the development and documentation of ground fissures that may develop.

Mitigation Recommendations

- Mitigation measures as appropriate for subsidence and caves would be developed through adaptive management as described in **Appendix A**.

Residual Impacts

- Subsidence effects could occur as long as pumping continues. Subsidence of the ground surface is likely to be permanent.

3.2.2.12 Alternative C

Groundwater Development Area

Geological Hazards

Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion

Caves

There is a potential for disturbance or damage to caves from construction and drilling activities. Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities.

Paleontological Resources

Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources.

Summary of Impacts Alternative C Groundwater Development

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative C, groundwater development, in **Table 3.2-12**.

Table 3.2-12 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative C Groundwater Development

Effects/Conclusion

- Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures. Proposed mitigation measures would lessen the risk of karst hazards.
- Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities.
- Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. Facility maintenance is not expected to pose risks to paleontological resources.

ACMs

- ACM A.6.1: A field survey will be conducted of areas within the ROWs identified as having a high potential for paleontological resources, based upon a paleontological records search using the Potential Fossil Yield Classification System. The field surveys will identify if there are surface exposures containing visible fossils and if there is a potential for buried fossils within the construction footprint. If any important fossils or middens are found during the field survey, a program will be developed and implemented to remove any exposed fossils prior to construction.
- ACM A.6.2: Areas identified as having a high potential for buried paleontological resources based upon the field survey will be monitored by a qualified paleontologist during construction activities involving ground disturbance, including grading, excavation, and trenching.
- ACM A.6.3: Any fossils recovered during the field survey or construction monitoring will be prepared in accordance with standard professional paleontological techniques. The fossils will be curated in a BLM-approved facility. A report on the findings and significance of the salvage program, including a list of the recovered fossils, will be prepared following completion of the program. A copy of this report will accompany the fossils, and a copy will be submitted to the Nevada State Museum.

Proposed Mitigation

GW-G-1: Prior to ground disturbing or drilling activities in areas close to identified cave resources, the conditions of approval will require appropriate site specific measures for the protection of caves that may be at risk such as, but not limited to, the following:

- Reasonable and appropriate setbacks and buffers around caves.
- Limitations on blasting.
- Requirements for the storage and handling of hazardous materials such as fuels.
- Other measures that may be appropriate for wells including procedures when encountering subsurface voids while drilling, closed drilling fluid (mud) systems (no earthen mud pits), use of freshwater mud, directional drilling, and special casing programs.

This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.

GW-G-2: If underground voids are unexpectedly encountered during facility construction or drilling, the following measures would apply:

- Work will be halted and the BLM will be notified immediately.
- The BLM, in consultation with the permittee, shall assess the risk of further drilling or siting of surface facilities in the area where the voids are encountered.
- Risk assessment may require the use of appropriate geotechnical methods to gather relevant data on the extent of karst features.

This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.

Table 3.2-12 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative C Groundwater Development (Continued)

Residual Impacts
• Even if construction monitoring is implemented, some scientifically valuable fossils would be disturbed and lost during excavation and grading over underdetermined distances. As a consequence, there would be a small incremental loss of fossil material that would be offset by the material that is recovered, and curated for scientific study purposes. • Since public access to the groundwater development and surrounding areas would not be prohibited by the BLM, the risk of unauthorized collection of fossil material would remain. • A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement, seismicity, and karst.

Groundwater Pumping

Geological Hazards

The major geologic hazard associated with groundwater pumping would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits. Simply stated, subsidence occurs in unconsolidated aquifers when compaction occurs in response to withdrawal of water. A measure of potential subsidence was estimated based on the assumption that every 20 feet of drawdown would result in 1 foot of surface subsidence. Using the drawdown values calculated in the groundwater withdrawal model, the amount of subsidence and risk of severe subsidence over the withdrawal areas can be estimated by using the drawdown contour maps. For example, **Figure 3.3.2-21** depicts the drawdown for Alternative C full build out plus 200 years. The groundwater drawdown contours of 10 feet, 50 feet, 100 feet, and 200 feet enclose areas potentially subject to varying degrees of subsidence. For Alternative C at full build out plus 200 years, it is estimated that about 1 square mile would be at high risk for subsidence greater than 5 feet in the Cave Valley basin.

Potential subsidence effects include impacts to roads, buried utilities (including the proposed project utilities), and isolated structures where subsidence fissures become manifest. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.

Subsidence monitoring as described in Section 3.2.2.9, Proposed Action, is recommended to assess the magnitude and extent of subsidence.

Caves

Conclusion. Insufficient hydrogeologic data exist to estimate drawdown effects to cave water sources.

Paleontological Resources

Groundwater pumping is not expected to have effects on paleontological resources

Summary of Impacts Alternative C Pumping

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative C, groundwater pumping, in **Table 3.2-13**.

Table 3.2-13 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative C Pumping

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Effects/Conclusion • The areas at highest risk for subsidence greater than 5 feet are Spring Valley and Cave Valley basins. A risk of lesser subsidence could occur outside the 100-foot contour to the 10-foot contour (from 0.5 to 5 feet). The effects of subsidence may be permanent even if pumping ceases. Potential subsidence effects includes damage to roads, buried utilities (including the proposed project utilities), and isolated structures. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. • Groundwater pumping impacts on caves cannot be estimated from available information. • Groundwater pumping is not expected to have effects on paleontological resources.			
Subsidence greater than 5 feet (square miles)	0	<1	1
ACMs			
• None.			
Monitoring Recommendations			
GW-G-3. Subsidence monitoring is recommended in current and proposed water withdrawal areas in order to provide baseline data before build out begins. As groundwater extraction occurs in full production, monitoring would be needed to assess the magnitude and extent of subsidence in order to take actions that would mitigate subsidence where necessary. Subsidence Monitoring to include: • Baseline Subsidence Monitoring. • Initial Subsidence Modeling, Exploratory Phase. • Monitoring During Pumping. • Establish a periodic and systematic inspection of water development areas to observe the development and documentation of ground fissures that may develop.			
Mitigation Recommendations			
• Mitigation measures as appropriate for subsidence and caves would be developed through adaptive management as described in **Appendix A**.			
Residual Impacts			
• Subsidence effects could occur as long as pumping continues. Subsidence of the ground surface is likely to be permanent.			

3.2.2.13 Alternative D

Groundwater Development Area

Geological Hazards

Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion

Caves

There is a potential for disturbance or damage to caves from construction and drilling activities. Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities.

Paleontological Resources

Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources

Summary of Impacts Alternative C Groundwater Development

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative D, groundwater development, in **Table 3.2-14**.

