PUBLIC

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Pine Prairie Energy Center LLC

A SEMPRA ENERGY DEVELOPMENT

CP04-379-000
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CP04-381-000

Pine Prairie Energy Center, LLC

Abbreviated Application for Certificate of Public Convenience and Necessity Authorizing Construction and Operation of High-Deliverability Natural Gas Storage Facility, for Blanket Certificates and for Approval of Market-Based Rates Under Section 7 of the Natural Gas Act

Volume I of IV, Part 2A

Public

PUBLIC

RESOURCE REPORT 6
GEOLOGICAL RESOURCES

Pine Prairie Energy Center Storage Project
Evangeline Parish, Louisiana

July 2004

RESOURCE REPORT 6 – GEOLOGICAL RESOURCES
FERC ENVIRONMENTAL CHECKLIST

Filing Requirements	Company Compliance or Inapplicability of Requirement
1. Identify the location (by milepost) of mineral resources and any planned or active surface mines crossed by the proposed facilities.	§ 6.2 Mineral Resources Figures 6.1-1 through 6.1-10
2. Describe hazards to the facilities from mining activities, including subsidence, blasting, slumping or landsliding or other ground failure.	§ 6.3.6 Surface and Subsurface Mines
3. Identify any geologic hazards to the proposed facilities.	§ 6.3 Geologic Hazards Figure 6.2-1 Generalized Subsurface Fault Map of Louisiana
4. Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities.	§ 6.4.7.7 Blasting
5. For underground storage facilities, how drilling activity by others within or adjacent to the facilities would be monitored, and how old wells would be located and monitored within the facility boundaries.	§ 6.5.1 Monitoring of Old Wells § 6.5.2 Monitoring Drilling Activities of Others Within the Field
6. Briefly summarize the physiography and bedrock geology of the project area.	§ 6.2.2 Subsurface Geologic Setting
7. Describe monitoring of potential effects of the operation of adjacent storage or production facilities on the proposed facility, and vice versa.	§ 6.5.3 Monitoring Potential Effects of the Operation of/on Adjacent Storage or Production Facility
8. Describe measures taken to locate and determine the condition of old wells within the field and buffer zone and how the applicant would reduce risk from failure of known and undiscovered wells.	§ 6.2.3 Mineral Resources Currently or Potentially Exploitable
9. Identify and discuss safety and environmental safeguards required by state and Federal drilling regulations.	§ 6.4.3 Well Completion, Casing and Cementing § 6.4.6 Raw Water for Solution Mining § 6.4.7 Brine Disposal Wells § 6.5 Gas Storage Caverns Operation Monitoring and Safety

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6.1 PROJECT DESCRIPTION

The Pine Prairie Energy Center Storage Project (Project) is a high deliverability, natural gas storage facility designed for injecting and storing natural gas in salt caverns and for the withdrawal of stored gas from these caverns for delivery to various gas transmission pipelines. Three gas storage caverns, each with a storage working capacity of 8.0 billion cubic feet (Bcf), will be solution mined in the Pine Prairie Salt Dome, located in southwestern Louisiana. The Project will be configured to accommodate a fourth Gas Storage Cavern, for an ultimate working gas capacity of 32 Bcf.

The Project will consist of the following surface and subsurface components:

- A Gas Handling Facility
- Three Gas Storage Caverns
- Four Raw Water Wells
- Four Brine Disposal Wells
- Four Pipeline Corridors
- Six Meter and Regulator Sites, and Interconnects
- Required Utilities and Roadways

6.1.1 GAS STORAGE SITE

The natural gas storage-related elements of the Project will be located at the Gas Storage Site, which is set on a 60.57-acre parcel of company-owned land approximately 15 miles north of Eunice and approximately 1 mile west of Easton, in Section 36, Township 3 South, Range 1 West in Evangeline Parish, LA. The property is unimproved land that consists primarily of pine forest, native grasses and shrubs.

The Gas Storage Site is made up of three tracts of land:

- The Gas Handling Facility will be located at the south end, and Cavern Wellhead 1 will be located at the north end of **Tract C**.

- Cavern Wellhead 2 and Cavern Wellhead 3 will be located in the west-central and east-central portions of **Tract B**.

- The future expansion Cavern Wellhead 4 will be located in the north-central section of **Tract A**.

6.1.2 GAS STORAGE CAVERN DEVELOPMENT

Three Gas Storage Caverns will be solution-mined, one at a time, in three main steps. (See **Figure 6.3-1** *Gas Storage Site Layout.*) In the first step, the cavern will be developed up to 1,000,000 barrels of free space in about 4 months. In the second step, the cavern volume will be increased up to approximately 6,000,000 bbl in about 7 months. At this stage, a gas tightness test will be carried out and the cavern will be commissioned and converted to gas service. In the third step, the cavern volume will be increased up to the final design capacity of 8,000,000 bbl by using the Solution Mining Under Gas (SMUG) technique. The flow rate will be maintained at around 5500 gpm during this operation, and only the bottom part of the cavern will be increased in size during this phase. The final cavern volume will be reached after another 4 months. A detailed discussion of the solution mining process to be used for this Project can be found in **Section 6.4.5** of this Resource Report.

Four definitive phases have been scheduled to develop the Project:

- **Phase 1** – Gas Storage Cavern 1 will be developed to a working gas capacity of up to 6.0 Bcf. Phase 1 will also incorporate the required pipeline infrastructure and incremental compression.

- **Phase 2** - Gas Storage Cavern 2 will be developed to a working gas capacity of 6.0 Bcf. Phase 2 will also incorporate the required additional pipeline infrastructure and incremental compression.

- **Phase 3** - Both Gas Storage Cavern 1 and 2 will be solution mined using the Solution Mining Under Gas (SMUG) process to add an additional quantity of working gas capacity to each of the caverns to bring each cavern up to a total working gas capacity of 8.0 Bcf.

- **Phase 4** - Gas Storage Cavern 3 will be developed to a working gas capacity of 8.0 Bcf. Phase 4 will also incorporate the required additional pipeline infrastructure and incremental compression.

Since it takes approximately 17 months to create a Gas Storage Cavern (excluding the drilling of the well), the overall Project duration is expected to be around 4.5 years, at which time Gas Storage Cavern 3 should be ready for commissioning.

6.1.3 BRINE DISPOSAL AND RAW WATER WITHDRAWAL

The Brine Disposal and Raw Water Withdrawal Site will be located on a 10-acre parcel of land to be acquired by PPEC. (See **Figure 6.3-2** *Brine Disposal and Raw Water Withdrawal Facility Site Layout.*) The precise dimensions of this parcel are being established through negotiations with the affected landowners; however, it will fall entirely within a larger area of approximately 30 acres that PPEC and its consultants have already evaluated for purposed of PPEC's application and the various Resource Reports associated with it. This site will be located approximately 1.92 miles southwest of the Gas Handling Facility. (See **Figure 1.1-4A1** *Primary Brine Disposal and Raw Water Withdrawal Site Layout.*)

PPEC will drill and complete four Raw Water Wells to draw raw water from the Evangeline aquifer for its solution mining activities. The base of the Evangeline formation occurs at approximately 700 feet below ground level. The Raw Water Wells will be drilled to a depth of approximately 800 feet using a traditional commercial rotary-type water well rig. A Typical Raw Water Withdrawal Site diagram is shown in **Figure 1.1-14A1**.

A total of about 80 million bbl of raw water will be necessary to create one Gas Storage Cavern (one needs about 10 bbl of water to create one bbl of free space in the given configuration). **Section 6.4.6** contains further discussion of the Evangeline aquifer and its role in the proposed Project.

PPEC will also drill and complete four Brine Disposal Wells in the Lower Miocene to Pleistocene age formations. These injection wells will be used to dispose of brine produced in the salt cavern solution mining process. A Typical Brine Disposal Well site diagram is shown in **Figure 1.1-15A1**. A detailed discussion of the Brine Disposal Wells to be constructed for this Project can be found in **Section 6.4.7**.

6.2 MINERAL RESOURCES

6.2.1 SURFACE GEOLOGIC SETTING

The Pine Prairie salt diapir and associated structure is located in central Evangeline Parish, Louisiana. More specifically, the dome occurs in sections 23, 25-27, 35-37, Township 3 South, Range 1 West and sections 1-3, Township 4 South, Range 1 West (New Orleans Geological Society, 1962).

The Gas Storage Site is located on the Pine Prairie salt dome.

The Pine Prairie dome is one of the northernmost salt domes of the South Louisiana salt basin and it is situated on Pleistocene terrace surfical deposits. The resulting topography is rather flat with stream entrenchment being the main element of surface relief. This position is "dry" as compared to many of the salt domes in the South Louisiana salt basin that are surrounded by marshes or swamps (wetlands). Fisk (1944) described the extensive fluvial terraces along the Mississippi River and some of its tributaries such as the Arkansas and Red rivers. Four major terrace systems are recognized. These systems from oldest to youngest are the Williana, Bentley, Montgomery, and Prairie Terraces (Bryant et al., 1991).

A generalized geologic map of Louisiana from the Louisiana Geological Survey shows two prominent physiographic provinces in Evangeline Parish. (See **Figure 6.1-1** *General Geologic Map of Louisiana.*) A narrow strip of lower elevation in the northeast corner of the parish consists of alluvial valley fill. Most of the Parish is to the west of the alluvial valley fill, which consists of Pleistocene uplands or terrace upland deposits (Varvaro, 1957). These Pleistocene terrace deposits occupy ~ 25% of the state's surface and consist of sand, gravel, and mud

(Louisiana Geologic Survey-Generalized Geology of Louisiana). These terrace surfaces are remnants of preexisting flood plains, and exhibit trends along the major rivers in north Louisiana and in parallel to the coast belts in south Louisiana. The terrace deposits were raised as the coastal plain tilted in response to downwarping of the Gulf of Mexico basin. (Varvaro 1957) describes two terrace systems in Evangeline Parish. The older Montgomery terrace, which is more elevated, steeply tilted, and dissected which occurs in the north-northwesterly part of the parish and the younger, lower and less tilted Prairie terrace.

Figure 6.1-2 *Extract of Geologic Map of Evangeline Parish* is derived from the geologic map of Evangeline County (Varvaro, 1955). The Pine Prairie dome is located on the southern edge of the Montgomery terrace system where Pleistocene terrace sediments of the Montgomery Formation generally outcrop at the surface. Stream entrenchment of the terrace deposits is generally the main element contributing to surface relief, however ~ 15-20 feet of surface elevation is associated with the Pine Prairie salt dome (Barton, 1926). The younger terrace sediments of the Prairie Formation outcrop in areas of lower topographic relief such as the northwestern portion of section 35, southeastern section 27 and most of section 26. Recent alluvium is found in the local stream valleys. The following description of the Montgomery and Prairie Formations is primarily derived from Varvaro (1954).

6.2.1.1 Montgomery Formation

The Montgomery terrace deposits are generally thought to represent much of Pleistocene time (Bryant et al., 1991). In Evangeline Parish, this formation outcrops topographically higher and north of the Prairie formation. It dips more steeply southward and occurs under the Prairie formation. At the outcrop the formation is mainly red, brown or buff clays containing numerous calcareous, phosphatic, and limonitic nodules of pea gravel size with occasional streaks of manganese dioxide. The clays vary in thickness from 15 to 50 feet and borings show an increase in grainsize from clay to sand & gravel at depth (Varvaro, 1954).

6.2.1.2 Prairie Formation

Surface outcrops in Evangeline Parish are mainly clays, silty clays, and silt. Clay predominates and completely blankets the outcrop area. This clay has an average thickness of 30 feet (Varvaro, 1954). Beneath the clay layer, which contains calcareous, limonite, and manganese nodules, occur coarser sediments that grade downwards from silt to sands and gravels at about 100 feet. The fluvial sediments equivalent with the terrace deposits are typically sandy and gypsiferous at the outcrop (Varvaro, 1954).

6.2.2 SUBSURFACE GEOLOGIC SETTING

6.2.2.1 Methods

A suite of geologic maps and cross-sections were constructed to characterize the geology of the Pine Prairie salt dome and the flank sediments around most of the dome (**Figures 6.1-3 through 6.1- 10**). The scope of work included:

- Updating at a more detail scale the caprock/salt map to incorporate those wells that have been drilled since the 1959 New Orleans Geologic Society map,
- Providing appropriate subsurface structure maps to characterize the flanks of the dome and a brine disposal area and
- Integrating the above into geologic cross-sections.

A database of over 170 well logs and all of the available well completions histories for Pine Prairie Field were acquired. Mapping was done at a scale of one inch equals five hundred feet.

6.2.2.2 Caprock/Salt Map

The data for the caprock/salt maps (**Figures 6.1-3** *Top of Salt / Caprock above 7000 ft*) was obtained directly from well logs, completion history cards, and published sources. Indirect (sometimes referred to a negative) well control was used in constructing the caprock/salt map. Indirect control consists of using the total depth of those wells that did not penetrate caprock or salt in the placement of contours. Only those wells in which a well log was available were used as indirect control. Because of the lack of data separating the caprock from the top of salt, the first occurrence of either the caprock or salt was use for mapping. The map, therefore, depicts the geometry of the combined salt diapir and the associated caprock. With the information to be obtained from the proposed cavern wells, an attempt to map the caprock thickness and its attributes as well as the top of salt can be made.

It was early recognized that the area overlying the Pine Prairie salt dome was 15 to 20 feet higher in elevation than the adjacent areas of the Pleistocene terrace (Barton, 1926). Surface exposures of limestone in the area had been known and exploited for lime since before the Civil War. However, subsurface exploration was not begun until 1908 when Myles Mineral Company began a drilling program for limestone and salt (Barton, 1926). The first well on the dome to encounter salt was the Myles Mineral Co. Fee #1 well drilled in 1908 (New Orleans Geological Society, 1962). The top of the caprock at Pine Prairie actually is exposed at the surface over small areas of section 35 and was quarried for lime in the mid-1800s as reported by Barton (1926). The incorporation of this information into the caprock/salt map (Figure 6.1-3) could not be accomplished in detail. The -500 foot contour is the shallowest definable depth shown on the map. From about -1000 feet to -4000 feet the salt diapir flanks are almost vertical. Between –4000 feet and –6000 feet, the salt flares gently outward. This part of the salt diapir is generally well established by well control, both direct and indirect. Between –6000 feet and –7000 feet the salt develops a very pronounced overhang all the way around the diapir with the salt surface now sloping inward to a depth of at least 12,000 feet. This overhang is documented by the oil and gas wells drilled for the deep Wilcox below the overhang. However, these wells provide mainly indirect control on the salt, so that part of the salt below the overhang is not well controlled. The portion of the diapir below the overhang has been mapped but has not been presented as part of this report.

Figures 6.1-4 through 6.1-10 show the location of the proposed salt caverns in relation to the edge of salt and the shallow Conoco/Targa caverns in both plan and profile view. Six profile sections (**Figure 6.1-5 – 6.1-10**) illustrate the cavern positions relative to each other and to the edge of the salt. From the standpoint of the geometry of the salt diapir and the position of the caverns to the edge of the salt, there appears to be ample space for cavern development. The shallow depth of the caprock and the complex shape of the diapir indicate that salt movement has been complex and geologically recent.

6.2.2.3 Structure Maps of Flank Sediments Adjacent to the Dome

The correlation of the well logs for Pine Prairie showed basically good correlations over substantial areas of the dome. Correlations for the Cibicides hazzardi (Cib hazz) and deeper sections (Vicksburg, Cockfield, Sparta, and Wilcox formations) were previously established in the field by oil and gas activity. The section above the Cib hazz was informally subdivided and designated by letter for this study. This section comprises and undifferentiated section of sands and shales of Pleistocene to Lower Miocene age. Mapped horizons are (from youngest to oldest): "O", "J", Cib hazz, and Vicksburg. Production was associated with the deeper Cockfield, Sparta, and Wilcox formations except for some very shallow Miocene production in section 36.

As part of this geologic site characterization, two structure maps of the flank strata were constructed to provide a general idea of the nature of the domes' flanks and the associated faulting. The structure maps presented in **Figures 6.1-11** and **6.1-12** are the "J" marker and top of Vicksburg that bracket the proposed brine disposal interval. These maps define the general character of the west, south, and east flanks of the dome.

The east flank is more extensive and is associated with more faulting than the west flank. There are areas adjacent to the salt on the maps in which the structure has not been resolved in certain areas located high on the flanks of the dome because of correlation or structural complexities. These areas do not affect the general characterization of the dome's flanks. The faulting for the most part appears to be radial faulting associated with the extension of the strata produced by continued movement of the salt relative to the surrounding strata. The radial faults seldom extend to or beyond the rim syncline as seen on the mapped flanks of the dome. Faulting shown on the various structure maps is inferred by contour pattern and not documented by related fault cuts in the well logs. An attempt was made to track individual faults from one horizon to the next.

Since the focus of the study was on the southern portion of the dome, the northern third of the Pine Prairie dome was not mapped. Because the structure on the various shallow horizons provides useful information that can be related to the internal structure of the salt and salt fabric, the detailed mapping of these horizons could be considered in the future.

6.2.2.4 Brine Disposal Formations

The area selected for brine disposal is located in the Eastern part of section 4, T 4S-R1W on the west flank of Pine Prairie dome. **Figures 6.1-13** and **6.1-14** are structure maps of the Horizon "J" and Vicksburg that define the upper and lower boundaries of the brine injection interval. These maps step out further from the dome than **Figures 6.1-11** and **6.1-12** to cover the area between Pine Prairie dome and Reddell field, which is a deep-seated salt structure. Both maps show radial faulting and a rim syncline associated with Pine Prairie dome. The faults die out before reaching the rim syncline and are expected to only have a minimal impact upon brine disposal.

The relatively minor occurrence of small faulting in the vicinity of the brine disposal area may have a minor negative impact upon individual disposal wells, but does not pose any risk to the feasibility of brine disposal for the Project. Site-specific injection testing will be done to acquire the data needed to properly characterize the reservoir properties and capabilities of the disposal horizon.

A stratigraphic section (**Figure 6.1-15**) and a cross-section (**Figure 6.1-16**) have been constructed for the proposed brine disposal area off the west flank of the dome SW across the rim syncline to the Inexco Co. Pardee #1 well. Well control away from the flank of the dome is sparse; however, correlation markers can be projected between the two wells, which are approximately 2 miles apart. **Figure 6.1-15** is a profile section showing the marker horizons and the Pine Prairie salt stock. The stratigraphic section (**Figure 6.1-16**) was hung on the "J" datum and shows the stratigraphic relationships of the sands in the "J" and Cib hazz interval that is the recommended brine disposal interval.

The cross section and profiles show that brine disposal interval is approximately 2600-2700 feet thick, and is composed of interbedded well defined sands 10 to100 feet thick, with shaley intervals generally between 5 to 40 feet thick. These sands are laterally persistent in the area and are vertically separated from one another by shale or shale dominant intervals. This should allow for closely spaced wells to utilize various intervals within the overall disposal interval without the wells interfering with each other. Based upon the well log, net "good" sand is somewhere in the order of 800' to 1000' thick in the Gulf Refining #2 Gourney well on the west flank of the Pine Prairie dome. The brine disposal area is further downdip off the flank and closer to the syncline to the west; therefore it is expected that there may be a somewhat thicker disposal interval and possibly better sand development.

While no site-specific porosity or permeability data was available, the Atlas of Major Central and Eastern Gulf Coast Gas Reservoirs (Gas Research Institute, 1992) lists general porosity values of 26 to 28 percent and permeabilities of several hundred millidarcies to several darcys for these same formations. This data was selected from downdip fields where the gas reservoirs are above 10,000 feet.

6.2.2.5 Raw Water Formation

The raw water for the solution mining of the caverns will be drawn from the Evangeline aquifer. The Evangeline aquifer is comprised of unnamed Pliocene sands and the Pliocene-Miocene Blounts Creek Member of the Fleming formation. The Blounts Creek consists of sands, silts and silty clays with some gravel and lignite. The Evangeline is separated in most areas from the overlying Chicot aquifer by clay beds. Both aquifers dip gulfward and are recharged in their updip outcrop areas (LGS Geological Bulletin No. 31 and LDEQ appendix 4 of Triennal Summary Report of 2001).

The quality of the water is good and the water hardness is soft. The top of the Evangeline aquifer is approximately 700 BGL whereas its base is between 1,400 and 1,900 feet BGL in the raw water production area. There are no known water quantity limitations or quality issues in the area of the Project.

6.2.3 MINERAL RESOURCES CURRENTLY OR POTENTIALLY EXPLOITABLE

6.2.3.1 Oil & Gas Exploration

Barton (1926) provides information on the pre-1926 drilling activity associated with the dome. The Myles Mineral Company Fee #8 well established the first commercial oil production in 1912 (New Orleans Geological Society, 1962). Since that time, hundreds of wells have been drilled on the Pine Prairie salt dome in search of oil and gas. This resulted in production being established in the shallow Miocene section and in the deeper Cockfield, Sparta, and Wilcox formations around the flanks of the dome. The logs and completion histories of these wells provided the database for this study.

Most of the known oil and gas exploration on the Pine Prairie dome is on the eastern flank of the dome. However, there are a few wells shown that are on top of the salt dome. The closest nearby oil and gas wells and their proximity to the proposed salt cavern wells are listed below. These shallow wells were drilled to depths of approximately 500-550 feet and are between 650-1000 feet from the nearest proposed cavern wells. Well data from the Strategic Online Natural Resources Information System (SONRIS), made available by the Louisiana Department of Natural Resources, list the current status of these wells as dry and plugged.