Table 3.2-14 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative D Groundwater Development

Effects/Conclusion
• Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures. Proposed mitigation measures would lessen the risk of karst hazards. • Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities. • Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. Facility maintenance is not expected to pose risks to paleontological resources.
ACMs
• ACM A.6.1: A field survey will be conducted of areas within the ROWs identified as having a high potential for paleontological resources, based upon a paleontological records search using the Potential Fossil Yield Classification System. The field surveys will identify if there are surface exposures containing visible fossils and if there is a potential for buried fossils within the construction footprint. If any important fossils or middens are found during the field survey, a program will be developed and implemented to remove any exposed fossils prior to construction. • ACM A.6.2: Areas identified as having a high potential for buried paleontological resources based upon the field survey will be monitored by a qualified paleontologist during construction activities involving ground disturbance, including grading, excavation, and trenching. • ACM A.6.3: Any fossils recovered during the field survey or construction monitoring will be prepared in accordance with standard professional paleontological techniques. The fossils will be curated in a BLM-approved facility. A report on the findings and significance of the salvage program, including a list of the recovered fossils, will be prepared following completion of the program. A copy of this report will accompany the fossils, and a copy will be submitted to the Nevada State Museum.
Proposed Mitigation
GW-G-1: Prior to ground disturbing or drilling activities in areas close to identified cave resources, the conditions of approval will require appropriate site specific measures for the protection of caves that may be at risk such as, but not limited to, the following: • Reasonable and appropriate setbacks and buffers around caves. • Limitations on blasting. • Requirements for the storage and handling of hazardous materials such as fuels. • Other measures that may be appropriate for wells including procedures when encountering subsurface voids while drilling, closed drilling fluid (mud) systems (no earthen mud pits), use of freshwater mud, directional drilling, and special casing programs. This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves. **GW-G-2**: If underground voids are unexpectedly encountered during facility construction or drilling, the following measures would apply: • Work will be halted and the BLM will be notified immediately. • The BLM, in consultation with the permittee, shall assess the risk of further drilling or siting of surface facilities in the area where the voids are encountered. • Risk assessment may require the use of appropriate geotechnical methods to gather relevant data on the extent of karst features. This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.

Table 3.2-14 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative D Groundwater Development (Continued)

Residual Impacts
• Even if construction monitoring is implemented, some scientifically valuable fossils would be disturbed and lost during excavation and grading over underdetermined distances. As a consequence, there would be a small incremental loss of fossil material that would be offset by the material that is recovered, and curated for scientific study purposes. • Since public access to the groundwater development and surrounding areas would not be prohibited by the BLM, the risk of unauthorized collection of fossil material would remain. • A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement, seismicity, and karst.

Groundwater Pumping

Geological Hazards

The major geologic hazard associated with groundwater pumping would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits. Simply stated, subsidence occurs in unconsolidated aquifers when compaction occurs in response to withdrawal of water. A measure of potential subsidence was estimated based on the assumption that every 20 feet of drawdown would result in 1 foot of surface subsidence. Using the drawdown values calculated in the groundwater withdrawal model, the amount of subsidence and risk of severe subsidence over the withdrawal areas can be estimated by using the drawdown contour maps. For example, **Figure 3.3.2-25** depicts the drawdown for Alternative D full build out plus 200 years. The groundwater drawdown contours of 10 feet, 50 feet, 100 feet, and 200 feet enclose areas potentially subject to varying degrees of subsidence.

The areas at highest risk for subsidence greater than 5 feet are Lake Valley, southern Spring Valley and Cave Valley basins.

Of note in exception to the other alternatives, there is a risk of subsidence greater than 5 feet beginning at full build out. Potential subsidence would occur in south Spring Valley, the portion within Lincoln County. As pumping continues through time, subsidence risk would remain concentrated in the south Spring Valley, but by full build out plus 200 years, the aforementioned valleys would also be at risk for subsidence greater than 5 feet. Potential subsidence effects include impacts to roads, buried utilities (including the proposed project utilities), and isolated structures where subsidence fissures become manifest. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.

Subsidence monitoring as described in Section 3.2.2.9, Proposed Action, is recommended to assess the magnitude and extent of subsidence.

Caves

Conclusion. Insufficient hydrogeologic data exist to estimate drawdown effects to cave water sources.

Paleontological Resources

Groundwater pumping is not expected to have effects on paleontological resources.

Summary of Impacts Alternative D Pumping

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative D, groundwater pumping, in **Table 3.2-15**.

Table 3.2-15 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative D Pumping

Effects/Conclusion

- The areas at highest risk for subsidence greater than 5 feet are Lake Valley, southern Spring Valley and Cave Valley basins. A risk of lesser subsidence could occur outside the 100-foot contour to the 10 foot contour (from 0.5 to 5 feet). The effects of subsidence may be permanent even if pumping ceases. Potential subsidence effects includes damage to roads, buried utilities (including the proposed project utilities), and isolated structures. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.
- Groundwater pumping effects on caves cannot be estimated from available information.
- Groundwater pumping is not expected to have effects on paleontological resources.

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	25	139	269

ACMs

- Mitigation measures as appropriate for subsidence and caves would be developed through adaptive management as described in **Appendix A**.

Monitoring Recommendations

GW-G-3. Subsidence monitoring is recommended in current and proposed water withdrawal areas in order to provide baseline data before build out begins. As groundwater extraction occurs in full production, monitoring would be needed to assess the magnitude and extent of subsidence in order to take actions that would mitigate subsidence where necessary. Subsidence Monitoring to include:

- Baseline Subsidence Monitoring.
- Initial Subsidence Modeling, Exploratory Phase.
- Monitoring During Pumping.
- Establish a periodic and systematic inspection of water development areas to observe the development and documentation of ground fissures that may develop.

Mitigation Recommendations

- None.

Residual Impacts

- Subsidence effects could occur as long as pumping continues. Subsidence of the ground surface is likely to be permanent.

3.2.2.14 Alternative E

Groundwater Development Area

Geological Hazards

Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures. Proposed mitigation measures would lessen the risk of karst hazards.

Caves

There is a potential for disturbance or damage to caves from construction and drilling activities. Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities.

Paleontological Resources

Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. The BLM BMPs and ACMs would ensure that important fossils are properly documented and curated, and therefore lessen potential impacts during construction of the pipeline and related facilities. Facility maintenance is not expected to pose risks to paleontological resources.

Summary of Impacts Alternative E Groundwater Development

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative E, groundwater development, in **Table 3.2-16**.

Table 3.2-16 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative E Groundwater Development

Effects/Conclusion

- Except for potential karst, geologic hazards are not likely to pose risks during drilling and construction of groundwater development facilities. During facility maintenance, active faults, fissures, and potential karst pose potential concerns. The proposed pipeline and facilities are not likely to be at risk from expected ground motion. The ACMs would provide protection for facilities with regard to active faults and fissures. Proposed mitigation measures would lessen the risk of karst hazards.
- Mitigation measures are proposed to lessen potential impacts to caves during groundwater development construction and drilling activities. Cave resources would not be affected by maintenance of the groundwater facilities. Karst features may have impacts on construction and maintenance of groundwater facilities. Mitigation measures are proposed to lessen the potential impact of karst features during construction, drilling, and maintenance of groundwater development facilities.
- Portions of proposed groundwater development areas may contain deposits of medium to high potential for scientifically important fossil resources. Facility maintenance is not expected to pose risks to paleontological resources.

ACMs

- ACM A.6.1: A field survey will be conducted of areas within the ROWs identified as having a high potential for paleontological resources, based upon a paleontological records search using the Potential Fossil Yield Classification System. The field surveys will identify if there are surface exposures containing visible fossils and if there is a potential for buried fossils within the construction footprint. If any important fossils or middens are found during the field survey, a program will be developed and implemented to remove any exposed fossils prior to construction.
- ACM A.6.2: Areas identified as having a high potential for buried paleontological resources based upon the field survey will be monitored by a qualified paleontologist during construction activities involving ground disturbance, including grading, excavation, and trenching.
- ACM A.6.3: Any fossils recovered during the field survey or construction monitoring will be prepared in accordance with standard professional paleontological techniques. The fossils will be curated in a BLM-approved facility. A report on the findings and significance of the salvage program, including a list of the recovered fossils, will be prepared following completion of the program. A copy of this report will accompany the fossils, and a copy will be submitted to the Nevada State Museum.

Proposed Mitigation

GW-G-1: Prior to ground disturbing or drilling activities in areas close to identified cave resources, the conditions of approval will require appropriate site specific measures for the protection of caves that may be at risk such as, but not limited to, the following:

- Reasonable and appropriate setbacks and buffers around caves.
- Limitations on blasting.
- Requirements for the storage and handling of hazardous materials such as fuels.
- Other measures that may be appropriate for wells including procedures when encountering subsurface voids while drilling, closed drilling fluid (mud) systems (no earthen mud pits), use of freshwater mud, directional drilling, and special casing programs.

This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.

GW-G-2: If underground voids are unexpectedly encountered during facility construction or drilling, the following measures would apply:

- Work will be halted and the BLM will be notified immediately.
- The BLM, in consultation with the permittee, shall assess the risk of further drilling or siting of surface facilities in the area where the voids are encountered.
- Risk assessment may require the use of appropriate geotechnical methods to gather relevant data on the extent of karst features.

This measure would be highly effective in avoiding impacts to caves and to provide a margin of safety for construction and maintenance activities with respect to caves and possible underground voids that may be associated with caves.

Table 3.2-16 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative E Groundwater Development (Continued)

Residual Impacts
• Even if construction monitoring is implemented, some scientifically valuable fossils would be disturbed and lost during excavation and grading over underdetermined distances. As a consequence, there would be a small incremental loss of fossil material that would be offset by the material that is recovered, and curated for scientific study purposes. • Since public access to the groundwater development and surrounding areas would not be prohibited by the BLM, the risk of unauthorized collection of fossil material would remain. • A very small risk of facility damage would remain after implementation of geotechnical studies, and design measures for fault movement, seismicity, and karst.

Groundwater Pumping

Geological Hazards

The major geologic hazard associated with groundwater pumping would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits. Simply stated, subsidence occurs in unconsolidated aquifers when compaction occurs in response to withdrawal of water.

A measure of subsidence risk was estimated based on the assumption that every 20 feet of drawdown would result in 1 foot of surface subsidence. Using the drawdown values calculated in the groundwater withdrawal model, the amount of potential subsidence over the withdrawal areas can be estimated by using the drawdown contour maps. For example, **Figure 3.3.2-29** depicts the drawdown for Alternative E full build out plus 200 years. The groundwater drawdown contours of 10 feet, 50 feet, 100 feet, and 200 feet enclose areas potentially subject to varying degrees of subsidence. For Alternative E at full build out plus 200 years, it is estimated that about 161 square miles would be at high risk for subsidence greater than 5 feet.

The areas at highest risk for subsidence greater than 5 feet are Spring Valley and Cave Valley basins. The reduction in areas at risk for subsidence greater than 5 feet suggests that the reduced pumping proposed in Alternative E is responsible. Potential subsidence effects include impacts to roads, buried utilities (including the proposed project utilities), and isolated structures where subsidence fissures become manifest. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible.

Caves

Conclusion. Insufficient hydrogeologic data exist to estimate drawdown effects to cave water sources.

Paleontological Resources

Groundwater pumping is not expected to have effects on paleontological resources.

Summary of Impacts Alternative E Groundwater Pumping

A summary of impact information, including ACMs (where applicable) and mitigation recommendations is provided for Alternative E, groundwater pumping, in **Table 3.2-17**.

Table 3.2-17 Summary of Geologic Resource Impacts, ACMs, and Monitoring and Mitigation Recommendations for Alternative E Pumping

Effects/Conclusion • The areas at highest risk for subsidence greater than 5 feet are Spring Valley and Cave Valley basins. A risk of lesser subsidence could occur outside the 100-foot contour to the 10-foot contour (from 0.5 to 5 feet). The effects of subsidence may be permanent even if pumping ceases. Potential subsidence effects includes damage to roads, buried utilities (including the proposed project utilities), and isolated structures. Also, changes in surface topography could affect runoff and fissures may become conduits for diverting surface flows. Subsidence impacts would be considered unavoidable adverse impacts and in some cases irreversible. • Groundwater pumping effects on caves cannot be estimated from available information. • Groundwater pumping is not expected to have effects on paleontological resources.			
Impact Indicators By Model Timeframe	**Full Build Out**	**Full Build Out Plus 75 Years**	**Full Build Out Plus 200 Years**
Subsidence greater than 5 feet (square miles)	0	5	153
ACMs			
• Mitigation measures as appropriate for subsidence and caves would be developed through adaptive management as described in **Appendix A**.			
Monitoring Recommendations			
GW-G-3. Subsidence monitoring is recommended in current and proposed water withdrawal areas in order to provide baseline data before build out begins. As groundwater extraction occurs in full production, monitoring would be needed to assess the magnitude and extent of subsidence in order to take actions that would mitigate subsidence where necessary. Subsidence Monitoring to include: • Baseline Subsidence Monitoring. • Initial Subsidence Modeling, Exploratory Phase. • Monitoring During Pumping. • Establish a periodic and systematic inspection of water development areas to observe the development and documentation of ground fissures that may develop.			
Mitigation Recommendations			
• None.			
Residual Impacts			
• Subsidence effects could occur as long as pumping continues. Subsidence of the ground surface is likely to be permanent.			