Well Name	Date Drilled	TD (feet)	Status	Distance from Nearest Cavern Well
Pan American Pet. Co. #1	1950	497	Dry & Plugged	~650 feet NE Cavern 4 ~ 780 feet NW Cavern1
Federal Royalty et al., #1	1950	555	Dry & Plugged	~ 980 feet ESE cavern 1
Ledanois Land & Stone #1	1950	521	Dry & Plugged	~ 850 feet NW cavern 3
Freeport Sulpher Ledanois #2		518	Dry & Plugged	~410 feet ESE cavern 2

The oil and gas production at Pine Prairie is limited to the flank sediments around the dome, with no deep salt well penetrations near the Project area. There is no supradomal or caprock production. Brine disposal will be located a sufficient distance away from any existing production.

6.2.3.2 Abandoned Limestone Quarry

The caprock of the Pine Prairie dome outcrops at the surface. Surface exposures of limestone in the area had been known and exploited for lime since before the Civil War. Varvaro (1954) reports that in 1934 a crushing plant and commercial lime plant was erected at the outcrop on

Pine Prairie dome by the Louisiana Stone and Lime Corporation and operated for several years. This plant is no longer in operation and has been completely removed. Only a water-filled pit surrounded by scattered boulders of caprock remain (Varvaro, 1954). There is a surface quarry shown in Section 35 on the USGS topographic map which is located ~ 2350 feet west of Gas Storage Cavern 3 and ~ 2600 feet west of the future Gas Storage Cavern 4. This old surface quarry is outside of the Project area.

6.2.3.3 Abandoned LPG Storage

According to the SONRIS database, there are three old LPG storage caverns south of the proposed Gas Storage Caverns. These LPG caverns were drilled from 1951 – 1956 and are currently listed as being owned by ConocoPhillips. Cavern 001-B is listed as plugged & abandoned. Caverns 002-B & 003-B are listed as active. These cavern wells have reported depths of between 1,460 – 1,516 feet, which are significantly higher than the proposed top of cavern depths of 3,000 feet for the proposed Project. The ConocoPhillips site has not been operational since 1996. The horizontal distance of these LPG cavern wells from the proposed salt cavern well locations is shown below.

LPG Well	Date Drilled	TD (feet)	Status	Distance from Nearest Cavern Well
001-B	1951	1,460	Plugged & Abandoned	~ 945 feet SE cavern 3 ~ 460 feet S cavern 2
002-B	1952	1,510	Active	~ 780 feet SE cavern 2
003-B	1956	1,516	Active	~ 1,370 feet SE cavern 2

6.3 GEOLOGIC HAZARDS

6.3.1 EARTHQUAKES/SEISMIC RISK

USGS Earthquake Hazard Map shows that the project area is located in a very small hazard zone: 4 to 6% g peak acceleration, with 2% probability of exceedance in 50 years (USGS Louisiana seismic hazard map on their website).

Louisiana is not considered seismically active although historical records indicate that small earthquakes occasionally occur (Stevenson & McCulloh, 2001). Historical data indicate that 43 mostly low intensity earthquakes with recorded magnitudes of ~ 2.7 to 4.4 have been felt in Louisiana since 1843 (Stevenson & McCulloh, 2001). No detected earthquakes have definitely been attributed to any specific mapped fault systems in Louisiana (Stevenson & McCulloh, 2001).

6.3.2 ACTIVE FAULTS

Louisiana is within the Gulf Coast Basin tectonic province generally characterized by south dipping and thickening sedimentary strata. In south Louisiana, the most prominent structural features are parallel to the coast growth faulting and salt domes or diapirs. **Figure 6.2-1** is a generalized map showing the major subsurface faults in Louisiana. The regional fault systems in south Louisiana are growth faults that are generally contemporaneous with deposition where active movement generally occurs during periods of rapid localized sedimentation and basin subsidence. Movement along growth fault systems is generally related to a process of gradual creep as opposed to sudden rupture of rock that is associated with earthquakes.

The Project area occurs north of the northernmost growth fault system in south Louisiana as depicted in **Figure 6.2-1**. Review of more detailed published subsurface maps of the area (Geomap 2001, Varvaro, 1957) show the Pine Prairie Salt Dome to be in an area of gentle southward dip except where modified by the salt withdrawal area associated with the dome. There is no local faulting shown except for some radial faulting associated with the dome. The closest regional growth faulting is ~ 5 miles to the south, where a regional east-west trending fault system terminates into the deep-seated Reddell salt dome.

Examination of well data and the structure maps of the flank sediments surrounding the Pine Prairie dome in the interval down to the Vicksburg (which is the lowermost horizon considered for brine disposal) give no indication of faulting other than some radial faulting associated with the dome (**Figures 6.1-4** and **6.1-5**). No topographic features suggestive of active faulting have been recognized in the Project area. Currently, the data give no indication of active faulting that could pose a risk to the Project.

6.3.3 SOIL LIQUEFACTION

Soil liquefaction is a phenomenon in which saturated, cohesion-less soils temporarily lose their strength and liquefy when subjected to dynamic forces such as intense and prolonged ground shaking. FERC defines areas with potential soil liquefaction as "areas which are underlain by Holocene deposits which are likely to be non-cohesive, such as alluvial, lacustrine, and littoral deposits, and where the water table occurs at 10 feet or less below the surface, and where the U.S.G.S. Open-File Report (OFR) 82-1033 indicates a 90 percent probability that horizontal ground accelerations of 10 percent of gravity or greater would be exceeded in 50 years." *Northeast U.S. Pipeline Projects*, 44 FERC ¶ 61,149 at 61,420 (1988).

The Ground Shaking Hazards from Earthquakes in the Contiguous United States map presented on the USGS website showing the geographic distribution of major hazards indicates that the State of Louisiana is a low risk area for soil liquefaction where there is less than a 10% chance of experiencing an earthquake strong enough to cause appreciable damage in a 50 year period. USGS OFR 82-1033 indicates that there is a 90% probability that horizontal ground acceleration of 4-6% of gravity or greater would not be exceeded in 50 years in the Project area.

Although some portion of the Project area may have cohesion-less soils or have a water table at 10 feet or less below the surface, the limestone/anhydrite of the caprock outcrops at/or near the surface, the surface deposits are Pleistocene terrace sediments, and the seismic risk is low in the Project area. Therefore, the potential for soil liquefaction appears to be low in the Project area.

6.3.4 LANDSLIDING

The Landslides Areas in the Contiguous United States map (Radbruch-Hall et al., 1983) and USGS Open File Report 97-289 (Godt) showing the geographic distribution of major hazards indicate that Louisiana has a low susceptibility for landslides. Landsliding involves the downward and outward movement of earth material under the force of gravity due to natural or artificial cause. Landslide susceptibility is associated predominantly with the greater relief and more varied and rugged terrains than those found in the Project area.

The Project area is characterized by flat and gently rolling hills with elevation ranging from 95 to 120 feet above the mean sea level. The potential risk of ground failure due to landsliding appears to be low in the Project area.

6.3.5 KARST TERRAIN

Karst features, such as caves, caverns and sinkholes, form as the result of long-term dissolution of soluble carbonate (limestone, dolostone, and marble) rocks by slightly acidic groundwater. Although the caprock at Pine Prairie outcrops at the surface or occurs in the near-subsurface, there is no indication that karstic conditions exist in the Project area.

6.3.6 SURFACE AND SUBSURFACE MINES

There are no subsurface mines in the Project area. There is an inactive surface quarry ~ 2500 feet west of the project area. There are three LPG storage caverns in the salt south of the proposed Gas Storage Caverns, which are discussed in Section 6.2.3.3 of this report. Other than these three LPG caverns, there is no surface or subsurface mining known to be planned or active in the Project area. Therefore, the Project is not likely to hinder mine reclamation or expansion effort, nor induce contamination from surface mines or induce ground failure associated with surface and subsurface (underground) mining.

6.4 PROJECT DESIGN AND LOCATION

This section describes how the Project would be located or designed to avoid or minimize adverse effects to the resources or risk to itself, including geomechanical investigations and monitoring. It will discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities.

6.4.1 GENERAL STORAGE CAVERN DESIGN PARAMETERS

6.4.1.1 Suitability of the Pine Prairie Dome for Storage Construction

Underground salt cavern gas storage facilities must be created in impermeable salt formations and operated to prevent waste of the stored gases, uncontrolled escape of gases, pollution of fresh water, and danger to life or property.

The geologic review of the Pine Prairie Salt Dome shows that from a geologic viewpoint, there is sufficient opportunity for cavern development, brine disposal, and fresh water sources for the proposed Project. The geological information will be augmented during the initial construction phase of the Project by coring the caprock and salt to determine the nature of the caprock, salt dissolution activity, and the internal structure and mineralogy of the salt. Each of these items will be used to refine the design of the caverns during leaching operation and future gas storage operations. All cores should be slabbed, described in detail, and photographed. The logging of all wells is important and therefore the initial drilling of these wells should be done in a manner that will allow a quality log to be obtained. Information from logs and cores should be incorporated into the existing study.

6.4.1.2 Applicable Standards and Codes

The Project will be designed and operated in strict accordance with all federal and state standards and codes regulating the construction, operation, and safety of underground natural gas storage facilities including

- U.S. Department of Transportation (DOT) Pipeline Safety Regulations 49 CFR Part 192 - Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards
- FERC Regulations 18 CFR Part 380
- Louisiana Department of Natural Resources, Office of Conservation LAC-43 Natural Resources
- Louisiana Office of Conservation LAC 43: XVII, Statewide Order 29-M-Hydrocarbons storage wells in salt domes cavities
- Louisiana Office of Conservation LAC 43: XIX, Statewide Order 29-B
- All the most recent applicable federal, state and local codes and regulations.

PPEC is in the process of obtaining all required state and local permits for the project, including the permits authorizing:

- Drilling and solution mining of Gas Storage Caverns 1, 2 and 3 (PP-CW-01, 02 & 03)
- Drilling and operation of four Brine Disposal Wells (PP-BDW-01, 02, 03 & 04)
- Drilling and operation of four Raw Water Wells (PP-RWW-01, 02, 03 & 04)
- Future operation of the Gas Storage Caverns

6.4.1.3 Geotechnical Investigation

This section addresses the geomechanical issues related to the construction and operation of the three Gas Storage Caverns. A clear distinction will be made between issues related to the development of caverns in Gulf Coast salt dome structures and cavern development in bedded salt.

Creating a cavern in bedded salt is technically more challenging than creating a cavern in a salt dome. Doing the former requires a thorough understanding of the parameters that may affect the geomechanical stability of the system. These parameters include salt mass thickness, salt impurities repartition, existence of insoluble clay and shale beds within the salt mass, assessment of differential leaching and cavern shape, roof stability, and salt strength characteristic, as it may widely vary within the bedded salt mass.

In contrast, Gulf Coast salt domes represent a stable geologic media for gas storage caverns. The 326 known Gulf Coast salt domes are located in four states: Texas, Louisiana, Mississippi, and Alabama. (Halbouty, 1979) *The vast majority of the shallow salt domes have been extensively* explored and studied since the early 1900's for various applications, including U.S. Strategic Petroleum Reserve Storage, nuclear waste repository sites, salt mining, LPG storage, brine production, and natural gas storage.

Over several decades, salt cavern engineering and design methodologies, generally based on experience with similar caverns, have been developed and tested successfully. As a result, guidelines, regulations and compliance requirements from state agencies and other commissions integrating historical trial and error experiences have been established.

The homogeneity of the Gulf Coast salt domes, the purity of the salt (reportedly ranging as high as 99.2%), the consistent strength characteristics of the salt (Louann Salt), as well as the extent of the salt mass (typically 1 to 2 miles in diameter and 12,000 feet deep) has made it possible to *use conventional leaching techniques to create the caverns.* The *quasi- perfect* cavern shape (vertical ellipsoid) resulting from specifically engineered natural gas storage caverns using conventional leaching techniques provides geomechanical stability of the system, reducing greatly the risk of excessive subsidence, excessive shrinkage (creep) and the risks of catastrophic failure of the cavern.

Specific information on the mechanical behavior of various salt strata is well documented in the literature. In particular, the American nuclear waste management literature from the period 1970-1995, when salt was a major subject of study as a potential repository rock, provides large amounts of data.

PPEC is providing a geomechanical report for the proposed Project in Attachment 6-1. The report was prepared by Doctor Robert L. Thoms, professor emeritus at LSU and adjunct professor at Texas A&M. Dr. Thoms is currently a member of the environmental advisory committee for the United States Strategic Petroleum Reserve. He has also served as an expert consultant to the FERC on geomechanical issues related to development of salt cavern natural gas storage. He has more than 30 years experience in the field of salt rock mechanics, salt mining and cavern solution mining for natural gas and other hydrocarbon storage, and is a past president of the Solution Mining Research Institute.

The conclusions of the geomechanical report are summarized hereafter:

- Natural gas storage in Gulf Coast salt domes has been highly successful, accounting for 95% of gas stored in U.S. salt caverns. Problems involving loss of natural gas from salt caverns in the U.S. have been associated with old brine or liquid storage caverns that were retrofitted for natural gas storage.

- Gas storage caverns can be designed and constructed with confidence in Gulf Coast domes because of considerable experience with such caverns. Furthermore, the geology of domes is well suited to construction of caverns with abundant salt cover and thus good containment properties.

- Caverns engineered from the outset for storage of gas in Gulf Coast domes are stable containment reservoirs, since any local fracturing due to excessive loads will heal when the loads are reduced. And, containment of gas will be maintained because of the abundant salt cover available in domes.

- The proposed caverns are very similar to the Egan Storage Facility (ESF) Caverns that were analyzed in detail and discussed in the Sandia National Laboratory (SNL) Report 99-0421, Feb. 1999. The SNL Report finding of geomechanical suitability for gas storage by the ESF caverns can be safely transferred to the proposed Project caverns because the salt thickness will be greater between the proposed Project caverns than it is at the ESF caverns.

- Therefore, Dr. Thoms' opinion, from a geomechanical viewpoint, is that the PPEC's caverns, as proposed, are suitable for the safe storage of natural gas.

As a conservative measure, PPEC will take core samples in the first cavern well PP-CW-01. Geomechanical salt parameters can be expected to be generally similar over the entire heights of caverns constructed in Gulf Coast domes because of the homogeneity of salt present. However, core samples will be taken at various relevant depths within the salt formation. The cores will be tested to assess the elastic constants (i.e., Young's modulus and Poisson's ratio) of the salt cores. Additional tests will be performed to assess the time-dependent behavior of the salt cores (triaxial creep tests). To ensure the accuracy and validity of the test results, these experiments will be carried out over a period of several months. It is common knowledge that the results are informational only, and do not impact the feasibility nor the safety of the operation, but rather establish a baseline database needed to adjust and optimize the future operating ranges of the facility.

The design and solution mining process will be continually reviewed throughout the construction phase to take into account pertinent additional information. PPEC will inform the Commissioner of Conservation about any tests or surveys conducted during the construction phase and provide copies to the Commissioner of Conservation as soon as practicable.

6.4.2 STORAGE CAVERN LOCATION AND GEOMETRY

- The wellhead and bore hole will be located so the walls of the caverns at maximum development diameter are at least 100 feet from the property boundary and no less than 300 feet in any direction from the edge of the salt mass.

- The minimum separation of adjacent walls of the storage caverns as measured in any direction will be approximately 527 feet (wellhead to wellhead separation of 780 feet), and in no case will the pillar thickness be less than the 200 feet required by LAC 43: XVII, §301(D)(2)(b)(iv).

- The minimum distance from the caverns' walls and the edge of the salt mass is estimated above 1,500 feet at the casing seat depth.
- The will be developed to a maximum diameter of approximately 270 feet.
- The minimum vertical distance between the projected caverns and the existing LPG storage caverns 2B and 3B is estimated at 2495 feet.
- The base of salt extends below 7,000 feet, thus providing an ample buffer below the bottom of the completed cavern, which is estimated at approximately 5285 feet.

Figures 6.1-4 through 6.1-10 depict the profile of the Pine Prairie Salt Dome and show the location of all the caverns, the separation between caverns and between caverns, and the edge of the salt dome.

6.4.3 WELL COMPLETION, CASING AND CEMENTING

- The cavern wells will be drilled and completed in accordance with applicable statewide rules and regulations of the commissioner. LAC 43: XVII, §§ 101-303.
- The casing program includes two cemented casings from surface into the salt dome. A 26-inch intermediate casing will be set approximately 300 feet below the salt top (800 feet below surface) and a 20-inch production casing will be set at approximately 3,900 feet below ground surface. The salt interval between the top of salt and the production casing seat is around 3,400 feet.
- All casings have been designed in accordance with applicable regulations and good engineering practice. In particular, the tubulars will be welded to ascertain gas tightness and they will be cemented back to surface. All casing strings will be centralized throughout the interval to be cemented.
- Cement slurries will be compatible with the salt formation and cement will be placed by the plug and displacement method. The casing cement job will be documented by an affidavit from the cementing company showing the amount and type of cementing materials and the method of placement. All cementing and service reports will be filed with the Commissioner of Conservation within 30 days. As the casing string will be installed by welding, it will be of a weldable grade such as API 5L Grade B or an ASTM weldable grade.
- Casing string welders will be qualified under either Section 3 of API 1104 specification or Section IX of the ASTM Boiler and Pressure Vessel Code for the thickness to be welded. In addition to a visual inspection of the completed weld an x-ray or ultrasonic inspection will

be run on at least 10% of the string. The record of the inspection will be filed for review by the Commission. Defective welds will be ground, re-welded and re-inspected.

- The production casing will be pressure tested in accordance with the requirements of LAC 43: XVII, § 301(D)(3)(e). The hydraulic tests will be done before drilling out the plug. The test pressure calculated at the casing seat will equal the maximum operating pressure at that point. The test pressure will be maintained for a minimum of one hour to verify casing integrity and absence of thread leaks.

- The casing seat and cement of the final cemented casing string will be hydrostatically tested after drilling out the plug. At least 10 feet of salt below the casing will be penetrated prior to this test. The test pressure calculated at the casing seat will equal the maximum operating pressure at that point. However, the test pressure will not exceed 0.9 psi per foot of depth. The test pressure will be maintained for a minimum of one hour.

- The test will be prepared and supervised by a qualified engineer and a report of these test results attested to and filed with the Commissioner of Conservation within 30 days.

- **Figure 6.3-3** depicts the cavern well architecture.

6.4.4 CAVERN OPERATING PRESSURE

- The storage minimum and maximum operating pressures are currently based on the geological and geomechanical feasibility investigation findings on the Pine Prairie Salt Dome. As previously stated, these values will be revised after the above described site specific core tests are completed. The maximum allowable operating pressure at the 20-inch production casing seat of the cavern will not exceed 0.9 psi per foot of overburden.

- For a 20-inch production casing shoe of 3,900 feet the corresponding maximum operating pressure is 3,510 psig. The corresponding maximum surface pressure will vary depending on the average gas specific gravity and the bottomhole and surface gas temperatures. For a bottomhole temperature of 140° F and a surface temperature of 120° F and a natural gas specific gravity of 0.6, the maximum surface pressure will be around 3,218 psig.

- The minimum operating pressure at the 20-inch production casing seat of the cavern will not be above a 0.15 psig per foot of overburden corresponding to 585 psig at 3900 feet (20-inch production casing depth).

- The wellheads will be fitted with pressure control equipment in order to ascertain that the storage cavern will not be subjected to pressures in excess of the maximum operating pressure even for short periods of time.

6.4.5 SOLUTION MINING OPERATIONS

- The Gas Storage Caverns will be solution-mined one at a time and with a average flow rate of 5500 gpm. Both direct and reverse circulation will be used. A diesel oil blanket fluid will be utilized to prevent uncontrolled leaching of the cavern roof and protect the production casing seat.

- The leaching tubings will be 16-inch and 10-3/4-inch concentric strings. The initial cavern development will be performed utilizing direct circulation leaching, with the outer string located at 4,700 feet and the injection string at 5,650 feet. The protective diesel blanket will be initially located at 4,200 feet (500 feet above the outer leaching string).

- The blanket depth will be monitored and repositioned as necessary to protect the casing seat and create a cavern roof having the desired dome shape.

- Throughout the cavern development process, insoluble material will build up on the bottom of the cavern. Top of insoluble depth will be periodically verified and the 10-3/4-inch hanging string will be cut or perforated as necessary to prevent plugging of the string.

- The direct circulation phase of leaching will be complete after approximately 1,000,000 barrels of cavern space has been created (in about 4 months). At this point, the cavern shape and capacity will be confirmed by performing a sonar survey (through tubing technique). If the shape and volume are acceptable, the main cavern phase will start.

- The main cavern step will be done in reverse circulation mode, raw water being injected down the annulus of the 16-inch and 10-3/4-inch hanging strings and the resulting brine being produced through the 10-3/4-inch hanging string.

- The remainder of the cavern development will be accomplished with reverse circulation (in about 7 months). Blanket fluid depth will be raised at several intervals throughout the development to a final depth of 4,050 feet, leaving approximately 150 feet between the cavern well production casing shoe (3,900 feet) and top of cavern roof (4,050 feet). This protected zone is known as cavern neck. This process provides for shaping the roof for structural integrity. This will be confirmed during cavern development with additional sonar surveys. In all cases the blanket material will be maintained at a level to protect the production casing seat.