3.2.2.15 No Action

Groundwater Development Area

Under the No Action, groundwater development activities pursuant to the proposed project would not occur and there would be no impacts.

Groundwater Pumping

Under the No Action, groundwater pumping would continue under status quo condition as described in Chapter 2, Section 2.2, No Action.

Geological Hazards

The major geologic hazard associated with groundwater pumping would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits. As the project would not be pumping groundwater, no subsidence could be attributed to the project.

For the No Action Alternative at full build out plus 200 years, there would be no areas at risk for subsidence greater than 5. However, there is risk of 2.5 to 5 feet of subsidence in 369 square miles, mainly Patterson Valley and Lake Valley basins.

Caves

Conclusion. Insufficient hydrogeologic data exist to estimate drawdown effects to cave water sources.

Paleontological Resources

Groundwater pumping is not expected to have effects on paleontological resources.

3.2.2.16 Alternatives Comparison

Groundwater Development Area

Impacts to paleontological resources would be the same across the alternatives, even with the reduction in footprint of Alternative D and Alternative E, since high potential areas would not change. Similarly, there are no differences between alternatives in regard to risk from the geologic hazards from active faults or fissures.

Groundwater Pumping

Major differences in subsidence risk potential are highlighted in **Table 3.2-18**. Alternative B has the largest area that is at risk for subsidence 5 feet or greater. The No Action Alternative has no areas at risk of 5 feet or greater subsidence. The variable and distributed pumping scenarios proposed in Alternative C appear to reduce the potential of subsidence greater than 5 feet.

Table 3.2-18 Comparison by Alternative of Areas of Potential Subsidence Greater than 5 Feet

Scenario	Proposed Action	No Action	Alternative A	Alternative B	Alternative C	Alternative D	Alternative E
Full Build Out	<1	0	0	3	0	25	0
Full Build Out Plus 75 Years	147	0	5	172	<1	139	5
Full Build Out Plus 200 Years	525	0	159	669	1	269	153

3.2.3 Cumulative Impacts

3.2.3.1 Issues

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

- Risk of potential damage to past and present actions from geologic hazards including earthquake ground motion, movement of active faults, landslides, karst, and erionite.
- The proposed ROW and groundwater development would add infrastructure in areas that may already be at risk.
- The RFFAs would also add infrastructure in areas at risk for geological hazards.

Caves

- Adverse impacts may have occurred to caves from past and present actions.
- The proposed ROW and groundwater development potentially creates additional risk to caves.
- The RFFAs may present an additional potential risk to caves.

Paleontological Resources

- Potential damage and loss of scientifically important fossils may have already occurred from past and present actions.
- The proposed ROW and groundwater development construction may result in incremental loss of fossil resources in addition to past and present actions.
- The RFFAs have the potential to cause loss of fossil resources.

Groundwater Pumping

Geological Hazards

- The major geologic hazard associated with groundwater pumping for cumulative effects would be the risk of subsidence of the ground surface associated with withdrawal of subsurface fluids from valley fill deposits.
- Landslides and seismic hazards are not considered for analysis under cumulative effects for groundwater pumping.
- Erionite is not a considered for analysis for cumulative effects for groundwater pumping.

Caves

- Adverse impacts from groundwater pumping may have occurred to caves from past and present actions.

Paleontological Resources

- Cumulative effects to paleontological resources are not expected from groundwater pumping.

3.2.3.2 Assumptions

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

- The geographic scope of the analysis for geological hazards is limited to the basins in which actual ground disturbing activities would occur and include Cave Valley, Coyote Springs Valley, Delamar Valley, Dry Lake Valley, Garnet Valley, Hamlin Valley, Hidden Valley, Lake Valley, Las Vegas Valley, Snake Valley, and Spring Valley basins. These areas were chosen for cumulative analysis because they are where direct and indirect effects would be expected to occur.

- There may be hazards in these valleys that were not identified because they did not pose a risk to the proposed project, but may constitute risks to other projects.

Caves

- The geographic scope of the analysis for caves is limited to the basins in which actual ground disturbing activities would occur and include Cave Valley, Coyote Springs Valley, Delamar Valley, Dry Lake Valley, Garnet Valley, Hamlin Valley, Hidden, Lake Valley, Las Vegas Valley, Snake Valley, and Spring Valley basins. This analysis area was chosen for cumulative analysis because they are where direct and indirect effects would be expected to occur.

Paleontological Resources

- The geographic scope of the analysis for paleontological resources is limited to the basins in which actual ground disturbing activities would occur and include Cave Valley, Coyote Springs Valley, Delamar Valley, Dry Lake Valley, Garnet Valley, Hamlin Valley, Hidden Valley, Lake Valley, Las Vegas Valley, Snake Valley, and Spring Valley basins. These areas were chosen for cumulative analysis because they are where direct and indirect effects would be expected to occur.
- There may be areas of high fossil potential in these valleys, but not identified by this study.

Groundwater Pumping

Geological Hazards

- The cumulative analysis area for geological hazards (subsidence due to groundwater withdrawal) is within the 10-foot drawdown contour as shown on **Figure 3.3.3-5**. This area was chosen for cumulative analysis because it is where direct and indirect effects would be expected to occur from past and present actions and RFFAs.
- There may be areas where groundwater withdrawal has occurred in the past and into the present where subsidence has already occurred, but has not been identified or documented.

3.2.3.3 Methodology of Analysis

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

Review the past and present actions and RFFAs and assess the level of incremental risk exposure posed by the proposed project within the defined cumulative impact assessment area.

Caves

Review the past and present actions and RFFAs and assess the level of incremental risk to caves by the proposed project within the defined cumulative impact assessment areas.

Paleontological Resources

Review the past and present actions and RFFAs and assess the level of incremental impact that the proposed project is likely to incur on paleontological resources in the defined cumulative impact assessment area.

Groundwater Pumping

Geological Hazards

Review the past and present actions and RFFAs and assess the level of incremental risk of subsidence due to groundwater pumping posed by the proposed project within the defined cumulative impact assessment area.

Paleontological Resources

No analysis methodology is proposed.

3.2.3.4 No Action

Groundwater Development Area

Because the project would not be constructed, there would be no surface impacts to paleontological resources from construction and operation (see Section 3.3, Water Resources **Figure 3.3.1-1**).

Groundwater Pumping Effects

Geological Hazards

Existing groundwater pumping would continue, and may result in areas of subsidence within hydrographic basins that are currently experiencing pumping, and where pumping from foreseeable projects may occur in the future. The areas where risk of subsidence is greater than 5 feet include Clover Valley, Lower Meadow Valley Wash, and Panaca Valley. Others valley potentially at risk for lesser subsidence include Spring Valley, Lake Valley, Patterson Valley, Kane Springs, Coyote Springs Valley, Muddy River Springs Area, Garnet Valley, Hidden Valley (North), Las Vegas Valley and the Black Mountain Area (**Table 3.2-19**).

Table 3.2-19 Summary of Cumulative Potential Subsidence and Cave Resource Impacts for No Action Pumping

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	76	126	164

3.2.3.5 Proposed Action

Groundwater Development Area

Geological Hazards

All RFFAs (see **Table 2.9-1**) that involve ground disturbing activities could potentially be at risk to geological hazards of active faults, fissure, landsides, and karst. Protection measures including BMPs and ACMs applied to this project would cause a small decrease in risk from geological hazards.

Caves

There is a RFFA (Wilson Creek Wind Project) that involves ground disturbing activities above limestone bedrock where caves and voids could occur. This area is geographically separate from the GWD Project pipeline, and no cumulative effects caused by both projects are expected. Recommended mitigation measures include GW-G-1, GW-G-2, and G-3.

Paleontological Resources

The RFFAs that share the same utility corridors (ON transmission line, Wilson Creek Wind) that involve ground disturbing activities potentially could disturb paleontological resources (see **Figure 3.2-10**). Protection measures including BMPs and ACMs applied to this project would provide for the documentation and preservation of scientifically important paleontological resources. As a result, the Proposed Action and the RFFAs would cause a small reduction in paleontological resources.

Groundwater Pumping Effects

Geological Hazards

Figure 3.2-6 illustrates the estimated subsidence effects in hydrologic basins affected by Proposed Action operations. Cave Valley, Spring Valley, and Delamar are predicted to experience subsidence in excess of 50 feet at full build out plus 75 years from cumulative project operations. Both Spring and Snake Valley are predicted to experience subsidence in excess of 100 feet at full build out plus 200 years. In the near term, the cumulative effects of subsidence are nearly identical to those identified for the individual alternatives because there is limited existing or foreseeable pumping in the basins affected by the GWD Project. At full build out plus 200 years, there is some contribution from other groundwater pumping sources in addition to the GWD Project in Spring Valley.

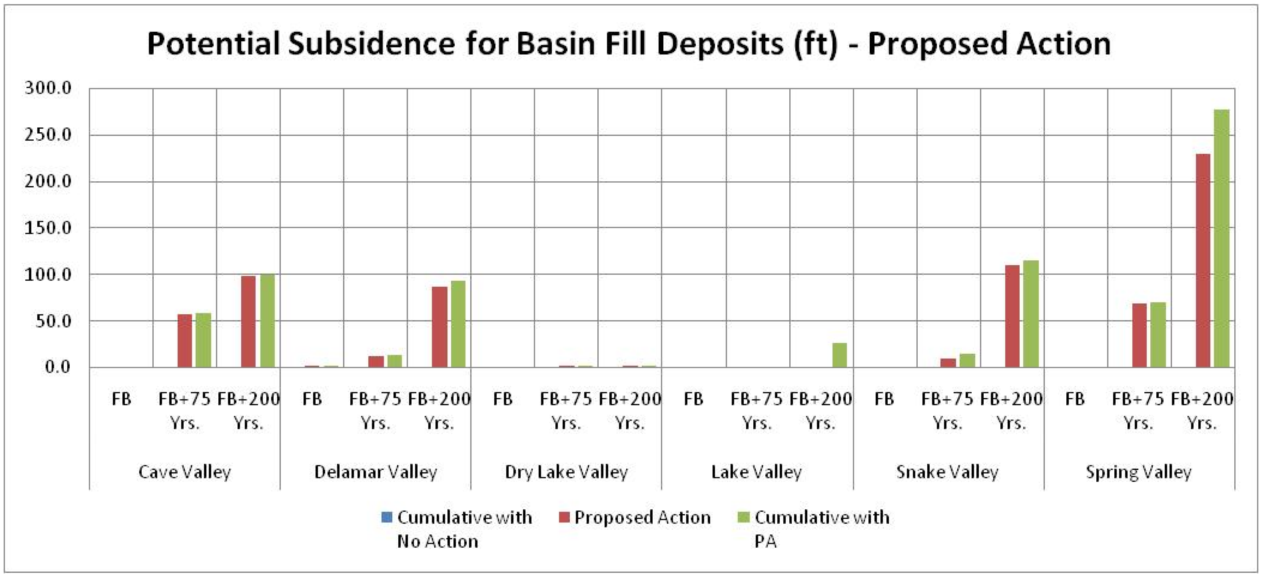

Figure 3.2-6 **Potential Subsidence for Basin Fill Deposits (feet) – Proposed Action**

It is possible that subsidence caused by groundwater pumping could damage roadways and structures, and could cause local alterations in drainage flow patterns. Because of the long time frames, there would be a long-term opportunity to monitor subsidence as it begins to appear, and to potentially alter pumping regimes to reduce the rate of subsidence. As discussed in Section 3.2.2.8, any subsidence measured at the soil surface is probably irreversible.

Table 3.2-20 summarizes the potential subsidence area resulting from groundwater pumping from the Proposed Action and other cumulative sources over three time frames.

Table 3.2-20 **Summary of Cumulative Potential Subsidence Impacts for Proposed Action Pumping**

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	76	283	781

3.2.3.6 Alternative A

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

All RFFAs (**Table 2.9-1**) that involve ground disturbing activities could potentially be at risk to geological hazards of active faults, fissure, landsides, and karst. Protection measures including BMPs, ACMs, and recommended mitigation measures GW-G-1 and GW-G-2 applied to this project would cause a small decrease in risk from geological hazards.

Paleontological Resources

The RFFAs that share the same utility corridor (ON Transmission Line, Wilson Creek Wind) that involve ground disturbing activities that could potentially impact paleontological resources. Protection measures including BMPs and ACMs applied to this project would provide for the documentation and preservation of scientifically important paleontological resources. As a result, Alternative A would cause a small increase in overall impacts to paleontological resources.

Groundwater Pumping Effects

Geological Hazards

It is possible that there would be effects of subsidence by water withdrawal by reasonably foreseeable projects. At this time, it is not possible to precisely predict the amount of additional incremental subsidence as a result of groundwater withdrawal by other projects. **Table 3.2-21** summarizes cumulative effects of potential subsidence and to caves through the model time frames.

Table 3.2-21 Summary of Cumulative Subsidence Impacts for Alternative A Pumping

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	76	131	349

Figure 3.2-7 illustrates the estimated subsidence effects in hydrologic basins affected by Alternative A. No subsidence in excess of 50 feet is estimated in any valley through full build out plus 75 years. Spring Valley would experience subsidence in excess of 100 feet at full build out plus 200 years. At full build out plus 200 years, there is a small contribution from other groundwater pumping sources in addition to the GWD Project in Spring Valley.