- Solution mining software called SANSMIC (developed by Sandia National Laboratory) and WinUBRO (developed by Chemkop) have been run to simulate the leaching process described above and predict cavern shape.

- Throughout the cavern creation process, the cavern capacity will be verified utilizing sonar surveying technology (acoustical wave reflection technology). The sonar surveys will determine the size, shape and overall extent of the cavern.

- At completion of the cavern development, a final sonar survey in brine (and without the leaching tubings) will be performed and submitted to the Louisiana Department of Natural Resources (this last survey in brine will be measured with the leaching strings pulled out of the well).

- After cleaning and inspection, the hanging strings will be run back into the well for dewatering and future Solution Mining Under Gas (SMUG) operations.

- Prior to conversion of the cavern, the cavern will be shut-in for stabilization during about one month and a Nitrogen/brine interface Cavern Mechanical Integrity Test will be performed as required by LAC 43: XVII, § 109(B)(9). This test is done by pressuring the entire cavern, well and wellhead system while monitoring any associated movement of the interface nitrogen. A mass balance is then calculated for the nitrogen over the whole test.

- The surface test pressure will be calculated in order to pressure up the cavern to a pressure equivalent of 0.90 psi per foot of depth at the production casing seat.

- Following the confirmation and approval by the Louisiana Department of Natural Resources of the pre-operation requirements, as provided in LAC 43: XVII, § 109(B)(5), the caverns will be converted to natural gas storage service. The caverns will be dewatered by injection of natural gas in the annulus of the 20-inch production casing and the 16-inch hanging string. Brine will be displaced from the caverns up the 10 ¾-inch hanging string for ultimate disposal in brine disposal wells. Natural gas will be injected under pressure and withdrawn from the caverns through expansion and pressure reduction. The duration of the gas first fill operation is around 2 months.

- The cavern volume will be increased up to the final 8,000,000 bbl by use of the Solution Mining Under Gas (SMUG) technique. The flow rate will be maintained at around 5,500 gpm during this operation. Only the bottom part of the cavern will be increased in size during this phase. The final cavern volume will be reached after about 4 months.

- **Figures 6.3-4 through 6.3-8** illustrate the results of the simulations.

6.4.6 RAW WATER FOR SOLUTION MINING

- The four Raw Water Wells will be drilled and completed in accordance with the rules and regulations provided by the Louisiana Department of Transportation and Development (LDTD), Office of Public Works. The LDTD, Office of Public Works "is responsible for registering water wells and holes in Louisiana." (LAC 70: XIII, § 101(A)(2)).

- The raw water for the solution mining of the caverns will be drawn from the large Evangeline aquifer. PPEC will have all necessary water rights at the Project location. There are no known water quantity limitations or quality issues in the area of the Project. The quality of the water is good and the water hardness is soft.

- The top of the Evangeline aquifer is approximately 700 BGL whereas its base is between 1,400 and 1,900 feet BGL in the raw water production area.
- There are no other industrial facilities in the area of the PPEC Project to compete with water quantities and therefore the water production for the project is not anticipated to have a substantial effect on the existing water table.
- The raw water wells will have an 18-inch casing and will employ submersible turbine pumps and motors.

6.4.7 BRINE DISPOSAL WELLS

Four Brine Disposal Wells will be drilled and completed in accordance with LAC 43: XIX, §§ 403-443.

Brine resulting from the solution mining of the Gas Storage Caverns will be disposed by deep well injection off and away from any influence from the Pine Prairie Salt Dome. The brine will be *injected in the highly permeable sand formation between the J marker and the* Vicksburg formation. The interval of interest is well defined in the area of PPEC with considerable well control. Since there is no other brine disposal in the area of PPEC, there should not be any interference from other disposal wells.

6.4.7.1 Notice and Hearings

- PPEC will give notice by mailing or delivering a copy of the application to the county clerk and to affected persons, including operators of wells located within one-quarter mile of the proposed disposal well. PPEC will also publish a notice of the application once in a newspaper of general circulation for the county where the well will be located. PPEC will provide proof of publication prior to the hearing or administrative approval.
- PPEC will give notice of its petition to operate an Underground Injection Control Class II Well at least 15 days prior to the date of the hearing in accordance with the provisions of Statewide Order 29-B. PPEC will notify the Commissioner within 30 days of the date upon which disposal commenced according to LAC 43: XIX, § 417(D).

6.4.7.2 Well Design And Construction Specifications

- The brine disposal wells will be drilled to a depth of approximately 6,000 ft using a traditional rotary type rig.
- The disposal wells will be completed, equipped, operated and maintained in a manner that will prevent endangerment of any underground source of drinking water (USDW) or damage to sources of oil and gas and will confine injected fluids to the intervals approved. The casing program will be designed for the lifetime of the well.

- The surface casing will be set through the base of the deepest USDW and cemented back to surface in accordance with LAC 43: XIX, § 109(B)(1). The intermediate casing will be cemented above the injection zone surface in accordance with LAC 43: XIX, § 109(D)(3).
- The disposal well will be equipped with tubing set on a mechanical packer. The packer will be set no higher than 150 feet above the top of the disposal zone. The wellheads will be equipped with above-ground pressure observation valves on the tubing and each annulus. The valves will be equipped with operable one-half inch female fittings.
- Within 20 days after the completion of the disposal wells, PPEC will file in duplicate to the commissioner a completed form WH-1.

6.4.7.3 Monitoring And Reporting

PPEC will monitor the injection pressure and injection rate of each disposal well on a monthly basis. The results of the monitoring will be reported annually on form UIC-10. PPEC will report on form *UIC-10* any casing annulus pressure monitoring used in lieu of pressure testing and any other casing annulus pressure test performed. All reports submitted to the Office of Conservation will be signed by a duly authorized representative of PPEC.

6.4.7.4 Logging And Testing Programs

- Before operating the disposal well, the tubing/casing annulus will be tested under the supervision of the Office of Conservation at a pressure not less that the maximum authorized injection pressure, or at a pressure of 300 psi whichever is greater.
- The open-hole and cased-hole logging program will be conducted in accordance with requirements in LAC 43: XIX, § 419.
- The Brine Disposal Wells will be tested to demonstrate their mechanical integrity at least once every five years. PPEC will notify the Commissioner at least 48 hours prior to any testing. A complete record of all Mechanical Integrity Tests will be made out, verified and placed on file in duplicate on the form PLT-1 within 30 days after the testing.

6.4.7.5 Confinement of Fluids

If the PPEC determines that the disposal operation is causing fluid to enter an unauthorized stratum or to escape to the land surface, PPEC will shut-in the well immediately and notify the Commissioner by telephone within 24 hours. LAC 43: XIX, § 421(A) Injection into the well will not be resumed until the Commissioner has determined that the well is in compliance with all material permit conditions. *Id.* If the certificate of compliance is not issued within 90 days, PPEC will plug and abandon the well in accordance with §137. *Id.*

6.4.7.6 Wellheads and Flowline Equipment

- All wellhead components (casinghead, tubinghead, etc.), valves and fittings will be of steel. The water side of the wellhead will have the same pressure rating as the products side. Each flowline connected to the wellhead will be equipped with a remotely operated shut-off valve as well as a manually operated positive shut-off valve located on the wellhead. The wellhead, flowlines, valves, and all related connections will have a test pressure rating at least equivalent to125 percent of the maximum pressure which could be exerted at the surface. All valves will be periodically inspected and maintained in good working order.

- The wellhead and storage cavern will be protected with safety devices to prevent pressures in excess of maximum operating pressure from being exerted on the storage cavern, and to prevent backflow of stored products in event of flowline rupture. The brine flow line will be equipped with a safety shut-off valve to prevent the escape of gas.

- Competent personnel will be present at the control room during injection or withdrawal of gas.

- The wellheads will be protected from mechanical damage by trespassers and/or accidental physical damage.

6.4.7.7 Blasting

No blasting is anticipated for the Project. Therefore, potential risks for the structures caused by blasting does not exist. However, should any blasting be required, it will be conducted in accordance with applicable Federal, State and local regulations.

6.5 GAS STORAGE CAVERNS OPERATION MONITORING AND SAFETY

This section of this Resource Report describes how PPEC would monitor potential effects of the proposed underground storage operation on adjacent operations and vice versa; describes the measures that would be taken to determine the condition and location of old wells; and finally, identifies and discusses safety and environmental safeguards required by state and federal drilling regulations.

6.5.1 MONITORING OF OLD WELLS

Oil and gas activities have been conducted or are currently being conducted just offsite on the immediately adjacent properties to the south, east, and north. The Strategic Online Natural Resources Information System (SONRIS) database operated by the Louisiana Department of Natural Resources (LDNR) was queried to determine current or past existence of oil, natural gas, injection wells, or other mineral activities on Tracts A, B, C and on adjoining property. Although LDNR's records indicate that drilling activity began in the vicinity of the Project area in the early 1900s, the first well drilled onsite did not occur until 1949. The results of the query indicate that at least one (1) well has been identified and registered with the LDNR on Tract C, and at least five (5) wells have been registered with the LDNR on adjoining property. The onsite registered well (41997 at Latitude 30° 44' 53.52" & Longitude 92° 2' 35.04") appears to be located in a swale area in the southern portion of Tract C. The registered wells (41383, 38355, 197959, 37722, and 37580) are located on the adjacent property to the west, and two unregistered additional wells were located along the mid east edge of that property. According to LDNR records, all eight wells were reported to have been plugged and abandoned or dry and plugged. Additionally, several visible petroleum pipeline markers/signs and a short section of what appears to be 3-inch flowline have been observed along the Eastern and Southeastern portions of the adjoining property to the east.

This well review ascertains that there will be no communication between old wells and the Gas Storage Cavern wells. Furthermore, each cavern well will have two casing strings cemented to the surface and completed into the salt mass. The second intermediate casing will be completed at least
300 feet into the salt and the production casing will be completed approximately 3400 feet into the salt mass. This dual protection will alleviate potential communication between the cavern and any overlying strata containing old wells.

6.5.2 MONITORING DRILLING ACTIVITIES OF OTHERS WITHIN THE FIELD

Special field rules for the drilling activities in the vicinity of the storage field would have to be implemented by the Office of Conservation. Should any drilling activity occur within the field, the operator would have to comply with these special field rules.

6.5.3 MONITORING POTENTIAL EFFECTS OF THE OPERATION OF/ON ADJACENT STORAGE OR PRODUCTION FACILITY

The only adjacent storage facility (once used for LPG) is not active. PPEC is not aware of, nor does it anticipate, any surface or subsurface activity either on or near the proposed storage location.

6.5.4 MONITORING AND INSPECTIONS DURING GAS OPERATION

6.5.4.1 Safety Inspections

PPEC will carry out semi-annual inspections of the surface gas facilities and file a written report with the Commissioner of Conservation within 30 days of the inspection, as required by LAC 43: XVII, § 301(E)(1)(a)(i). PPEC will notify the Commissioner of Conservation at least five days prior to such inspections so that his representative may be present to witness the inspections. Id.

These inspections will include, as a minimum, the following:

- Operation of all manual valves
- Operation of all automatic shut-in safety valves, including sounding of alarm devices
- Flare system installation, or hydrocarbon filters
- Earthen brine pits, tanks, firewalls and related equipment
- Flowlines, manifolds, and related equipment
- Warning signs, safety fences, etc.

6.5.4.2 Cavern Capacity Determination

The storage cavern capacity will be verified at least once every five years in accordance with the requirements of LAC 43: XVII § 301(E)(1)(b). These capacity verification data will be submitted to the Commissioner of Conservation within 30 days of the measure.

6.5.4.3 Cavern Mechanical Integrity Test

Prior to storing natural gas, the cavern will be subjected to a Mechanical Integrity Test conducted in accordance with the requirements of LAC 43: XVII, § 109(B)(9).

A detailed testing procedure will be submitted to the Louisiana Department of Natural Resources for review and approval prior to conducting the Mechanical Integrity Test as required by LAC 43: XVII, § 109(B)(9)(d). The outline of the test procedure will be as follows:

After the end of the leaching phase, the cavern brine temperature and salt saturation will be allowed to approach stability. For test purposes, the cavern will be considered stable and the test will commence when the shut-in brine pressure changes less than 10 psig in 24 hours. Calibrated temperature and pressure gauges will be used to monitor both wellhead and ambient temperatures throughout the test.

A conventional nitrogen-brine interface test will then be conducted, in which sufficient nitrogen will be injected to lower the nitrogen-brine interface in the outer annulus to below the final production casing, but above the cavern roof. Temperature and interface surveys will be run at the beginning and at the end of the test. This data will be combined with surface pressure and temperature data to determine the mechanical integrity of the well.

6.5.4.4 Christmas Tree and Cemented Casing Inspection

Once the cavern is in service, the Christmas tree and the casing will be inspected every five years as required by LAC 43: XVII, § 301(E)(1)(c).

6.5.4.5 Cavern Inventory Monitoring

The volume of gas injected into and withdrawn from each storage well will be determined by gas movement data from the master meter and records of pressure and temperature change (or by an alternate method approved by the Commissioner of Conservation).

6.5.4.6 Cavern Pressure Monitoring

The pressure of the storage caverns will be monitored continuously. Cavern wellheads will be instrumented with a high and low level pressure recorder and alarms/shutdowns. This system will prohibit any violation of maximum and minimum operating pressure limits even for a short period of time. All gas injection and withdrawal activities will be continuously monitored by an individual who is experienced and trained in such activities.

6.5.4.7 Subsidence Monitoring

A subsidence-monitoring plan will be implemented and maintained throughout the life of the Project. Permanent monuments will be installed around the storage cavern and regular monitoring program to check the elevation changes on each monument will begin. The monuments will be anchored into the bedrock below the ground to avoid detection of local tilt subsidence (or at 30 feet below the surface). The cavern wellhead will be part of the subsidence-monitoring program. The frequency of the elevation survey (cavern wellheads and monuments) will be once every six months during the dewatering period and once a year thereafter. The surveys will take place in the same season of the year to minimize the effect of ambient temperature.

6.5.5 PLANNED SAFETY AND EMERGENCY RESPONSE PLANS

The Commissioner of Conservation has jurisdiction over safety precautions regarding the storage and transmission of the gas while it is stored underground and in the associated wellhead facilities. PPEC must have all required safety measures and equipment in place before the facility may begin operation as required by LAC 43: XVII, §§ 101-301 (2001), amended by 29 La. Reg. 914, § 3123 (2003).

6.5.5.1 Risk Identification

Geomechanical Accident

The risk of a geomechanical accident that could lead to gas loss, explosion and/or subsidence will be minimized by using conventional salt cavern technology employed successfully for decades in the United States. This technology was used in the development of the cavern design at the Moss Bluff and Egan Hub Gas Storage Facilities, which have experienced no measurable volume loss due to creep, cavern instability or surface subsidence. If a geomechanical accident were to occur, it would be unique in nature and would require a case-specific analysis to determine the appropriate response. In any event PPEC would take appropriate action to ensure the safety of its employees and the public, and would take appropriate action to minimize damage and/or negative impact to the facilities and surrounding areas.

Gas Leak

In the case of a gas leak, the action taken would depend on the location of the leak. If the leak is above-ground (*e.g.*, on the wellhead, or piping leaving the wellhead), then the wellhead and/or piping would be shut in and isolated, and repairs made to stop the leak. These repairs could range from tightening flange bolts to removing and replacing components such as valves, fittings, etc.

If the leak is determined to be down-hole (e.g. cavern well) the operator will immediately notify the Commissioner of Conservation in accordance with LAC 43: XVII, §§ 101-301 (2001), amended by 29 La. Reg. 914, § 3109(H)(7) (2003). Under the supervision of the Commissioner, a work-over would likely be conducted to resolve the situation. However, each down-hole situation is unique in nature, and a thorough analysis would be conducted at the time of the incident in order to develop an appropriate solution to remedy the situation, on a case-by-case basis. If a solution to stop gas migration is not deemed feasible, the cavern causing gas migration would be plugged and abandoned in accordance with LAC 43: XIX, § 137.

6.5.5.2 Safety Warnings

Appropriate safety precaution signs will be displayed and unauthorized personnel kept out of the storage area. Each storage wellhead will be visibly marked with an appropriate identifying sign. LAC 43: XVII, § 301(E)(3).

6.5.5.3 Emergency Shutdown

Emergency shutdown valves will be installed on the gas injection/withdrawal piping of each storage wells and on any brine or fresh water piping that is connected at the wellhead.

For salt cavern storage automatic surface shut-in safety valves are used in lieu of down-hole shut-in safety valves. The gas operated automatic surface shut-in safety valves configured for Fail-Safe Closed operation (*i.e.*, valve will close automatically if there is a loss of control signal, loss of valve operator supply pressure, thermal (fire) activation, signal from a safety control sensing device, or manual activation of emergency shutdown system), will be installed within 10 feet of a positive shut-off manual wellhead valve on the fresh water, brine and gas piping.

Safety control sensing devices will include hydrocarbon sensors, overpressure sensors and excess flow sensors on the fresh water piping entering and brine piping that exits the cavern wellhead. These safety control sensors will be tied into the cavern emergency shutdown controls to shut in the appropriate gas operated automatic shut-in safety valves automatically in the event that gas enters the water or brine piping during cavern expansion operations. These valves can be actuated either by an automatic shutdown trigged by a safely sensing device, manually from the control room computer, or manually at the cavern. Closing these valves during an emergency situation would effectively isolate the caverns from the rest of the facility.

6.5.5.4 Fire Prevention and Control

- All equipment will be designed with the appropriate fail-safe emergency shutdown systems and alarms. Emergency shutdown valves, which will be capable of remote and local operation, will be activated automatically by 1) over- or under-pressuring in the natural gas system and 2) detection of natural gas heat or flame.

- Manual isolation valves will be installed on each wellhead.

- Ignition sources will not be located within 75 feet of a well or unprotected source of flammable gas.

- Any building containing a source of flammable gas will be constructed in accordance with all state and federal building codes and regulations applicable to hazardous locations.

- All piping and valves will be protected against thermal expansion of hydrocarbon.

6.5.5.5 Emergency Planning

An emergency response plan will be developed in accordance with all applicable local, state and federal regulations. The plan will include procedures for the safe control or shutdown of the storage facility in the event of a failure or other emergency. The emergency response plan will be documented and include roles and responsibilities; emergency response procedures; and training, testing, and implementation requirements so that:

- The safety of personnel is ensured,
- The protection of the environment is maximized, and
- Damage to property and the environment is minimized.

Emergency response equipment will be strategically positioned to ensure a rapid, efficient, and effective response to "most likely" events.

PPEC will also develop plans intended to minimize the possibility of emergencies. These plans will address:

- Methods for safe handling, storage, and disposal of hazardous and non-hazardous materials;
- Procedures for performing routine inspections of equipment and systems, storage tanks and drums, containment structures, storm water management devices;
- Procedures for repairing equipment leaks or drips; and
- Applicable pollution prevention laws, rules, and regulations.

6.5.5.6 Site Security

Security measures, including the installation of barricades, 6-foot small-mesh industrial-type steel fence, locking gates, security lighting and/or alarm systems, will be provided to prevent unauthorized access and protect the public, and alert the facility operator and other personnel of any abnormal operating conditions, so that they can react quickly in evaluating the situation. Heavy-duty barriers will be constructed to protect the wellhead and above ground piping in the wellhead area from vehicular and equipment damage. The facilities will be manned 24 hours per day. Operators will make rounds at scheduled intervals to ensure all equipment is operating as designed.

6.5.6 RECORDS RETENTION

All records pertaining to the Project design, construction and gas operation will be retained for the life of the storage caverns. These records will include: well drilling logs, electrical logs, directional surveys, completion and cementing data, pressure test records, geophysical records, solution mining records, surveys, photographs, inspection, maintenance, reports, permits, certified location plot, storage well pressures, volumes of gases injected and withdrawn, and the inventory of gas in storage.

6.5.7 NOISE CONTROL

The drilling of the cavern wells, the brine disposal wells and the fresh water wells will be conducted on a 24 hours per day basis, and may require site-specific noise control equipment for such 24-hour operations. Once a specific rig has been selected, PPEC will file with the FERC and the appropriate state and local authorities a description of the rig and its noise emitting characteristics, including a specification of noise control measures. The drilling operations will require 90 to 120 days per cavern well and approximately 20 to 45 days per well for the water wells and brine disposal wells.

6.5.8 ABANDONMENT PROCEDURE

Prior to starting the plugging operations on any Project well or the abandonment of the Project storage caverns, an application describing the method to be used will be filed with and approved by the Commissioner of Conservation and the FERC. LAC 43: XVII, § 301(E)(4). Unless the Commissioner specifies to the contrary, the wells will be plugged in accordance with LAC 43: XIX, § 137. *Id.*

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ATTACHMENT 6-1

Dr R.L. THOMS – GEOMECHANICS REPORTS

ATTACHMENT 6-1

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PINE PRAIRIE ENERGY CENTER

GEOMECHANICS REPORT

R. L. Thoms

Introduction: Geomechanics of Storage in Gulf Coast Salt Domes

Gulf Coast salt domes of the United States (U.S.) are located in four states: Texas, Louisiana, Mississippi, and Alabama (Halbouty, 1979). Louisiana domes are located in the Central Basin of Gulf Coast salt domes. All Gulf Coast domes evolved from the same "mother bed" of the Louann salt basin, and thus exhibit similar geomechanical characteristics. The dome configurations are usually circular or elliptical in plan, ranging from one to two miles in diameter; and are vertically extensive, ranging over tens of thousands of feet in depth. The salt is generally massive and impermeable, and thus exhibits excellent containment characteristics for gaseous and liquid hydrocarbons. In addition to storage of natural gas (gas) as discussed below, Gulf Coast salt domes are used to store the Strategic Petroleum Reserve (SPR) of the U.S. Department of Energy and also approximately 83% of all U.S. "light hydrocarbons" [mainly liquid propane gas (LPG)] (Thoms and Gehle, 2000).