Potential subsidence effects to natural and human resources are those described for the Proposed Action.

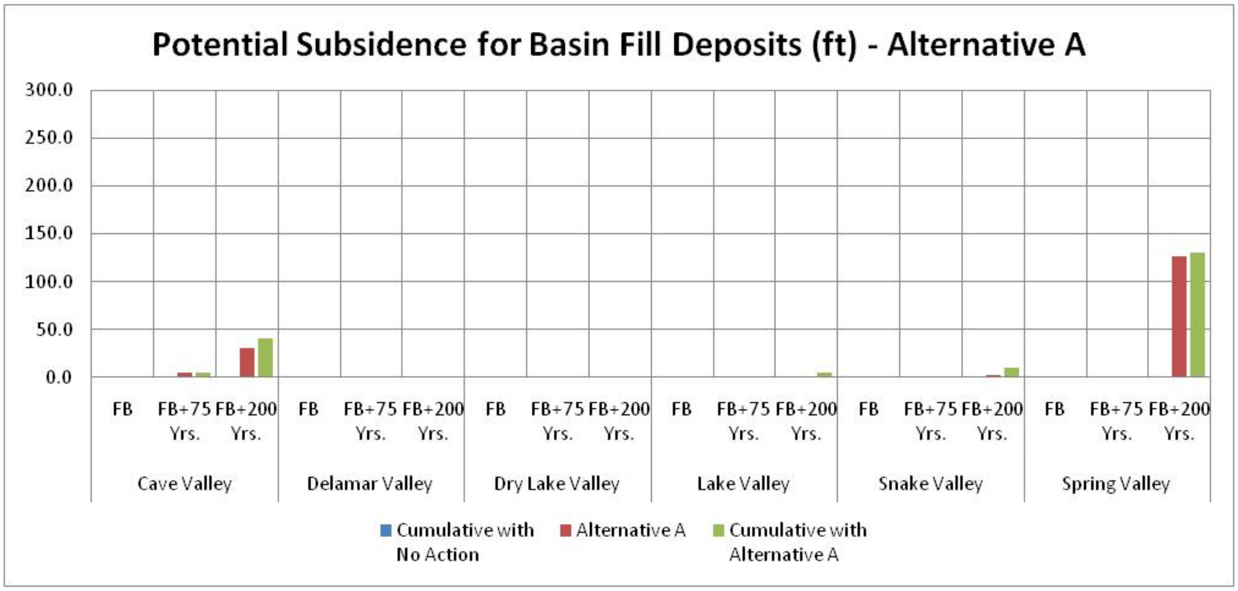

Figure 3.2-7 Potential Subsidence for Basin Fill Deposits (feet) – Alternative A

Table 3.2-21 summarizes the potential subsidence area resulting from groundwater pumping from the Proposed Action and other cumulative sources over three time frames.

3.2.3.7 Alternative B

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

All RFFAs (**Table 2.9-1**) that involve ground disturbing activities that could potentially be at risk to geological hazards of active faults, fissure, landsides, and karst. Protection measures including BMPs, ACMs, and recommended mitigation measures GW-G-1 and GW-G-2 applied to this project would cause a small decrease in risk from geological hazards.

Caves

There is a RFFA (Wilson Creek Wind Project) that involves ground disturbing activities above limestone bedrock where caves and voids could occur. This area is geographically separate from the GWD Project pipeline, and no cumulative effects caused by both projects are expected. Recommended mitigation measures include GW-G-1, GW-G-2, and G-3.

Paleontological Resources

The RFFAs that share the same utility corridors (ON transmission line, Wilson Creek Wind) that involve ground disturbing activities potentially could disturb paleontological resources (see **Figure 3.2-10**). Protection measures including BMPs and ACMs applied to this project would provide for the documentation and preservation of scientifically important paleontological resources. As a result, the Proposed Action and the RFFAs would cause a small reduction in paleontological resources.

Groundwater Pumping Effects

Geological Hazards

Figure 3.2-8 illustrates the estimated subsidence effects in hydrologic basins affected by Alternative B. Cave and Spring valleys are predicted to experience subsidence in excess of 50 feet at full build out plus 75 years from GWD Project operations. Delamar, Spring, and Snake valleys are predicted to experience subsidence in excess of 100 feet at full build out plus 200 years. Spring Valley is predicted to experience as much as 300 feet of subsidence, likely caused by very deep cones of depression caused by pumping at a small number of diversion points.

Potential subsidence effects to natural and human resources are those described for the Proposed Action.

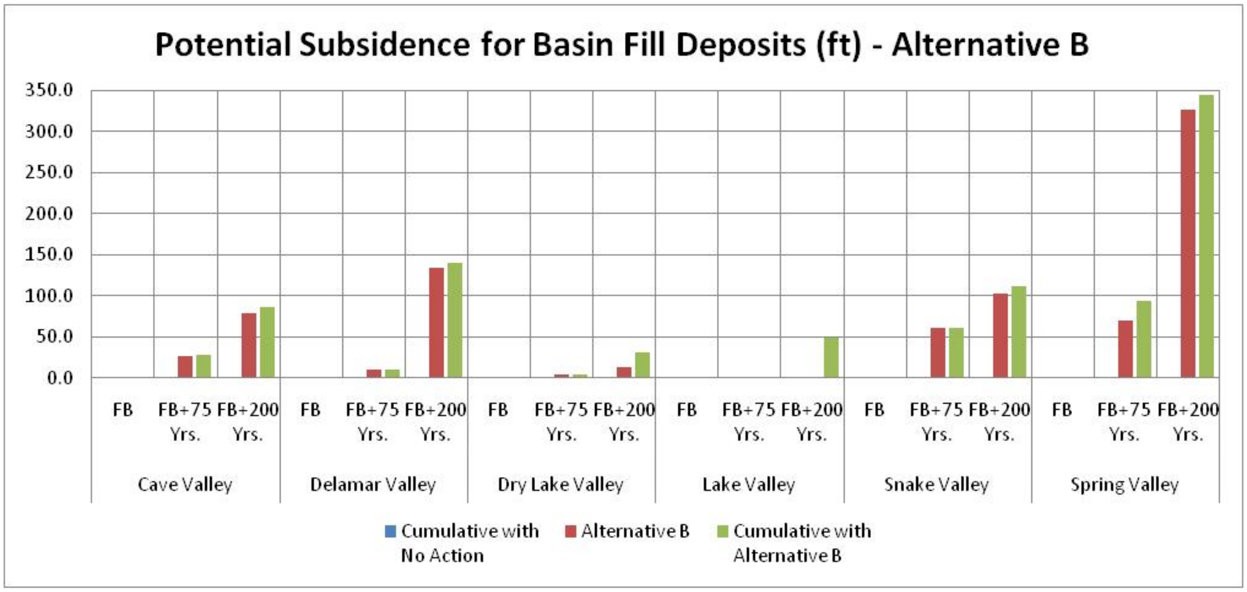

Figure 3.2-8 **Potential Subsidence for Basin Fill Deposits (feet) – Alternative B**

Table 3.2-22 summarizes the potential subsidence area resulting from groundwater pumping from the Proposed Action and other cumulative sources over three time frames.