Gulf Coast salt domes have been explored and studied since the early 1900's, first for oil and sulfur, and more recently, for storage of hydrocarbons or disposal of wastes (Veil, et al., 1996). Exploration for oil generated considerable data on the structural geology of domes, and studies of storage and disposal projects extended the database to include the geomechanical properties of domal salt. Consequently the structural geology and salt properties of Gulf Coast domes have been thoroughly investigated and are generally understood, especially for projects involving storage of gas, oil, or light hydrocarbons.

The first (two) salt caverns designed and constructed specifically for gas storage in the U.S. were completed in 1970 in the Eminence Salt Dome in Mississippi (Allen, 1972). The caverns were deep, with the tops of caverns at about 5500 ft and the bottoms extending to depths of about 6200 ft. The caverns exhibited excessive salt creep and "shrinkage" early on during periods of low internal cavern pressure. They were then re-solution mined at shallower depths and maintained with adequate minimum cavern pressure to control salt creep (Coates, et al., 1985). Today, over thirty years later, the now enlarged Eminence storage facility remains in operation. The early Eminence experience with excessive cavern shrinkage and subsequent mitigation represents a "lessons learned" example in controlling salt creep in gas storage caverns. And the continuing operation of the facility after three decades demonstrates the long-term containment properties of caverns designed and constructed, or "engineered", specifically for gas storage in Gulf Coast salt domes.

Large reserves of both bedded and domal salt occur in the U.S., and gas is stored in caverns in both types of formations. As of 1998 approximately 95% of all gas storage in U.S. salt formations was sited in Gulf Coast domes (Thoms and Gehle, ibid.). This dominant use of Gulf Coast salt dome caverns for storage of gas constitutes a strong endorsement of their use by the gas storage industry. It also implies that an extensive data base, much of it proprietary, and many years of satisfactory operating experience exist for these caverns.

The salt stocks of Gulf Coast domes typically consist of almost pure sodium chloride extending vertically for tens of thousands of feet. Thus near cylindrical vertical cavern shapes can be solution mined in the stocks over depth intervals of several thousands of feet and still leave hundreds of feet of salt cover above and below for safe containment of stored gas or liquids. For example, some of the oil storage caverns that were solution mined in domes for the U.S. Strategic Petroleum Reserve (SPR) extend over depth intervals of 2000 ft (Linn and Culbert, 1999). Furthermore, because of the generous amounts of salt in the vertical direction, dome-shaped roofs can be mined over salt dome caverns to achieve superior stability due to roof shape.

By contrast, interbedded "insolubles" occur in bedded salt formations and generally hamper solution mining of caverns. The insolubles typically consist of anhydrite, shale, and dolomite, and often occur in distinct massive layers and thereby bound the vertical extent of individual salt layers. Thus caverns in bedded salt formations are short and wide if limited to a single salt layer, or look like schematics of inverted Christmas trees if they extend vertically through several salt layers and intervening beds of insolubles. Also, cavern roofs in bedded salt tend to be flat or only slightly domed because of the limited vertical extent of salt. These roof configurations are inherently less stable than the deep dome-shaped roofs that can be constructed over caverns in salt domes.

Pine Prairie Energy Center Project in Pine Prairie Dome, Evangeline Parish, Louisiana

SG Resources Louisiana, L.L.C. (SGRL) has proposed the Pine Prairie Energy Center Project (PPEC) for storage of gas in the Pine Prairie Dome, located about 20 miles north of Eunice. The caverns proposed for storage are similar to caverns that were engineered for gas storage and are now operating in the Moss Bluff Dome, Liberty County, Texas, and in the Jennings Dome (Egan Storage Facility (ESF)), Acadia Parish, Louisiana (Gatewood and Dussaud, 1993; Klamerus and Ehgartner, 1999). Therefore the PPEC will incorporate a database resource comprised of experiences with successful gas storage caverns in Gulf Coast salt domes. The two ESF caverns operating in the Jennings Dome are of particular interest because they are essentially "twins" to the first two caverns proposed for the PPEC. Klamerus and Ehgartner (ibid.) of Sandia National Laboratories (SNL) carried out a detailed geomechanical study of the ESF caverns and included their findings in a report (SNL Report). The SNL Report is included as Attachment A to this document.

PPEC maps resulting from previous geological, geophysical, and preliminary cavern design studies are shown in the main body of this report. These maps include illustrations of the structure of the dome and the proposed locations of the storage caverns in the salt stock.

Figure 1 shows the Salt Structure map of the Pine Prairie Dome and the SGRL cavern storage property. The SGRL property is located over the shallowest salt of large areal extent, which is generally the best location for storage caverns in Gulf Coast domes. This is because the shallowest salt in Gulf Coast dome stocks tends to be more pure (sodium chloride) and thus essentially free of impurities. This can be inferred from Kupfer's suggestion (1967), "those portions of a salt stock which have moved the greatest distance are the purest". The salt stock movement noted here is during dome growth. Other desirable features associated with the shallowest salt of a dome usually include a well-known top of salt boundary and an abundant lateral salt cover for caverns

The salt structure map of the Pine Prairie Dome beneath the SGRL caverns does not indicate the presence of an "anomalous zone (AZ)" (Neal, et al., 1992). The presence of an AZ may be suspected if there is a valley-like depression running up a dome flank, and sometimes, across the top of a dome. AZs typically include some impurities, and perhaps gases and fluids, but are still mainly sodium chloride. Storage caverns intersected by AZs may be more expensive to operate because of increased maintenance costs relative to caverns constructed in "normal" Gulf Coast salt.

Figure 2 illustrates cavern configurations, spacing, and depths for the two caverns nearest the salt edge in the Pine Prairie Dome. This Figure will be referenced later for comparison to the ESF caverns.

Geomechanical Characteristics of Gulf Coast Domal Salt

Geomechanical salt test data are available in the technical literature for four Gulf Coast salt domes that are located within 75 miles of the Pine Prairie Dome. The Jennings (Egan), Jefferson Island, Avery Island, and Weeks Island Domes are located to the south and southeast of the Pine Prairie Dome at distances of approximately 35, 60, 70, and 75 miles, respectively. The two closest domes, Jennings and Jefferson Island, are currently used for storage of natural gas, and thus represent relevant examples for the Pine Prairie Dome project. The other two domes, Avery and Weeks Island, are the sites of operating rock salt mines.

Geomechanical test data for salt typically include values of strength and creep parameters derived from laboratory tests. Frequently derived strength parameters include Unconfined Compressive Strength, and the elastic properties denoted as Young's Modulus and Poisson's Ratio. Pfeifle, et al., (1993) have reported the values shown in Table 1 for the Jefferson Island, Avery Island, and Weeks Island Domes.

Table 1. Salt Parameters from Louisiana Domes

Salt Dome	Unconfined Strength (Mpa)	Young's Modulus (Gpa)	Poisson's Ratio
Jefferson Island	24.28	18.25	0.38
Avery Island	23.70	30.76	0.42
Weeks Island	13.17	31.87	

Similar salt parameters have been reported for the ESF site in the Jennings Salt Dome (SNL Report, ibid.). Values of Young's Modulus and Poisson's Ration for Jennings salt were 648,000 ksf (31 Gpa) and 0.25, respectively. The same values were also derived for salt from the Waste Isolation Pilot Plant (WIPP) located in bedded salt near Carlsbad, New Mexico. Although the salt parameters are the same in this case for both domal and bedded salt, it is important to note the significance of the difference in the structure of domes and bedded salt formations relative to geomechanical considerations for gas storage caverns.

Geomechanical salt parameters can be expected to be generally similar over the entire heights of caverns constructed in Gulf Coast domes because of the homogeneity of salt present. Material parameters in bedded formations will vary according to the individual layers of salt or insolubles encountered in cavern construction. Thus salt parameters determined for one dome can often be used to obtain reasonable estimates of the behavior of caverns in another dome, provided the caverns are located over the same depth intervals. The behavior of caverns in bedded salt is less likely to be transferable between sites unless the site formations display very similar layering of salt and insolubles spanning the same cavern depth intervals.

Salt creep is another geomechanical characteristic affecting performance of gas caverns, as noted in the previously cited early Eminence Dome experience. Steady state creep of salt is often described with the "Norton" material model, which involves a model "fitting" parameter, effective stress exponent, and activation energy term. Pfeifle, et al. (ibid.), have also reported values of salt creep parameters for Louisiana domal salts based on laboratory tests. These include effective stress exponent values of 2.49 and 4.15 for Jefferson Island and Avery Island salt, respectively.

Parameters derived from laboratory tests of salt are used as input to computer programs that implement finite element or finite difference codes for analyses of caverns. A number of codes and material models exist and continue to be developed for analyzing salt cavern behavior. Recent developments have included salt material models accounting for damage due to dilatancy, healing, transient creep, and load reversal (Munson, 1999). For example, a criterion for onset of dilatancy in salt was used in the analysis of a gas storage cavern in the Petal Dome in Mississippi (Ratigan, et al., 1993). In the same publication this criterion was also used to check spacing of existing brine caverns for possible temporary storage of natural gas until caverns engineered for such storage were constructed. Onset of dilatancy implies that salt will become locally permeable where it occurs, but it does not indicate general loss of cavern integrity.

The damage criterion for dilatancy, based on laboratory tests of salt, indicates that salt will dilate when the ratio of a shearing stress measure to a confining stress measure attains or exceeds a specified numerical value (Van Sambeek, et al., 1993). The shearing and confining stress measures are the square root of the second invariant of the deviatoric stress and the first invariant of the total stress tensors, respectively. The specified numerical value ranges from 0.25 to 0.27. It is interesting to note that a number of salt researchers in both the U.S. and abroad arrived at almost identical criteria for the onset of salt dilatancy at about the same time (Klamerus and Ehgartner, ibid.).

Preliminary designs of gas storage caverns in Gulf Coast domes are often based on considerable experience with previous similar caverns, applicable regulations, and economic considerations. Computer analyses incorporating site specific salt properties based on tests of specimens from the first well are then used to check the preliminary designs. In some cases such analyses may be used to investigate geomechanical issues related to further enlargement of operating caverns. Operating caverns can be enlarged by solution mining under gas (SMUG) provided the mining is carried out between gas injections and withdrawals (Gatewood and Dussaud, ibid.).

After operating for a number of years the ESF caverns were considered for enlargement by the SMUG process. The studies described in the SNL Report were carried out to investigate the geomechanical issues related to enlarging the ESF caverns so that their working gas capacity would be increased from 6 BCF to 8 BCF. As noted previously, the ESF and PPEC caverns are very similar, especially for the enlarged cases. The similarity can be verified by comparing the cavern schematics depicted in Fig. 1 of the SNL Report and in the corresponding Fig. 2 of this report. Numerical values of important features for the two sets of caverns are also listed in Table 2 for comparison purposes.

Table 2. Similar Features of PPEC and ESF Gas Caverns

Caverns (Gas Capacity)	Casing seat/ Bottom (Ft)	Spacing (Ft)	Diameter (Ft)	Max/Min Pressure (psi)
PPEC (6.0 BCF)	3900/5285	950	250	3510/585
ESF (8.0 BCF)	3750/5150	800	290	3375/563

The strong similarity of important features of the operating ESF caverns and the proposed PPEC caverns, including depths, can be seen. One difference is that the minimum spacing of the PPEC cavern wells is 950 ft, while the spacing of the ESF cavern wells is 800 ft. The salt between caverns constitutes the "pillar" (or "web"), and its thickness is about 510 ft for the enlarged ESF caverns and a more conservative 700 ft for the PPEC caverns. The maximum and minimum (max/min) operating pressures are based on the same gradients of 0.90 psi/ft and 0.15 psi/ft of depth, respectively, to the casing seats. Depths to the casing seats of the caverns differ by only 150 ft in 3900 ft, or by less than 4%. The thickness of salt roof, or "back" is not an issue for either site since it is over 3300 ft for the PPEC caverns and about 850 ft for the ESF caverns. The lateral cover of salt is also of no concern for the PPEC caverns, since its thickness is over 1500 ft for both caverns at a depth of 4000 ft. See Fig. 2.

Based on the above discussions of cavern similarities, the findings of the SNL Report for the enlarged ESF caverns are proposed as representative and even on the safe side for the PPEC caverns. Both sets of caverns have an abundant salt cover, therefore any major geomechanical issues involve possible fracturing or damage to the salt pillar between them. Thus the SNL Report findings for the ESF caverns will be on the safe side since the PPEC caverns have a thicker pillar. Salt creep is of interest, but poses no hazard for such deep caverns surrounded by abundant salt. Furthermore, facility operators will avoid excessive salt creep because of economic considerations i.e. valuable gas storage capacity is lost. And in real life operations gas caverns are seldom operated at maximum or minimum pressures, and if so, only for short periods of time.

Table 4 on page 36 of the SNL Report summarizes results of investigations for possible fracturing or dilatant damage to the pillar (or web) between the ESF caverns. In no case did maximum principal stresses become tensile in the pillar, thus ruling out a possible tensile fracture. In only one case did the dilatancy safety factor drop below 1.0, and that was at the bottom of one cavern in an area that did not affect cavern containment. Furthermore, the properties of faster creeping WIPP salt, rather than Jennings Dome salt, were assumed in obtaining this result. No dilatant damage was indicated for the site-specific Jennings Dome salt. Maximum surface subsidence predicted for the ESF caverns was about 0.85 ft after 20 years when WIPP salt properties were assumed, and only 0.16 ft after 50 years for Jennings Dome salt properties. The deeper PPEC caverns should cause even less subsidence. Finally, the SNL Report includes the statement on page 37 "The analysis predicted very little cavern interaction which suggests that the caverns are conservatively spaced." If this is true for the ESF caverns it indicates that the PPEC caverns are even more conservatively spaced. Therefore, based on the SNL Report for the ESF caverns it appears likely that the very similar PPEC caverns will also remain satisfactory for gas storage for up to 50 years.

From a geomechanics viewpoint Gulf Coast salt domes represent a stable geologic media for gas storage caverns. Munson (ibid.) reported that local fracturing of salt around an example cavern did not lead to general failure or increased permeation provided the salt surrounding the fractured zone remained impermeable. Furthermore, fractures in salt tended to heal if the loadings causing the fractures were reduced, and this can be accomplished by raising the minimum operating pressure in gas caverns. These observations are consistent with the previously cited experiences with the still operating Eminence gas storage facility.

Monitoring and Mitigating Measures

Subsidence monitoring over cavern fields can be performed with periodic leveling surveys. Mitigation measures for subsidence include designing cavern configurations and planning operating schedules to control excessive salt creep.

Cavern behavior can be predicted by taking salt cores during drilling of the first cavern well and testing specimens in the laboratory to obtain salt parameters for analysis of salt creep, fracturing, and cavern life. This is considered a prudent economic measure by most current cavern operators, but is not considered essential for avoiding hazardous events in caverns engineered from the outset for gas storage in Gulf Coast domes. Cavern integrity and containment can be monitored by diligent checking of gas inventory records to ensure that no gas has escaped.

Cavern shrinkage is a result of salt encroachment into a cavern via creep. Shrinkage can be monitored on the basis of cavern inventory records maintained by gas facility operators. Data from sonar surveys performed periodically to satisfy regulatory requirements can also be used to monitor cavern shrinkage. Mitigation of shrinkage is achieved by controlling salt creep, which has been discussed previously. Cavern shrinkage losses can be made up with the SMUG process if the initial cavern volume is to be maintained.

Conclusions

Natural gas storage in Gulf Coast salt domes has been highly successful, accounting for 95% of gas stored in U.S. salt caverns. Problems involving loss of natural gas from salt caverns in the U.S. have been associated mainly with old brine or liquid storage caverns in bedded salt that were retrofitted for natural gas storage.

Gas storage caverns can be designed and constructed with confidence in Gulf Coast domes because of considerable experience with such caverns. Furthermore, the geology of domes is well suited to construction of caverns with abundant salt cover and thus good containment properties.

Caverns engineered from the outset for storage of gas in Gulf Coast domes are stable containment reservoirs, since any local fracturing due to excessive loads will heal when the loads are reduced. And, containment of gas will be maintained because of the abundant salt cover available in domes.

The proposed PPEC caverns are very similar to the ESF caverns that were analyzed in detail and discussed in the SNL Report. The SNL Report finding of geomechanical suitability for gas storage by the ESF caverns can be safely transferred to the PPEC caverns because the salt thickness is larger between the PPEC caverns.

Therefore, my opinion from a preliminary geomechanical viewpoint is that the PPEC caverns, as proposed by SGRL, are suitable for safe storage of natural gas.

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Figure 1: Location of the proposed cavern and location of geologic cross sections N-S, W-E AND SW-NE

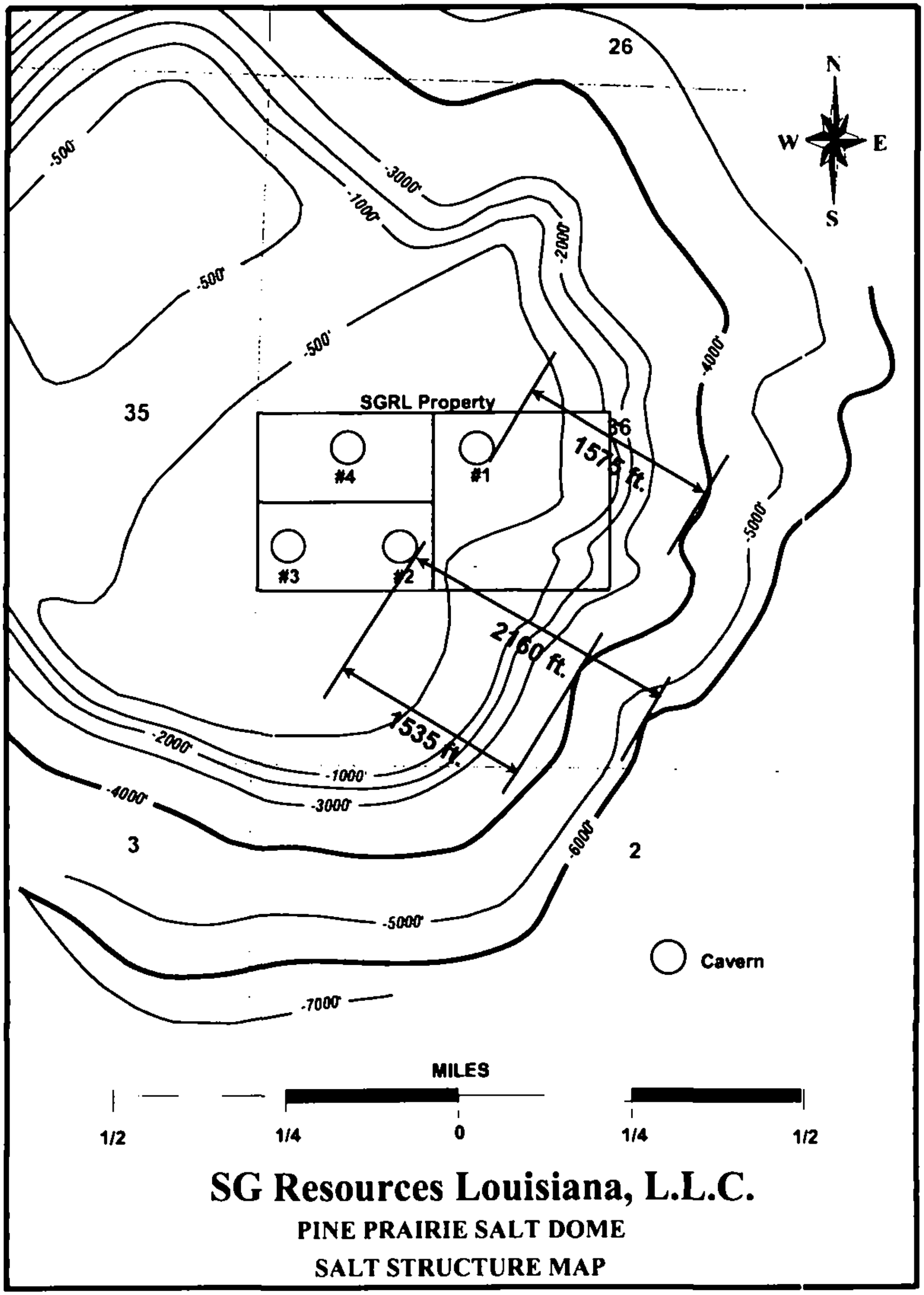
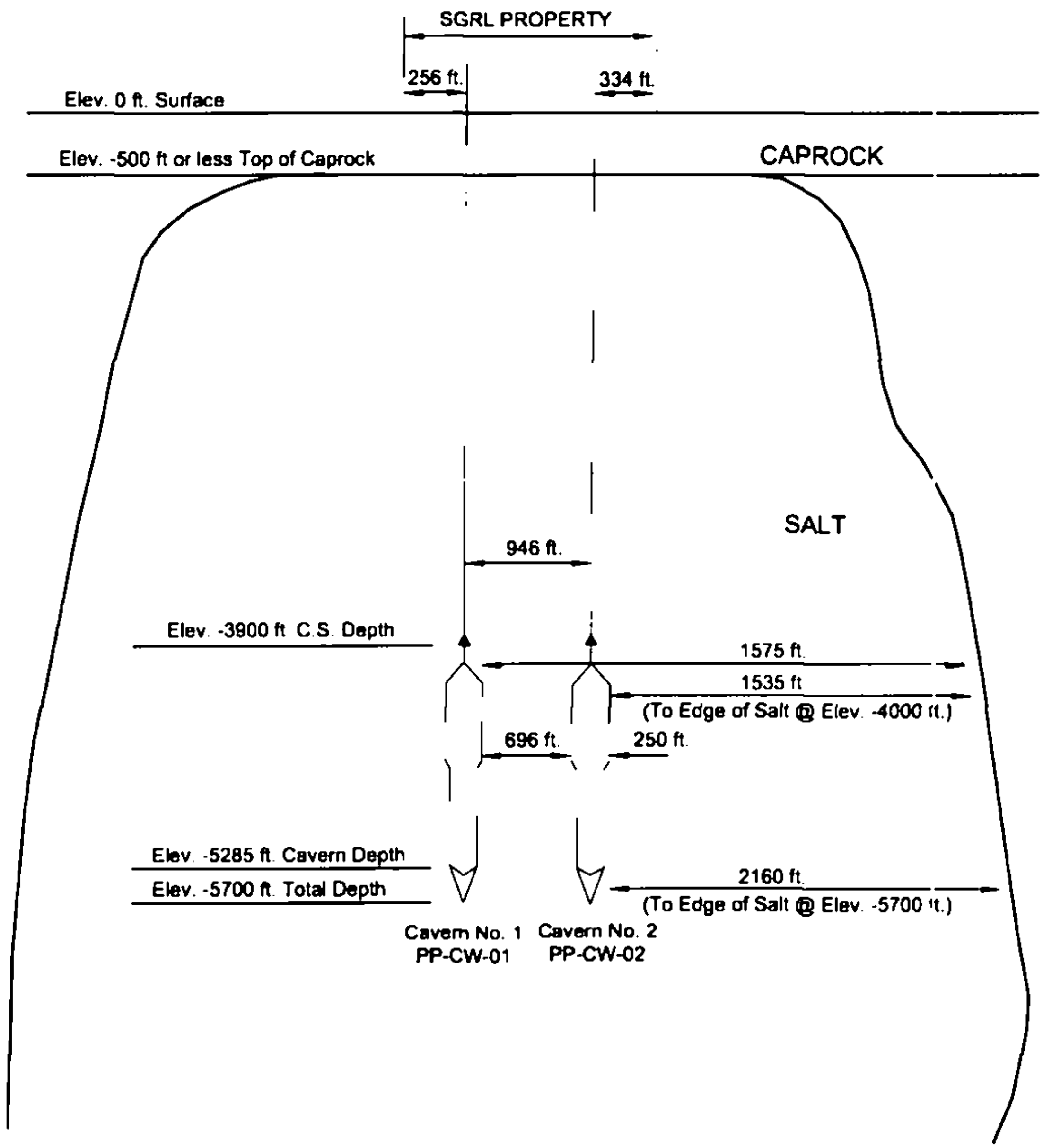


Figure 2: Profile of Pine Prairie Dome showing location of cavern 1 and 2



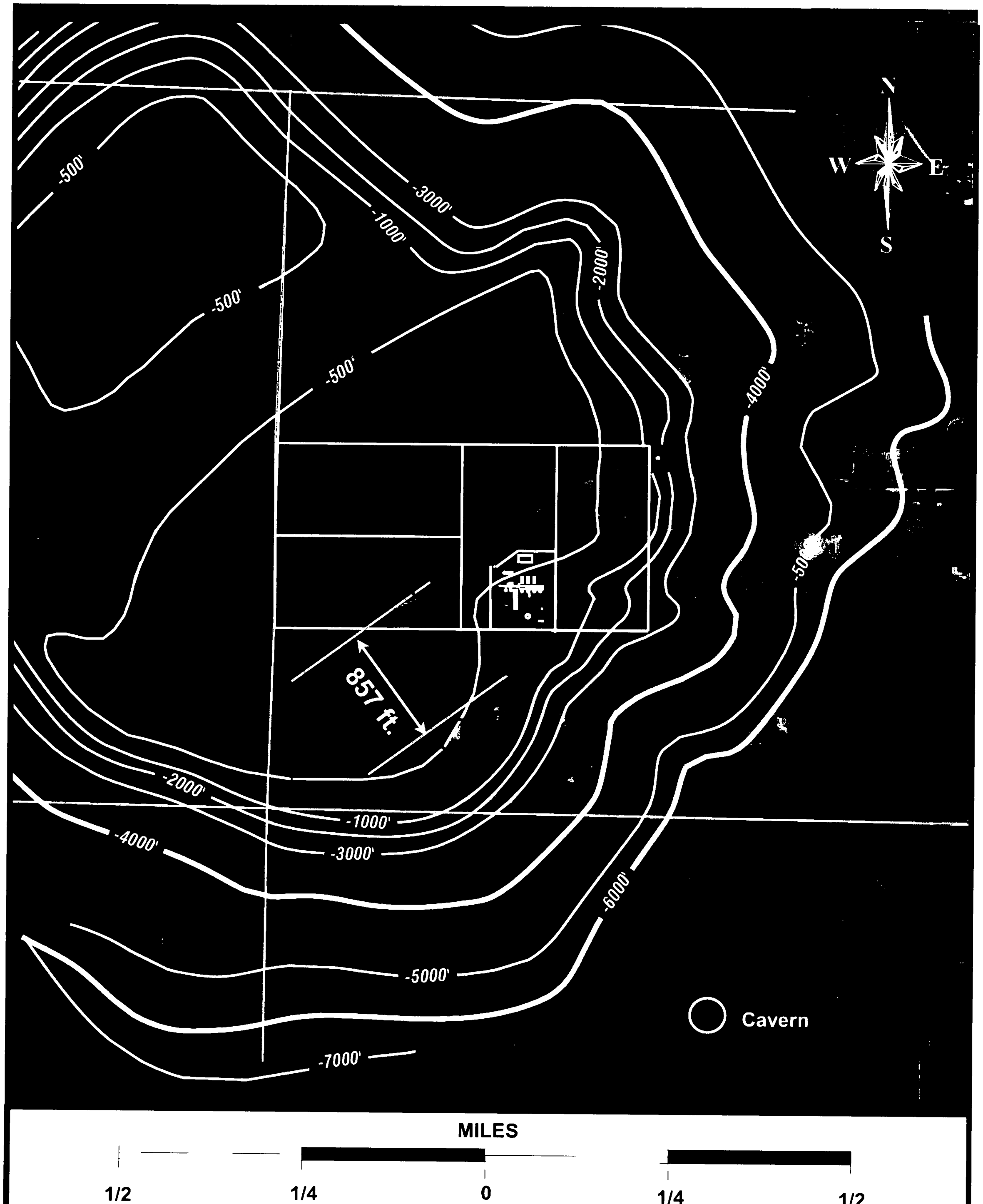
SG Resources Louisiana, L.L.C.

PINE PRAIRIE SALT DOME

CAVERN PROFILES

(not to scale)

Location of Pine Prairie Cavern Wells and Conoco Cavern 2B and 3B



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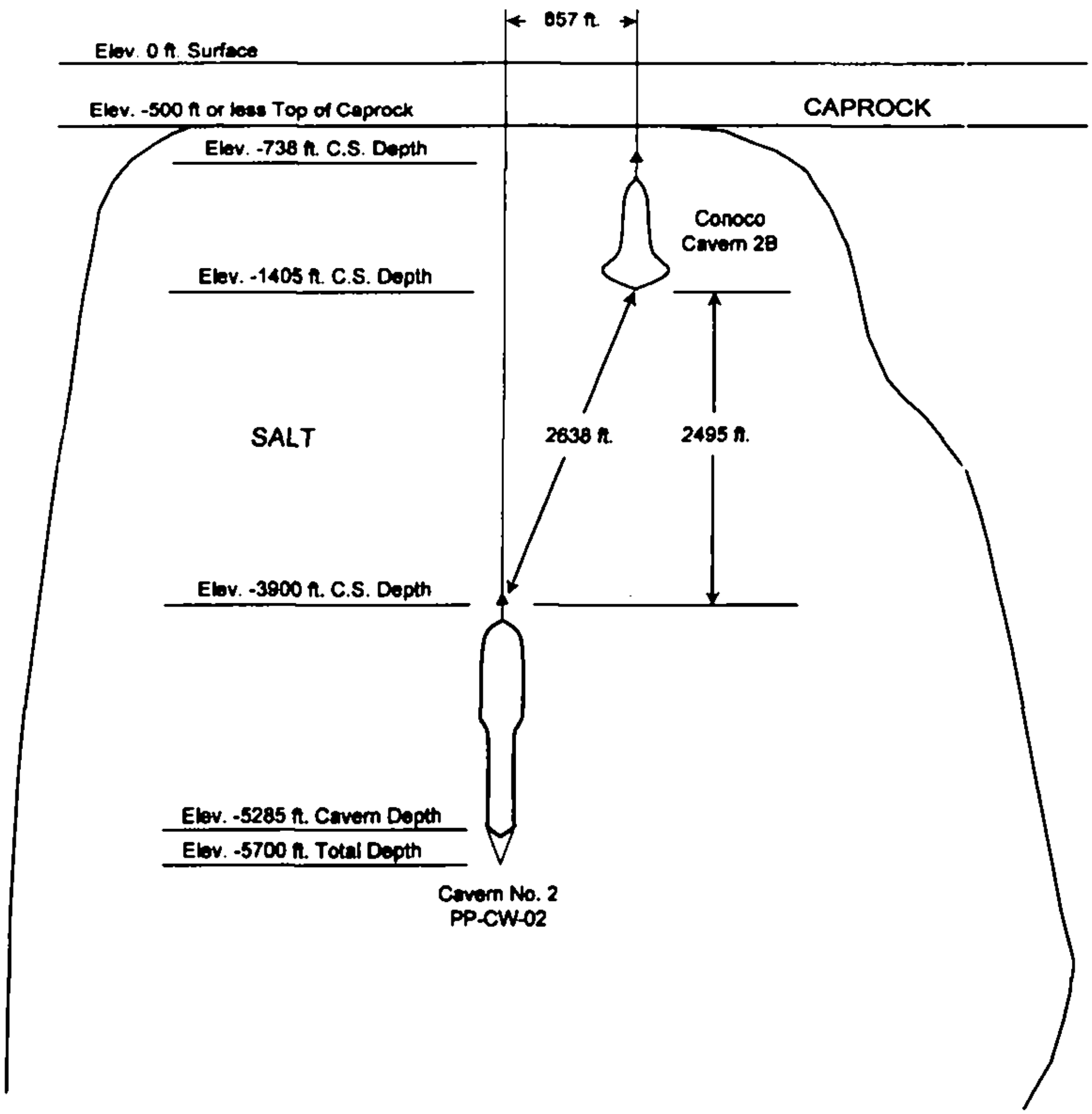
PINE PRAIRIE SALT DOME

Profile of Pine Prairie Dome showing location of Cavern #2 and Conoco Cavern 2B



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PINE PRAIRIE SALT DOME

CAVERN PROFILES

(not to scale)

ATTACHMENT A

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3-D Finite Element Analyses of the Egan Cavern Field

Eric W. Klamerus and Brian L. Ehgartner

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Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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3-D Finite Element Analyses of the Egan Cavern Field

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Abstract

Three-dimensional finite element analyses were performed for the two gas-filled storage caverns at the Egan field, Jennings dome, Louisiana. The effects of cavern enlargement on surface subsidence, storage loss, and cavern stability were investigated. The finite element model simulated the leaching of caverns to 6 and 8 billion cubic feet (BCF) and examined their performance at various operating conditions. Operating pressures varied from 0.15 psi/ft to 0.9 psi/ft at the bottom of the lowest cemented casing. The analysis also examined the stability of the web or pillar of salt between the caverns under differential pressure loadings.

The 50-year simulations were performed using JAC3D, a three dimensional finite element analysis code for nonlinear quasistatic solids. A damage criterion based on the onset of dilatancy was used to evaluate cavern instability. Dilation results from the development of microfractures in salt and, hence, potential increases in permeability. Its onset occurs well before large scale failure. The analyses predicted stable caverns throughout the 50-year period for the range of pressures investigated. Some localized salt damage was predicted near the bottom walls of the caverns if the caverns are operated at minimum pressure for long periods of time. Volumetric cavern closures over time due to creep were moderate to excessive depending on the salt creep properties and operating pressures. However, subsidence above the cavern field was small and should pose no problem to surface facilities.

This work, conducted at Sandia National Laboratories, was supported by Market Hub Partners, Houston, Texas.

Acknowledgement

The authors would like to thank Xavier Allemandou of Market Hub Partners for his support of this work and to Marty Molecke and Jeff Cherry for their thorough technical reviews of this report.

Contents

Tables

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1 INTRODUCTION

Three-dimensional (3-D) finite-element geomechanics analyses were performed for the expansion of the Egan Gas Cavern Field at Jennings Dome, Louisiana. The field initially consisted of one cavern which was enlarged to a 6 billion cubic feet (BCF) working gas capacity. Leaching then commenced on Cavern 2, located 800 ft. away. In this report, the stability of final cavern sizes of 6 and 8 BCF are evaluated. The locations of the caverns are shown in Figure 1.

The two cavern field necessitated the use of a 3-D structural model (Hoffman, 1993a). The analyses predicted surface subsidence, volumetric cavern closure, and cavern stability over a 50-year period for various operating cavern pressure conditions, varying from 0.15 to 0.90 psi/ft at the casing shoe, approximately 100 feet above the ceiling of the cavern.

The finite element model is described in the following section. Next, the analysis results are presented in terms of cavern performance and integrity. Finally, the conclusions of the investigation are presented in the last section.

2 PROBLEM DESCRIPTION

2.1 Cavern Geometry

The cavern geometries are based on leaching prediction simulations as shown in Figure 2. The caverns are approximately 3850 feet deep at the roof and stand approximately 1300 feet high. The enlargement from 6 to 8 BCF occurs in the lower section of the caverns, i.e., the body of the cavern bulges outward somewhat.

The finite element models used for this study include a typical domal stratigraphy of salt, caprock and overburden, as illustrated in Figure 1. The overburden and caprock are idealized at an average thickness of 2500 ft and 500 ft-thick, respectively. Since the caverns are located in the central portion of the dome, a symmetry plane can be used in the model. The location of this symmetry plane is illustrated in Figure 3.

2.2 Model History

The analysis history was simulated where Cavern 1 is initially 6 BCF and Cavern 2 does not exist. After 4 years, two possible cavern sizes for Cavern 2 (6 and 8 BCF) are examined. The analysis concludes by enlarging Cavern 1 and examining different scenarios for operating pressure as shown in Table 1. The range in gas operating pressure was equal to 0.15 and 0.9 psi/ft at the casing shoe. The casing shoe was assumed to be located 100 ft above the cavern roof. A constant uniform gas pressure was used during the low, typical, and high pressure periods in the analyses. The variation in cavern size and salt properties for the three different Cases studied are shown in Table 2.

Table 1. Time and Pressure History of the Two-Cavern Analysis

Time (yrs)	Cavern 1	Cavern 2	Comment
0	6 BCF		start analyses using typical operating pressure
4		6 or 8 BCF	Examine option of adding a new 6 BCF cavern (Case #1) or 8 BCF cavern (Case #2)
6	8 BCF		Enlarge Cavern 1 to 8 BCF
10 – 15	Low Pressure	High Pressure	Examine web stability under maximum pressure differential between caverns
15 - 20	High Pressure	Low Pressure	Examine web stability for other pressure scenario
20 – 25	Low Pressure	Low Pressure	Induce maximum creep using adverse operating conditions
25 – 30	High Pressure	High Pressure	Examine sensitivity of subsidence and cavern closure to increased pressure
30 – 50	Typical Pressure	Typical Pressure	return caverns to typical operating conditions and examine long-term performance
50			Stop analyses, repeat worst case with fast creeping salt properties from WIPP (Case #3)

Typical Pressure = 0.50 psi/ft = 1875 psi
Low Pressure = 0.15 psi/ft = 563 psi
High Pressure = 0.90 psi/ft = 3375 psi

Table 2. Cavern Size for each Analysis Case Study

Case	#1		#2		#3 *	
Salt	Jennings		Jennings		WIPP (fast creeping salt)	
Time	Cavern 1	Cavern 2	Cavern 1	Cavern 2	Cavern 1	Cavern 2
0-4 years	6 BCF	None	6 BCF	None	6 BCF	None
4-6 years	6 BCF	6 BCF	6 BCF	8 BCF	6 BCF	6 BCF
6-50 years	8 BCF	6 BCF	8 BCF	8 BCF	8 BCF	6 BCF