Table 3.2-22 **Summary of Cumulative Subsidence Impacts for Alternative B Pumping**

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	78	323	955

3.2.3.8 Alternative C

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

All RFFAs (**Table 2.9-1**) that involve ground disturbing activities that could potentially be at risk to geological hazards of active faults, fissure, landsides, and karst. Protection measures including BMPs and ACMs applied to this project would cause a small decrease in risk from geological hazards.

Caves

There is a RFFA (Wilson Creek Wind Project) that involves ground disturbing activities above limestone bedrock where caves and voids could occur. This area is geographically separate from the GWD Project pipeline, and no cumulative effects caused by both projects are expected. Recommended mitigation measures include GW-G-1, GW-G-2, and G-3.

Paleontological Resources

The RFFAs that share the same utility corridors (ON transmission line, Wilson Creek Wind) that involve ground disturbing activities potentially could disturb paleontological resources (see **Figure 3.2-10**). Protection measures including BMPs and ACMs applied to this project would provide for the documentation and preservation of scientifically important paleontological resources. As a result, the Proposed Action and the RFFAs would cause a small reduction in paleontological resources.

Groundwater Pumping Effects

Geological Hazards

Figure 3.2-9 illustrates the estimated subsidence effects in hydrologic basins affected by Alternative C. No subsidence in excess of 50 feet is estimated in any valley at any time period because groundwater would be pumped on an intermittent basis.

Potential subsidence effects to natural and human resources are those described for the Proposed Action.

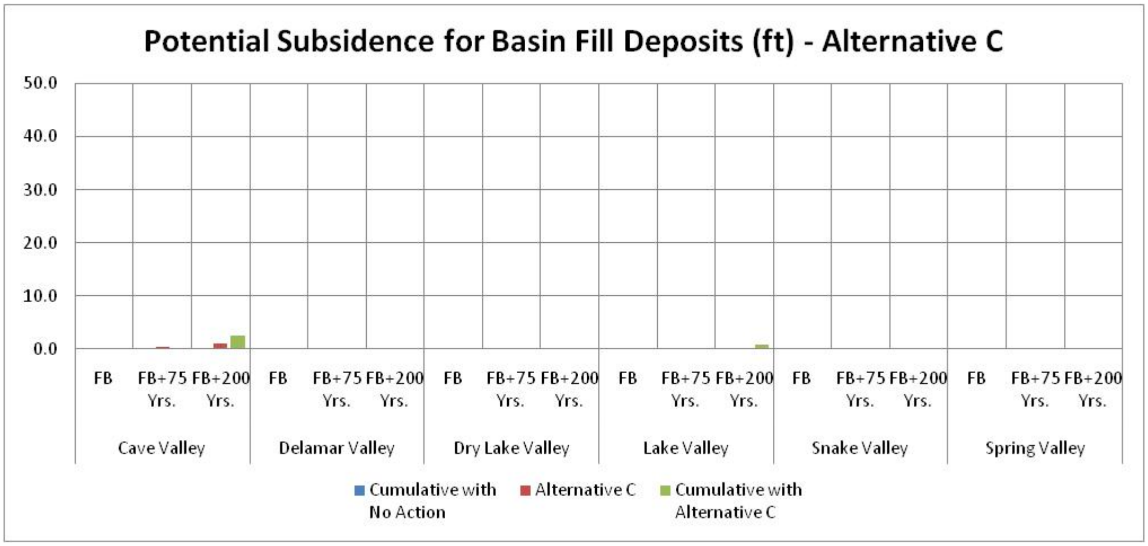

Figure 3.2-9 **Potential Subsidence for Basin Fill Deposits (feet) – Alternative C**

Table 3.2-23 summarizes the potential subsidence area resulting from groundwater pumping from the Proposed Action and other cumulative sources over three time frames.

Table 3.2-23 Summary of Cumulative Subsidence Impacts for Alternative C Pumping

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	76	126	167

3.2.3.9 Alternative D

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

All RFFAs that involve ground disturbing activities that could potentially be at risk to geological hazards of active faults, fissure, landsides, and karst. Protection measures including BMPs, ACMs, and recommended mitigation measures GW-G-1 and GW-G-2 applied to this project would cause a small decrease in risk from geological hazards.

Caves

There is a RFFA (Wilson Creek Wind Project) that involves ground disturbing activities above limestone bedrock where caves and voids could occur. This area is geographically separate from the GWD Project pipeline, and no cumulative effects caused by both projects are expected. Recommended mitigation measures include GW-G-1, GW-G-2, and G-3.

Paleontological Resources

The RFFAs that share the same utility corridors (ON transmission line, Wilson Creek Wind) that involve ground disturbing activities potentially could disturb paleontological resources (see **Figure 3.2-10**). Protection measures including BMPs and ACMs applied to this project would provide for the documentation and preservation of scientifically important paleontological resources. As a result, the Proposed Action and the RFFAs would cause a small increase in overall impacts to paleontological resources.

Groundwater Pumping Effects

Geological Hazards

Figure 3.2-10 illustrates the estimated subsidence effects in hydrologic basins affected by Alternative D. Subsidence in excess of 50 feet is estimated in Spring Valleys through full build out plus 75 years. Spring Valley would experience subsidence in excess of 150 feet at full build out plus 200 years, primarily from groundwater development pumping. Lake Valley could experience subsidence in excess of 100 feet, primarily from pumping from past, present, and foreseeable sources.

Potential subsidence effects to natural and human resources are those described for the Proposed Action.