* *The cavern sizes for this Case were chosen after completing Case #1 and #2*

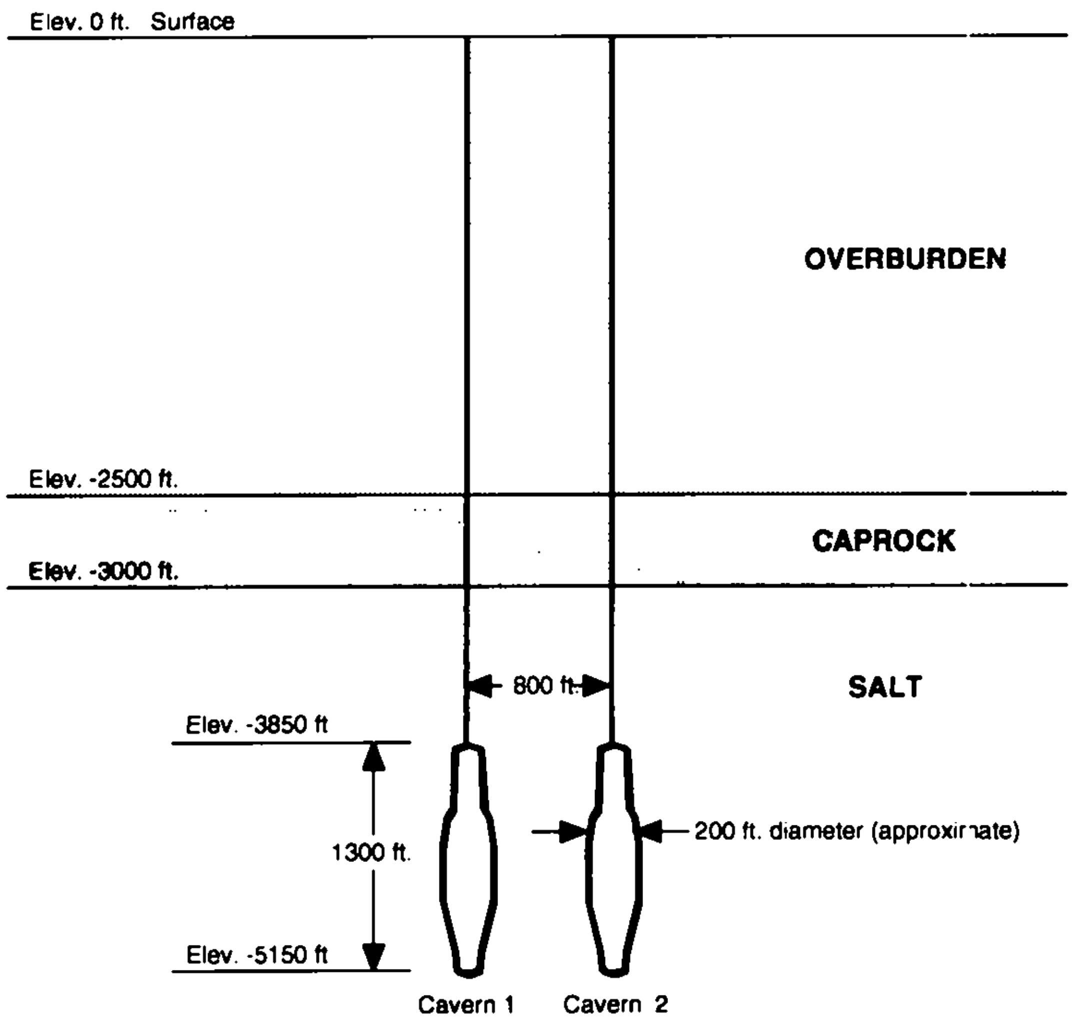

Figure 1. Profile of Jennings Dome Showing Location of Egan Caverns 1 and 2

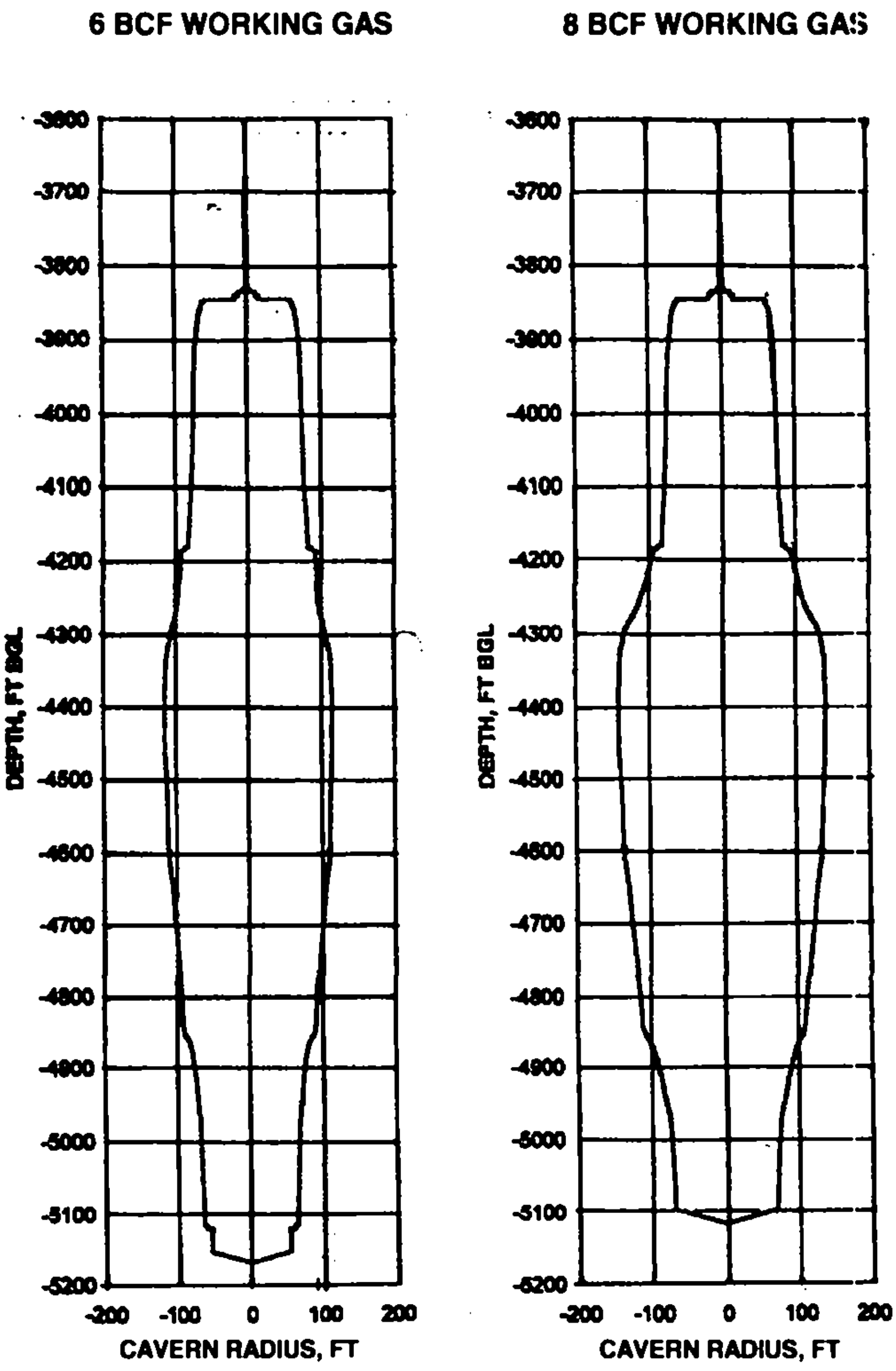

Figure 2. Predicted Geometries of Caverns 1 and 2 at 6 and 8 BCF

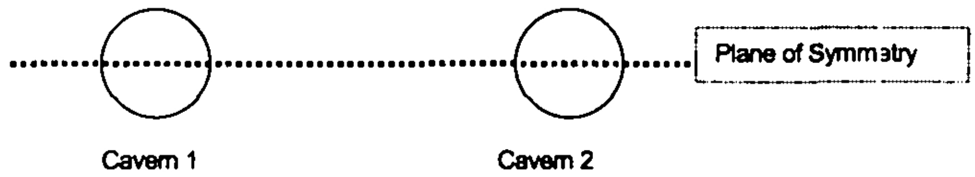

Figure 3. Plane of Symmetry used in the Finite-Element Model

2.3 Structural Model

Sandia has a long history of research and development in nonlinear large strain finite element codes and the application of these codes to geomechanics problems and cavern analyses similar to the ones solved in this report (Hoffman, 1993b). Sandia's quasistatic finite element technology is based on iterative solvers and has been extensively developed for large problems involving geometric and material nonlinearities. The use of iterative solvers and experience with nonlinear material response provides a base technology that offers efficient solution of very large complex geomechanics problems. The finite element code used in the present calculations, JAC3D (Biffle, 1992), uses an eight-node hexahedral Lagrangian uniform strain element with hourglass stiffness to control zero energy modes. A nonlinear conjugate gradient method is used to solve the nonlinear system of equations. This efficient solution scheme is considerably faster than the direct solvers which are used in most commercial codes.

Because of vertical symmetry, only one-half of the model is represented by the finite element mesh, as illustrated in Figure 4. The model, constructed of 8-node hexahedral elements consists of 48,274 nodes and 44,020 elements for analysis Cases #1 and #3. For Case #2, a larger Cavern 2 (8 BCF) resulted in a slightly smaller model consisting of 47,324 nodes and 43,060 elements. The finite element mesh showing detail around both Caverns for Case #1 and #3 is illustrated in Figure 5. Similarly, the Caverns for Case #2 are detailed in Figure 6. In both these Figures, Cavern 1 shows an inner mesh of a different color0. This inner mesh represents the difference between a 6 BCF Cavern and an 8 BCF Cavern. As described earlier and shown in Tables 1 and 2, Cavern 1 is initially a 6 BCF Cavern and is enlarged to an 8 BCF Cavern. This was accomplished by giving these elements a different material ID and using the element death option in JAC3D. The death option allows the analysis to continue using the same mesh but the material properties are eliminated and nodal movement is no longer restricted to the material restraints. The shapes of the Caverns in Figures 5 and 6 are comparable to the predicted cavern outlines shown in Figure 2.

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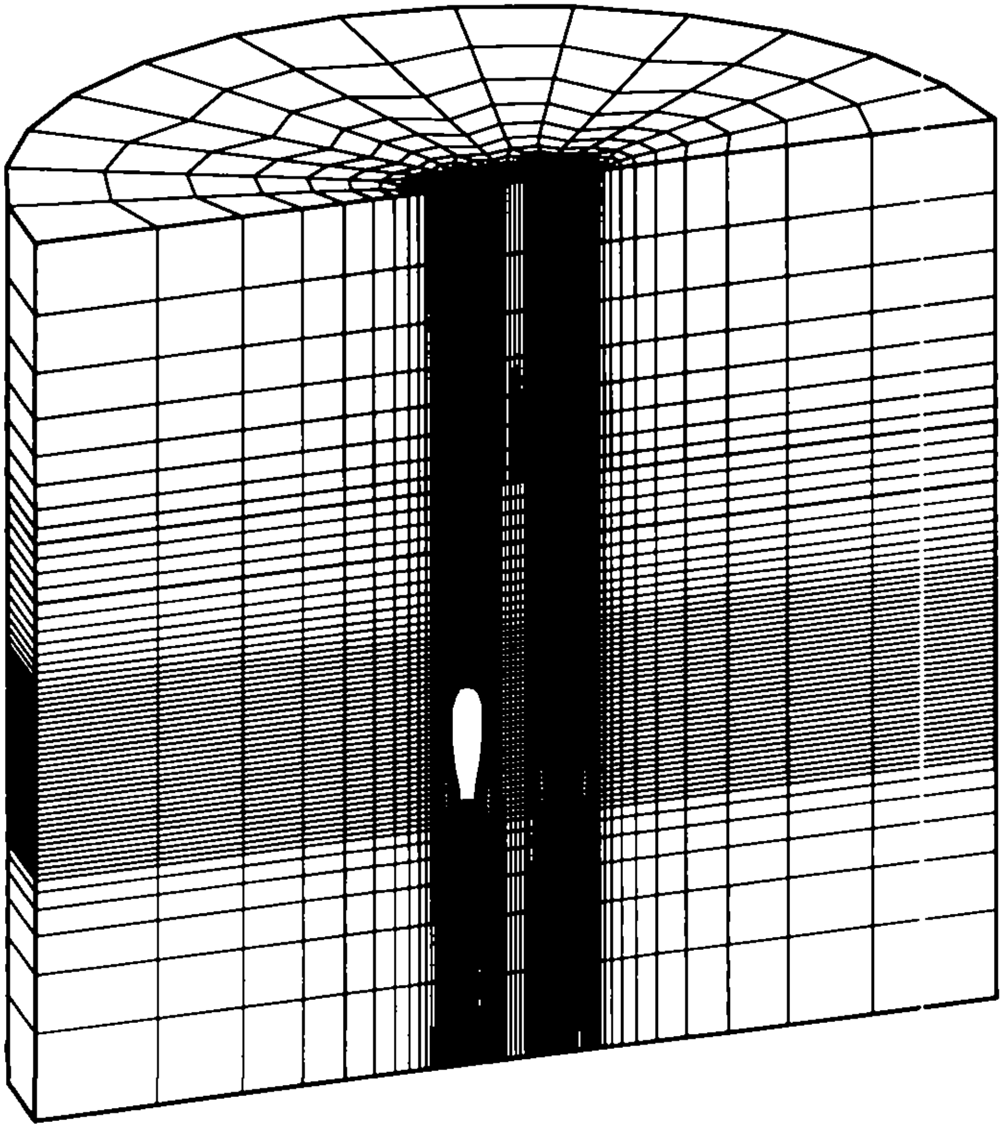

Figure 4. Finite Element Mesh

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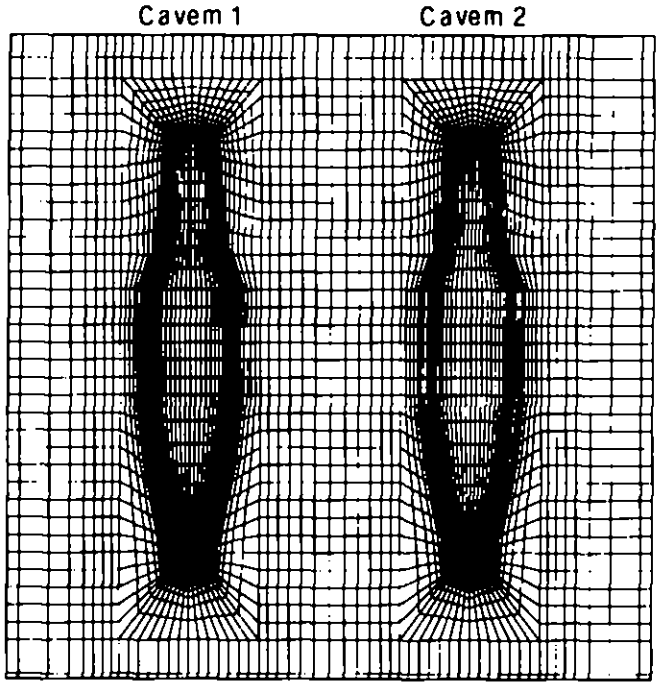

Figure 5. Case #1 and #3 – Cavern Mesh

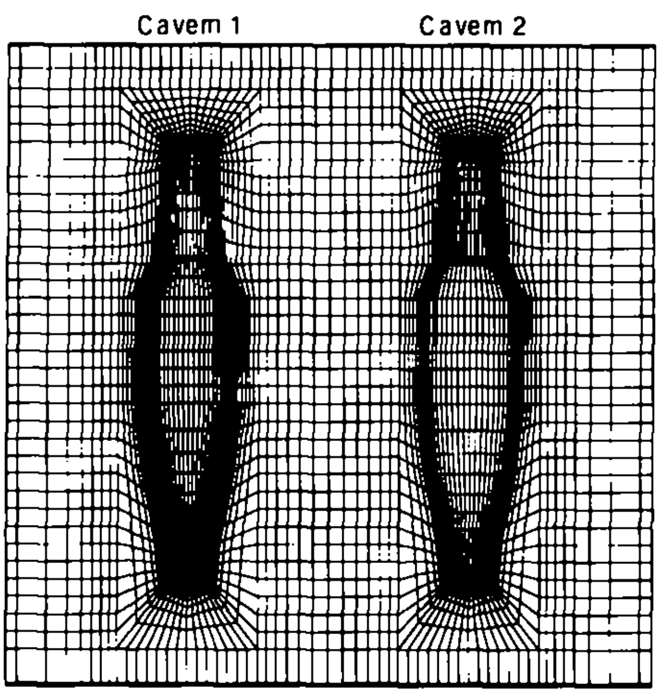

Figure 6. Case #2 – Cavern Mesh

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Displacements were constrained in the direction normal to the vertical plane of symmetry and the bottom of the mesh. The far field boundary (curved boundary) is 4,000 feet from the center point between the two caverns (a distance representing the edge of the dome) and was constrained only with a depth-dependent horizontal pressure.

A uniform pressure distribution was applied to the inside of the caverns to simulate gas storage. When a cavern was enlarged during the analysis (6 BCF to 8 BCF), the pressure surface changed from the smaller cavern surface to the larger cavern surface. The density of the gas was ignored. In reality, the stored gas will provide an increase in pressure with depth. Ignoring this effect is conservative since the additional pressure resulting from the density of the gas would result in reduced salt stresses and slower creep at the base of the cavern.

In addition to the pressure loads, gravitational body forces are applied to the rock. To ensure initial equilibrium, elevation-dependent initial stresses are applied to each element in the model based on the density of the overburden, caprock, and salt. In the elastic materials (overburden and caprock), the vertical stress component at a given location was applied based on the weight of the material above that point. The horizontal component was applied to be consistent with a vertically loaded elastic material in equilibrium. Under these load conditions, the resulting ratio of horizontal to vertical stress components is defined as follows:

$$\frac{\sigma_h}{\sigma_v} = \frac{\nu}{1-\nu}$$

where ν is the Poisson's ratio of the material. For the salt, an initial stress state was assumed in which the vertical and horizontal stress components are equal to the weight of the overlying material (lithostatic).

2.4 Thermal Model

The geothermal or *in-situ* temperature at Jennings dome was assumed to be 80 °F at the ground surface and increase at 0.012 °F per foot of depth. At the mid height (-4,500 ft) the corresponding temperature is 134 °F. A constant temperature of 134 °F was applied to all elements in the model. A constant temperature was considered reasonable because the gas inside the cavern will circulate and keep the walls of the cavern relatively the same. In addition, the elements along the cavern wall experience the highest change in stress and hence creep. The temperature is important because the creep response of the salt is temperature dependent. Radial temperature gradients due to cavern cooling were not considered in these calculations. Previous 2D cavern studies have shown the predicted cavern deformation to be insensitive to radial thermal gradients developed by cooling effects of the cavern product (Hoffman, 1992).

2.5 Constitutive Models and Material Properties

The geotechnical properties for Jennings salt were measured at two different laboratories (Wawersik and Zimmerer, 1993; Humbert and Vouille, 1994). A creep indicator test showed the salt to creep similar to Bryan Mound salt, a previously tested domal salt. For this reason Bryan Mound properties were selected as the baseline properties for the salt in Case study #1 and #2. However, the Jennings and Bryan Mound salts are the slowest creeping salts tested to date at Sandia and creep properties can vary within a dome. The testing by Humbert and Vouille (1994) showed some variability of salt creep at Jennings dome. Therefore, to be prudent, in addition to simulations using the expected Jennings properties, the properties of clean salt from the Waste Isolation Pilot Plant (WIPP) were used for Case study #3. The WIPP salt is well characterized and has a relatively fast creep rate. The creep properties of WIPP salt represent a conservative upper bound to those that could occur at Jennings.

The domal salt exhibits both elastic and creep behavior. The creep constitutive model used for this material is determined from the effective stress as follows:

$$\dot{\varepsilon}^{cr} = A\sigma^{n}\exp\left(-\frac{Q}{RT}\right)$$

where

$\dot{\varepsilon}^{cr}$ is the creep strain rate,

A and n are constants determined from fitting the model to creep data,

σ is the effective or von Mises stress,

Q is the effective activation energy (Cal/mole),

R is the universal gas constant (1.987 Cal/mole-K), and

T is absolute temperature.

The creep constants for salt are given in Table 3 and correspond to parameters for the Jennings or Bryan Mound salt (Wawersik and Zeuch, 1984) and Waste Isolation Pilot Plant salt (Krieg, 1984).

The overburden and caprock were modeled as elastic materials using the properties listed in Table 3. The properties assume a homogeneous material with typical properties of shale and sand (Touloukian and Ho, 1981; Carmichael, 1984) representing caprock, and overburden respectively.

Table 3. Structural Properties of Overburden, Caprock, and Salt

Materials	Young's Modulus, E (ksf)	Poisson's Ratio, ν	Density, ρ (k/ft³)	Structure Factor, A (ksf⁻ⁿ/sec)	Stress Exponent n	Activation Energy, Q (kcal/mole)
Overburden	2,000	0.33	0.1168	--	--	--
Caprock	146,000	0.29	0.1559	--	--	--
Jennings Salt	648,000	0.25	0.1434	4.26×10^{-11}	4.54	15.17
WIPP Salt	648,000	0.25	0.1434	1.33×10^{-12}	4.90	12.03

2.6 Structural Stability of Rock Salt

This study evaluated the potential for damage to or around the caverns based on two different criteria: tensile failure and dilatant damage. For the purposes of these analyses, the tensile strength of the salt was conservatively assumed to be zero. Tensile cracking in rock salt tends to initiate perpendicular to the largest tensile stress in the rock sample. The largest tensile stress is one of the principal stresses. Because the maximum principal stress is the algebraically largest of the three principal stresses (in 3D space) and the largest normal stress in any direction, the potential for tensile failure exists if the maximum principal stress is tensile or numerically positive.

Dilatancy is considered the onset of damage to the salt resulting in significant increases in permeability. An attempt was made to measure the dilatancy of Jennings salt in the laboratory testing. There was considerable uncertainty associated with the results (Ehgartner, 1994). Therefore, for purposes of these analyses, the dilatancy criterion will be taken from the literature which shows a very consistent ratio of 0.25 between the second invariant of the deviatoric stress and the first invariant of stress (Ehgartner, 1997).

The dilatant damage criterion is used to delineate potential zones of dilatancy in the salt formation surrounding the storage facility. Dilatancy is attributed to microfracturing or changes in the pore structure of the salt, resulting in an increase in permeability and, hence, a flow path through or into the salt. The potential for dilatant damage is defined by a "damage" safety factor (D) which is expressed as follows:

$$D = \frac{I_1}{4\sqrt{J_2}}$$

where J_2 is the second invariant of the deviatoric stress tensor, and I_1 is the first invariant of the stress tensor ($I_1 = 3\sigma_m$, where σ_m is the mean stress). When D is equal to or less than one, the shear stresses in the salt are large compared to the mean stress and the potential for dilatant behavior is high (Speirs, 1988; Van Sambeek 1993). Hunsche (1992) suggests that dilatancy is linked to creep rupture. He contends that as rock salt dilates, its structure loosens and may fail after some time due to creep rupture.

It should be clearly stated that the above dilatation criteria is not used in the present study to quantify damage, but merely to identify regions with a high potential for damage. This criteria identifies regions where the deviatoric stress is high and the mean stress is low, a stress state conducive to dilation. No comprehensive constitutive model exists at this time which can predict damage evolution in a reasonable computation time for a 3D problem of this size. Hence, the post-processed dilatation criteria was used as a conservative engineering approach to estimate possible regions of salt dilation. Much can be inferred from this criterion. For example, if the dilatant damage safety factor is decreasing with time, it can be concluded that the potential for damage is increasing. Hence, salt healing (a reduction in dilatancy) is not likely to occur. Second, if the predicted damage is growing in both size and magnitude, then the damaged region (fracture or dilation) may continue to grow. Similarly, if a tensile region is predicted to be growing in both size and magnitude, the resulting fractures, although not explicitly modeled, should also grow.

3 ANALYSIS RESULTS

3.1 Cavern Deformation

For Case #1 and #2, the analysis was performed using the Jennings salt properties for up to 50 years when the analysis was stopped. The final deformed shapes (t = 50 years) of the two caverns are shown in Figures 7 and 8. When compared to the original cavern meshes shown in Figures 5 and 6, no major changes in geometry are observable.

When Case #3 was run using the faster creeping WIPP salt properties, deformations at the base of the caverns after 20 years were large enough at the lower corner of the cavern that the sides and base of the caverns began to overlap. At this point, the analysis was stopped because surface contact algorithms were not included in the model. Deformation rates would be expected to slow once the walls of the cavern begin to contact the floor.

The deformed mesh for Case #3 at t=10 years is shown in Figure 9. At this point the deformations are relatively small. This is because only typical operating pressures were applied to the inside the caverns. Over the next ten years (10-20) each cavern alternately experienced a low operating pressure for 5 year. This low internal pressure resulted in high creep rates causing the cavern to close in much faster. The final deformed shapes (t = 20 years) for Case #3 are shown in Figure 10. As is expected, the majority of the deformation occurs in the lower half of the cavern where the creep rate is highest because of increased stress levels.

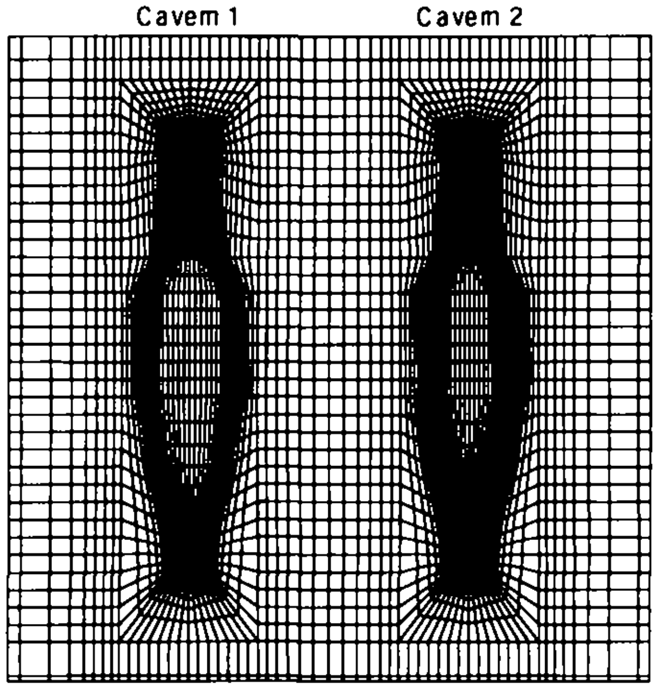

Figure 7. Case #1 – Deformed Caverns at 50 years

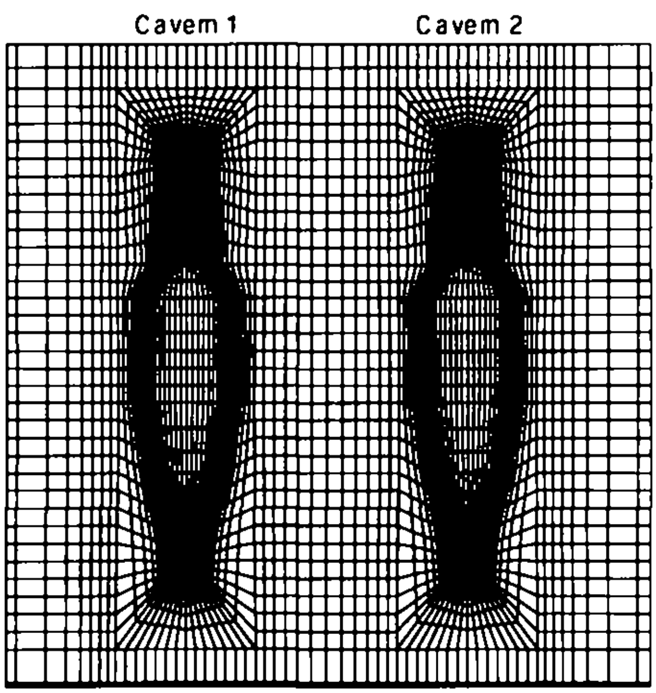

Figure 8. Case #2 – Deformed Caverns at 50 years

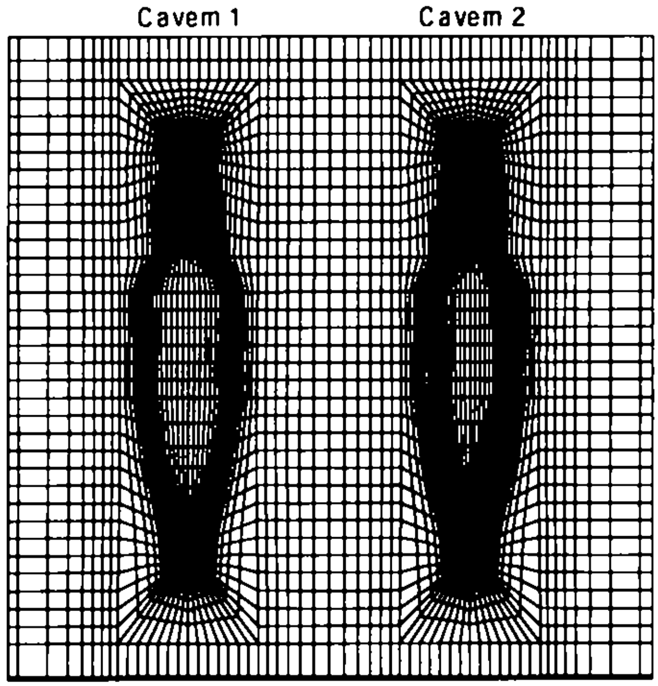

Figure 9. Case #3 – Deformed Caverns at 10 years

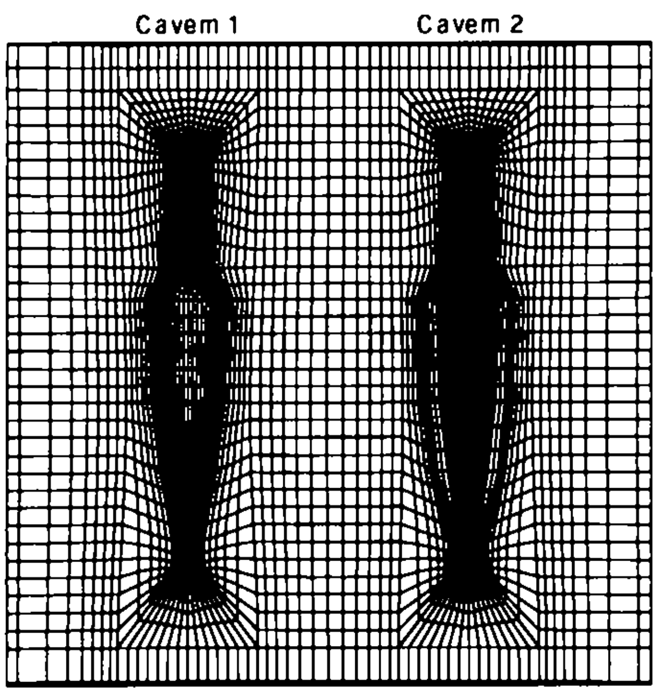

Figure 10. Case #3 – Deformed Caverns at 20 years

3.2 Storage Loss

Figures 11, 12, and 13 show the percentage of initial cavern storage volume as a function of time for Cases #1, #2 and #3 respectively. For both Cases #1 and #2, Cavern 1 reduces to about 85% of its initial volume and Cavern 2 reduces to about 86% of its initial volume after 50 years. The 1% difference is attributable to the four year delay in the creation of Cavern 2. Even though Cavern 2 is larger in Case #2 (8 BCF) than it was in Case #1 (6 BCF), the percentage loss was nearly the same.

For Cases #1 and #2 the rates of storage loss are very similar. When operating at high pressures the caverns experience almost no change in volume. When operating at typical pressures the caverns only loose about 1% of the storage volume every 5 to 10 years. At low operating pressures the caverns loose about 1% per year.

The much faster creeping WIPP salt properties (Case #3) had a significant effect on the storage loss of the Egan Caverns. After only 10 years and operating at typical operating pressures the volume reduced to 85% in Cavern 1 and 86% in Cavern 2. This is the same as the volume loss in both Cases #1 and #2 (using Jennings salt properties) after 50 years. For Case #3 after 20 years, Cavern 1 reduced to 45% of it's initial volume and Cavern 2 reduced to 46% of its initial volume. Once again this small difference was due mostly to the delay in the creation of Cavern 2.

The rates of storage loss were also significantly higher in Case #3. When operating at high pressures the caverns experience almost no change in volume. When operating at typical pressures the caverns loose about $1^1/_2$ to 2 % of the storage volume per year. At low operating pressures the caverns loose about 8% per year.

3.3 Subsidence

The ground surface subsidence above both caverns to the edge of the model is plotted in Figures 14, 15, and 16 for Cases #1, #2 and #3 respectively. For Case #1 and #2 the subsidence is plotted at 10, 30, and 50 years. For these two Cases there is almost no surface subsidence after 10 years. After 30 years the subsidence reaches 0.10 feet at the center point between caverns in Case #1 and 0.125 feet in Case #2. After 50 years the subsidence increases slightly to 0.13 feet in Case #1 and 0.16 feet in Case #2.

The faster creeping WIPP salt properties resulted in higher surface subsidence in Case #3 as shown in Figure 16. For this Case, subsidence was plotted at 10 and 20 years. At 10 years the subsidence at the center point between caverns reached 0.14 feet. After 20 years the subsidence reached 0.85 feet at the center.

For all the surface subsidence plots, the subsidence is nearly symmetric, forming a single surface depression, about the center point and extending to the edges of the model. This is due primarily to the depth of the Caverns (3,850 feet deep at the top) and relatively close distance between the two caverns (800 feet). Some surface subsidence is shown to be occurring above the edge of the dome, 4,000 feet away from the center of the model. This is probably realistic because the outer edge of the model is not mechanically

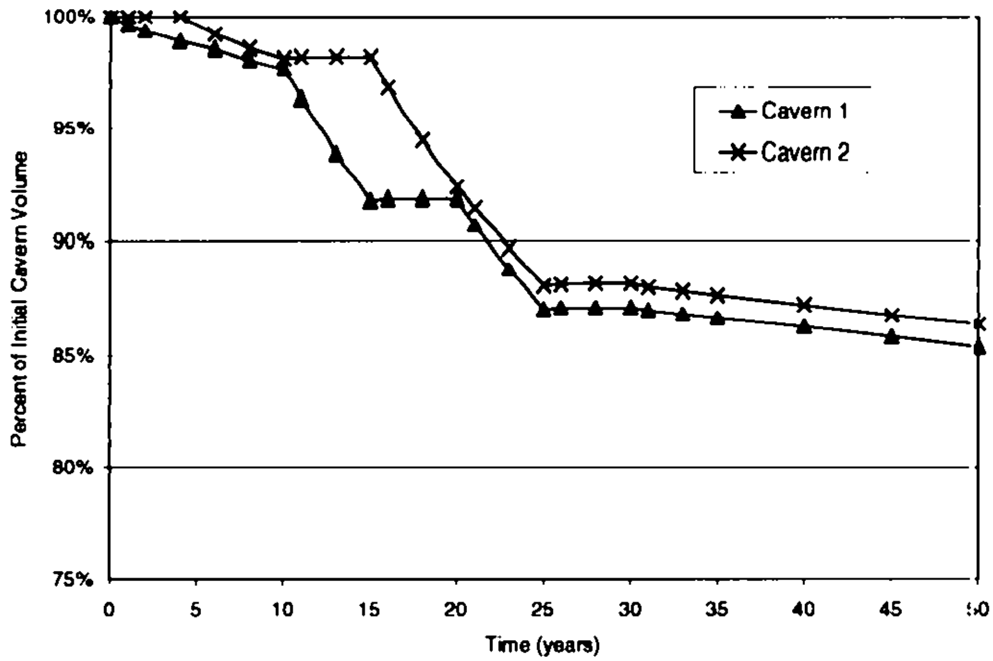

Figure 11. Case #1 – Storage Loss

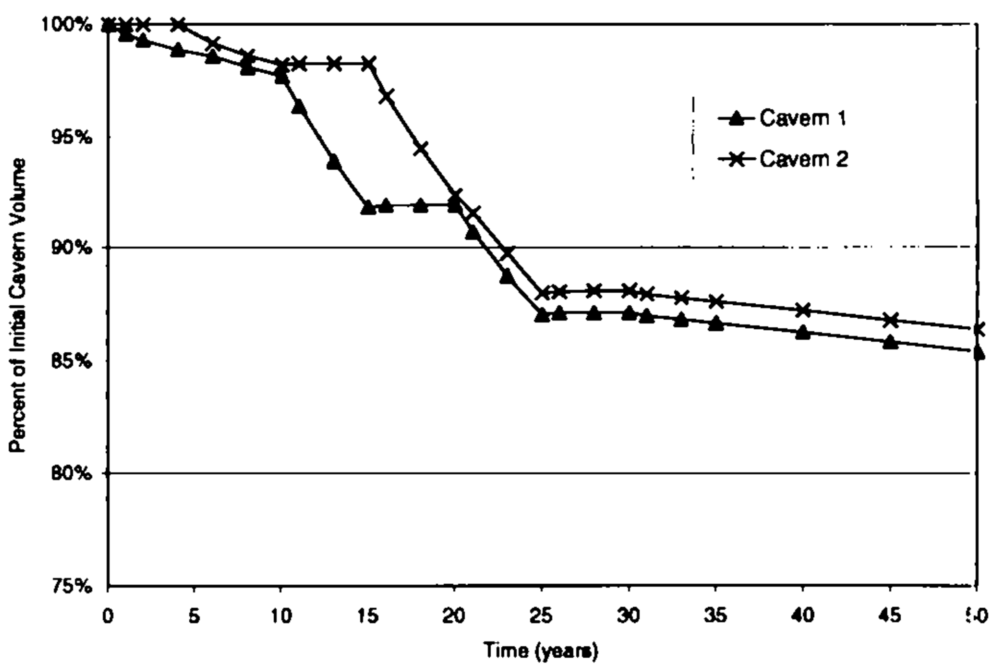

Figure 12. Case #2 – Storage Loss

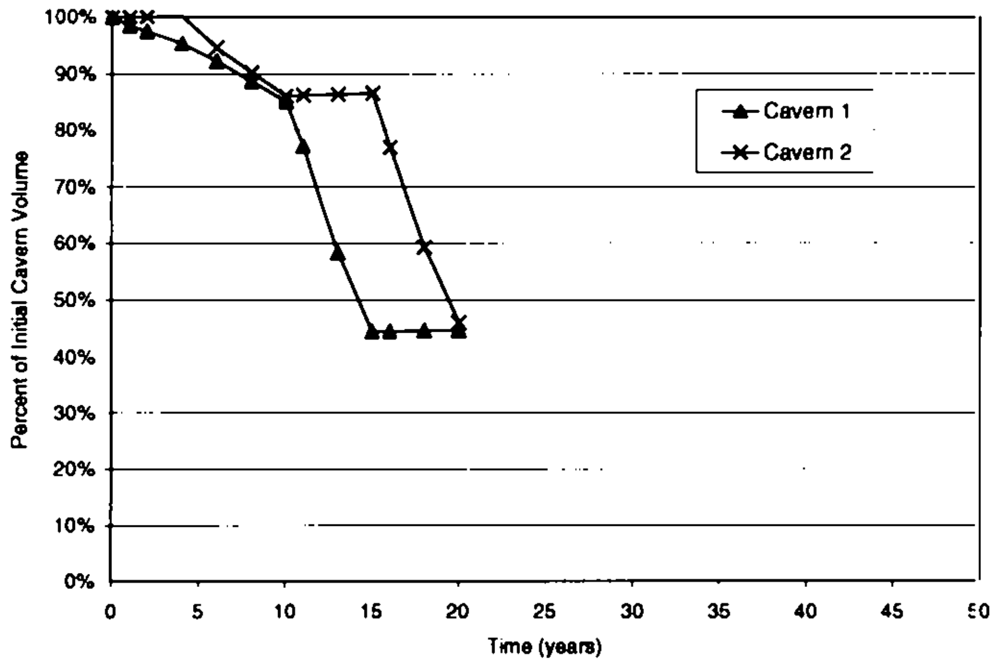

Figure 13. Case #3 – Storage Loss

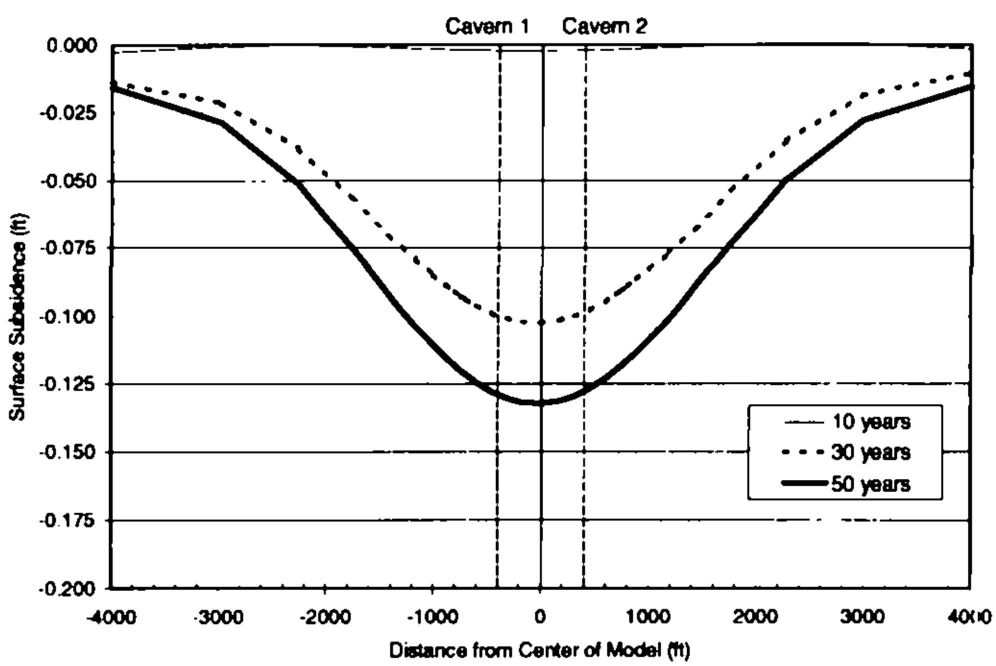

Figure 14. Case #1 – Ground Surface Subsidence

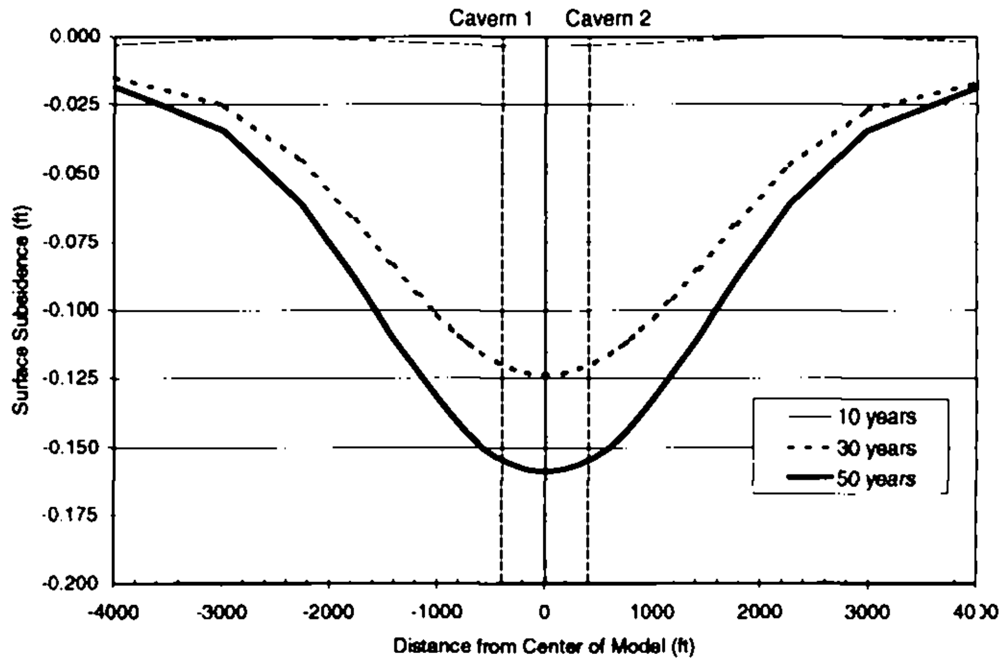

Figure 15. Case #2 – Ground Surface Subsidence

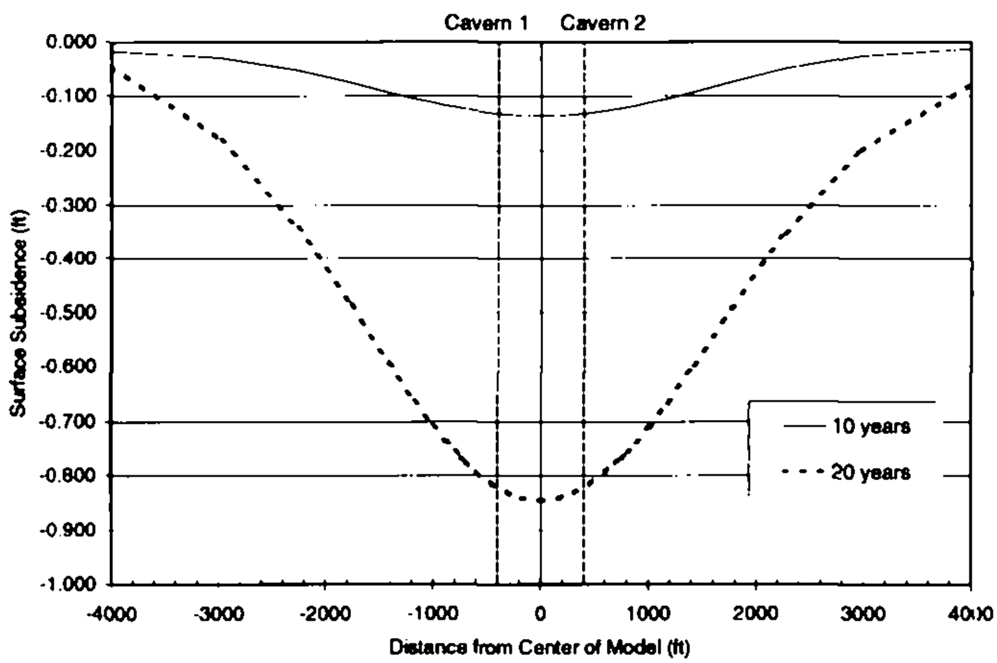

Figure 16. Case #3 – Ground Surface Subsidence

constrained in any direction, but has a depth dependent lateral pressure applied to match the insitu stress conditions occurring at the edge of the model.