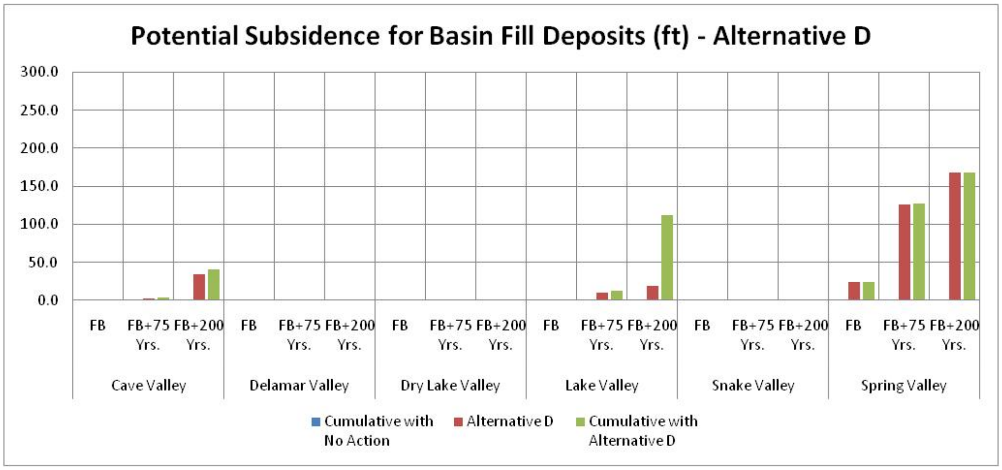

Figure 3.2-10 Potential Subsidence for Basin Fill Deposits (feet) – Alternative D

Table 3.2-24 summarizes the potential subsidence area resulting from groundwater pumping from the Proposed Action and other cumulative sources over three time frames.

Table 3.2-24 Summary of Cumulative Subsidence Impacts for Alternative D Pumping

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	88	281	561

3.2.3.10 Alternative E

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

All RFFAs (**Table 2.9-1**) that involve ground disturbing activities that could potentially be at risk to geological hazards of active faults, fissure, landsides, and karst. Protection measures including BMPs and ACMs applied to this project would cause a small decrease in risk from geological hazards.

Caves

There is a RFFA Wilson Creek Wind Project) that involves ground disturbing activities above limestone bedrock where lanes and voids could occur. This area is geographically separate from the GWD Project pipeline, and no cumulative effects caused by both projects are expected. Recommended mitigation measures include GW-G-1, GW-G-2, and G-3.

Paleontological Resources

The RFFAs that share the same utility corridors (ON transmission line, Wilson Creek Wind) that involve ground disturbing activities could potentially disturb paleontological resources (see **Figure 3.2-10**). Protection measures including BMPs and ACMs applied to this project would provide for the documentation and preservation of scientifically important paleontological resources. As a result, the Proposed Action and the RFFAs would cause a small reduction in paleontological resources.

Groundwater Pumping Effects

Geological Hazards

Figure 3.2-11 illustrates the estimated subsidence effects in hydrologic basins affected by Alternative E. No subsidence in excess of 50 feet is estimated in any valley through full build out plus 75 years. Spring Valley would experience subsidence in excess of 100 feet at full build out plus 200 years, primarily from groundwater development pumping. No other valleys would experience subsidence in excess of 50 feet at the longest time frame.

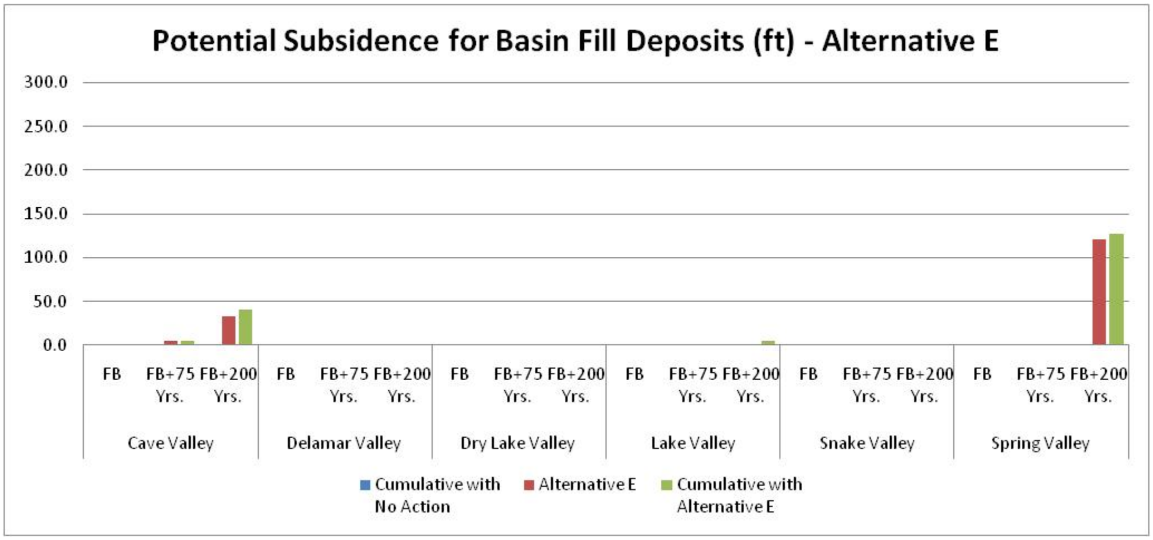

Figure 3.2-11 Potential Subsidence for Basin Fill Deposits (feet) – Alternative E

Potential subsidence effects to natural and human resources are those described for the Proposed Action.

Table 3.2-25 summarizes the potential subsidence area resulting from groundwater pumping from the Proposed Action and other cumulative sources over three time frames.

Table 3.2-25 Summary of Cumulative Subsidence Impacts for Alternative E Pumping

Impact Indicators By Model Timeframe	Full Build Out	Full Build Out Plus 75 Years	Full Build Out Plus 200 Years
Subsidence greater than 5 feet (square miles)	76	131	336

3.2.3.11 Alternatives Comparison

Rights-of-way and Groundwater Development Area Construction and Maintenance

Geological Hazards

Project exposure to geological hazards risks occurs on an individual, not cumulative basis.

Paleontological Resources

Cumulative impacts to paleontological resources could occur when the GWD Project, ON Transmission Line, and Wilson Creek Wind ROWs overlap.

Groundwater Pumping

Geological Hazards

At full build out plus 200 years, the Proposed Action and Alternatives B, D, and E pose a subsidence risk greater than the RFFAs and projected consumptive water uses. **Table 3.2-26** compares the alternatives with respect to potential cumulative effect of greater than 5 feet of subsidence. In the cumulative case, the No Action and Alternative C would result in the least area of risk greater than 5 feet of subsidence, while Alternative B potentially has the largest area at risk for greater than 5 feet of subsidence.

Table 3.2-26 Cumulative Impacts Comparison by Alternative of Areas of Potential Subsidence Greater than 5 Feet (square miles)

Scenario	Proposed Action		No Action		Alternative A		Alternative B		Alternative C		Alternative D		Alternative E	
	Project	Cumulative	Project	Cumulative	Project	Cumulative	Project	Cumulative	Project	Cumulative	Project	Cumulative	Project	Cumulative
Full Build Out	<1	76	0	76	0	76	3	79	0	76	25	88	0	76
Project Build Out Plus 75 Years	148	283	0	126	5	131	172	323	<1	126	152	281	5	131
Project Build Out Plus 200 Years	525	781	0	164	159	349	669	956	1	167	269	561	153	336