3.4 Cavern Stability

As described in Section 2.6 of this report, this study evaluated the potential for damage to or around the caverns based on two criteria: tensile failure and dilatant damage. The tensile strength of the salt was conservatively assumed to be zero and the largest tensile stress is the maximum principal stress. Therefore, if the maximum principal stress is positive, the potential for tensile failure exists. Dilatancy was also described in Section 2.6 of this report and was considered the onset of damage to the salt resulting in potentially significant increases in permeability. When the "damage" safety factor D is equal to or less than one, the potential for dilatant behavior is considered to be high.

Contour plots of the maximum principal stresses and dilatancy safety factors (D) are plotted in: Figures 17 and 18 for Case #1, Figures 19 and 20 for Case #2, and Figures 21 and 22 for Case #3. For Cases #1 and #2 the contours are plotted at 15, 20, 25 and 30 years. For Case #3 the contours are plotted at 6, 10, 15 and 20 years, again because the analysis was stopped after 20 years.

Comparing the maximum principal stress contours, particularly at 15 and 20 years, for all three Cases, there is not much difference in the magnitude or distribution of stresses. There also appears to be very little if any stress interactions between the caverns. When comparing the dilatancy contours at 15 and 20 years for all three cases, there is little difference in the magnitude or variation in the dilatant safety factor.

In all the maximum principal stress contours for all three Cases, the entire Cavern wall from top to bottom is showing stresses in the highest range plotted between -1,000 psi and 0 psi when a cavern is operating at low pressures. This implies that when operating at a low pressure (0.15psi/ft) this entire area, although still in compression, is the most vulnerable to tensile failure. It is interesting to note that the contours follow the shape of the caverns very well and there does not appear to be significantly higher stresses in the lower portion of the caverns as is typically the case when caverns are modeled as perfect cylinders (Hoffman, 1993b).

Similarly, the dilatancy contours for all three cases show the minimum safety factor 'D' between 1 and 1.5 over nearly the entire cavern wall when operation at low pressures. Again, this implies that for low operating pressures the entire cavern wall is most vulnerable to dilatant behavior.

For all these contour plots, both the maximum principal stresses and dilatancy safety factors appear very similar when comparing the site specific salt properties in Cases #1 and #2 to the faster creeping salt (WIPP) in Case #3. Comparing the actual peak values at the element level, results in a slightly different conclusion.

Most of the maximum principal stresses and dilatant safety factors occurred near the bottom of the cavern approximately 20 feet above the base. In addition, the values in the

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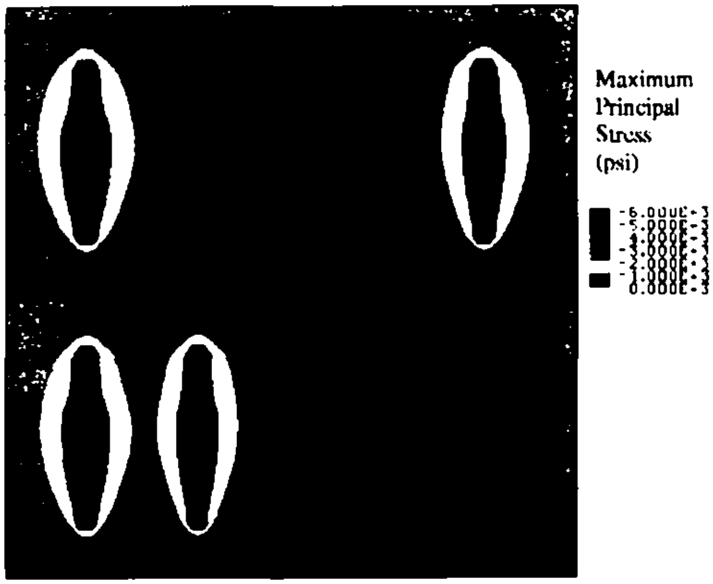

Figure 17. Case #1 – Maximum Principal Stresses at 15, 20, 25, and 30 years

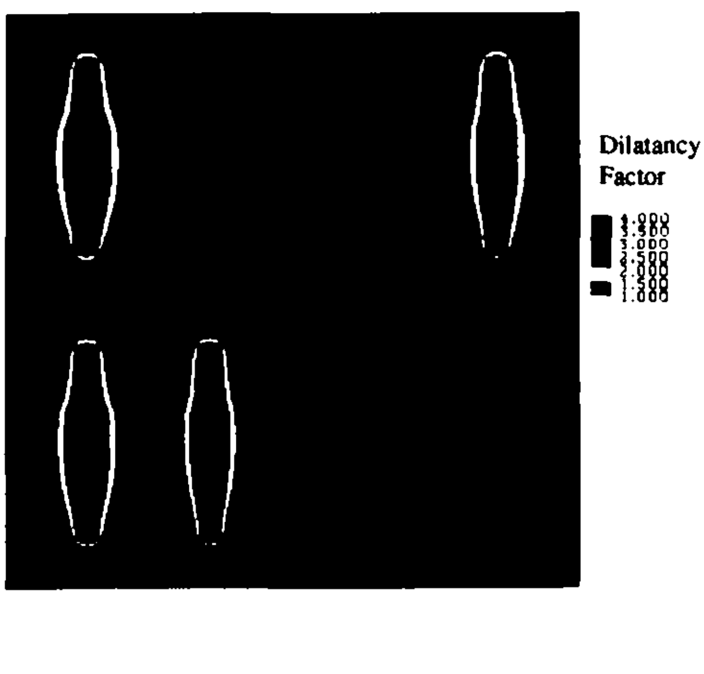

Figure 18. Case #1 – Dilatancy Safety Factors (D) at 15, 20, 25, and 30 years

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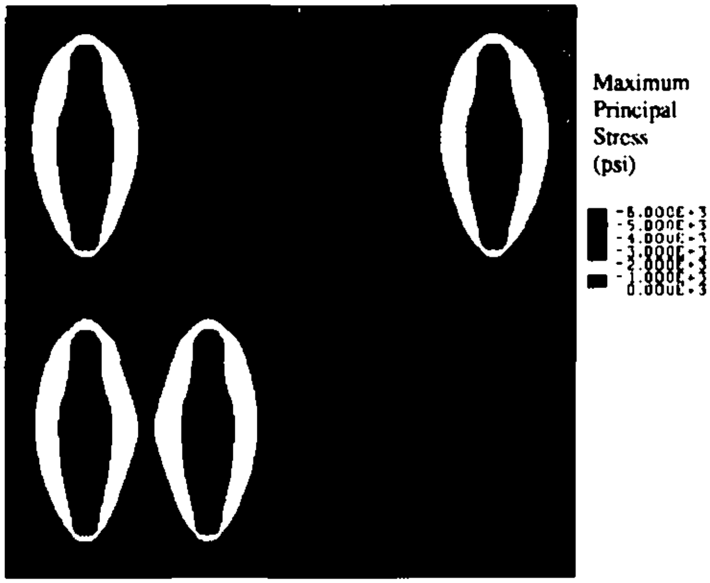

Figure 19. Case #2 – Maximum Principal Stresses at 15, 20, 25, and 30 years

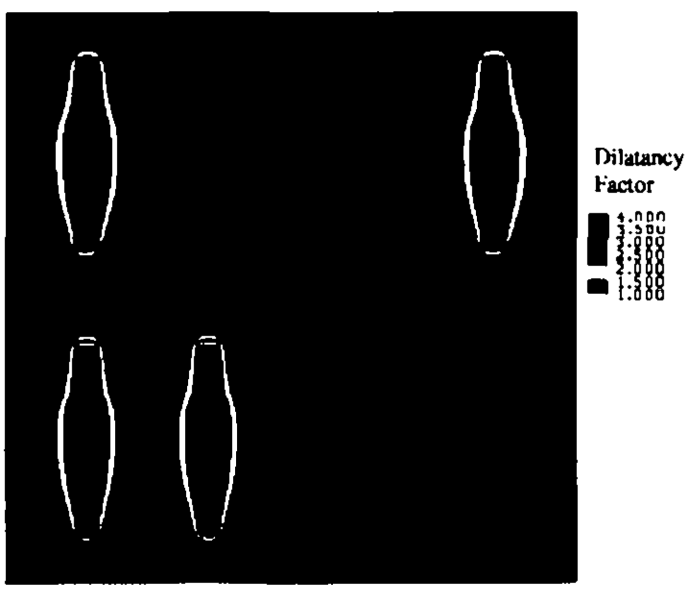

Figure 20. Case #2 – Dilatancy Safety Factors (D) at 15, 20, 25, and 30 years

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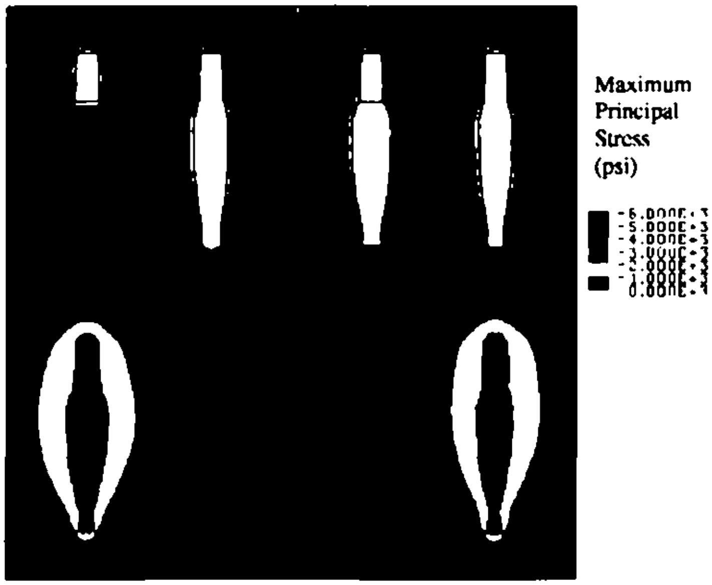

Figure 21. Case #3 – Maximum Principal Stresses at 6, 10, 15, and 20 years

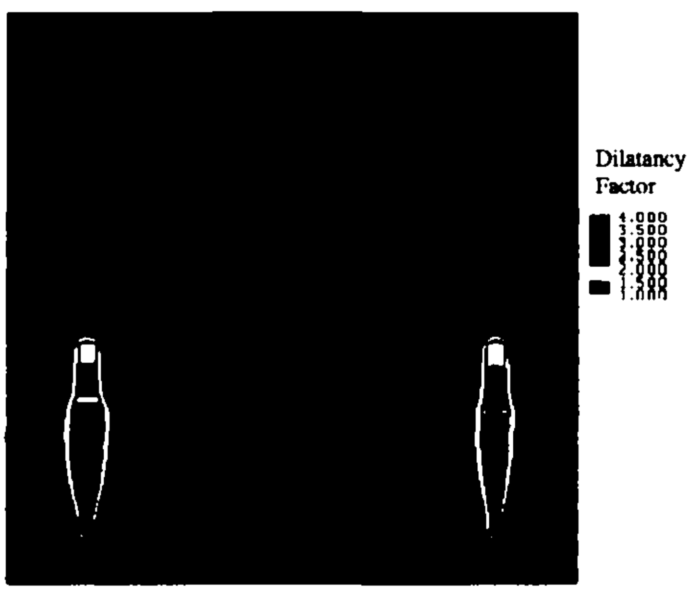

Figure 22. Case #3 – Dilatancy Safety Factors (D) at 6, 10, 15, and 20 years

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elements at the shoulder level of the cavern (the point in the bottle shaped cavern were the neck joins the body) sometimes showed increased stresses and lower dilatancy factors. Elements at these levels on both sides of each cavern were selected for monitoring the maximum principal stress and dilatancy safety factor history.

The maximum principal stresses for these locations in Caverns 1 and 2 for Case #1 are shown in Figures 23 and 24 respectively. The maximum stress in this Case is -323 psi and it occurs at 25 years into the analysis. The maximum principal stresses in Caverns 1 and 2 for Case #2 are shown in Figures 25 and 26 respectively. The maximum stress in this Case is -426 psi and it also occurs at 25 years. The maximum principal stresses in Caverns 1 and 2 for Case #3 are shown in Figures 27 and 28 respectively. The maximum stress in this Case is -171 psi and it occurs at 18 years.

The dilatant safety factor 'D' for the most vulnerable locations in Caverns 1 and 2 for Case #1 are shown in Figures 29 and 30 respectively. The minimum factor in this Case is 1.08 and it occurred at 25 years into the analysis. The dilatant safety factor in Cavern 1 and 2 for Case #2 are shown in Figures 31 and 32 respectively. The minimum factor in this Case is 1.15 and it occurred at 21 years. The dilatant safety factors in Caverns 1 and 2 for Case #3 are shown in Figures 33 and 34 respectively. The minimum factor in this Case is 0.92 and it occurred at 18 years.

A summary of all the maximum principal stresses and minimum dilatancy safety factors (D) are summarized in Table 4. The peak values are shown for each Case and also at the base of the cavern and near the shoulder. Peak values at the shoulder are usually not as high or low as near the base but if failure occurs at the shoulder it could have greater consequences than it were to occur near the base.

As shown in Table 4, the maximum principal stress was higher (-323 psi) in Case #1 than in Case #2 (-426 psi). These values are slightly below the minimum gas pressure exerted on the cavern walls (-563 psi), but well above the assumed tensile strength of salt (0 psi). Also, the dilatancy safety factor was much closer to 1.0 in Case #1 (1.08) than it was in Case #2 (1.15). This is why the Case #1 cavern geometries were chosen for the Case #3 analysis.

In the Case #3 analysis using the faster creeping WIPP salt properties, the maximum principal stress was higher (-171 psi) and the dilatancy factor dipped below 1 to 0.92 when the cavern was operated at low pressure. This indicates the potential for dilatant behavior exists if the salt at Jennings unexpectedly creeps like WIPP salt. However, this would probably be localized to a small area near the base. The values for stress and dilatancy at the shoulder of the Caverns in Case #3 actually improved compared to Cases #1 and #2 as shown in Table 4.

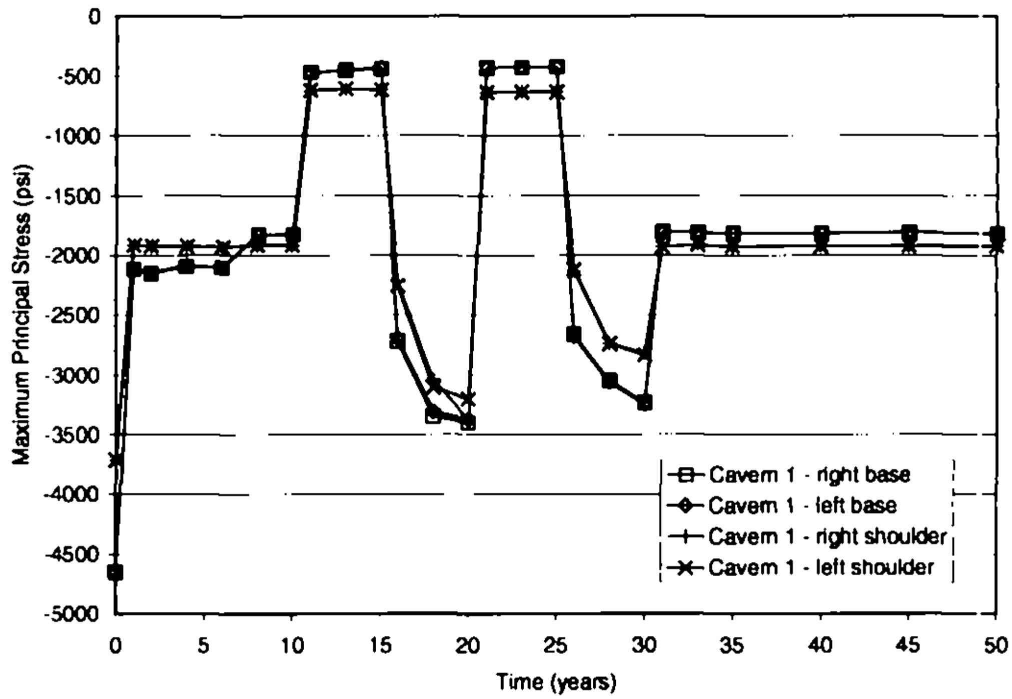

Figure 23. Case #1 – Maximum Principal Stresses, Cavern 1

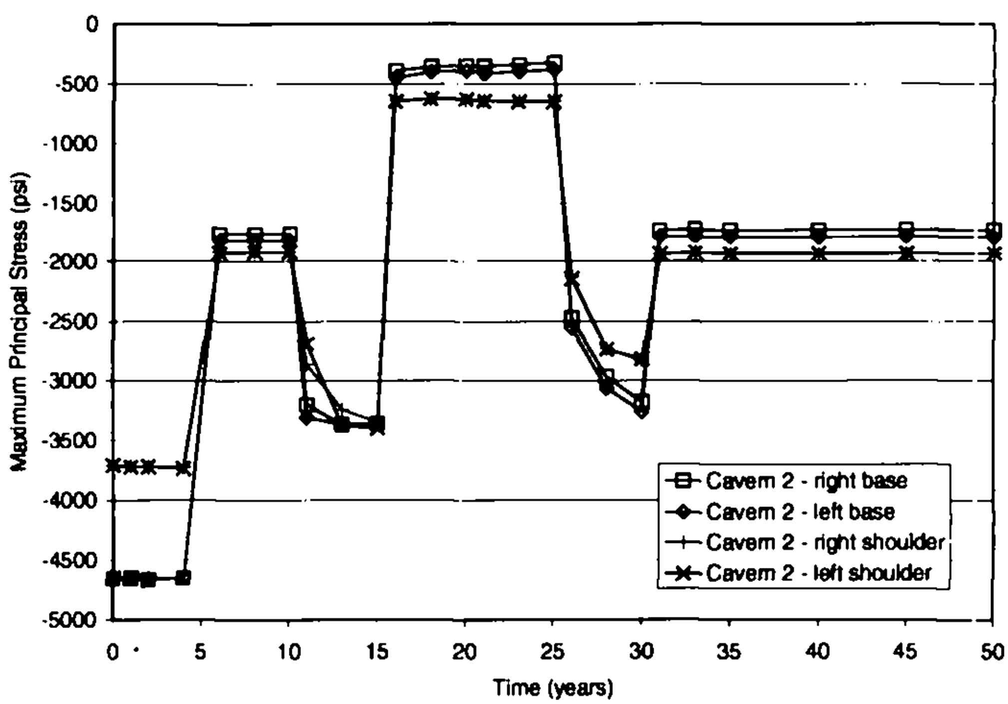

Figure 24. Case #1 – Maximum Principal Stresses, Cavern 2

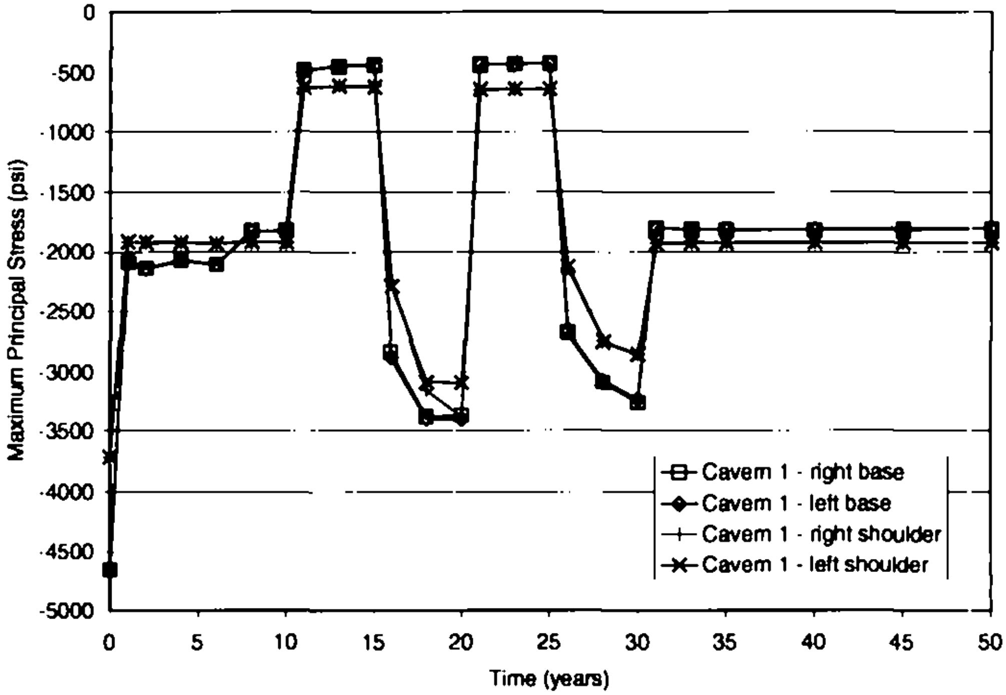

Figure 25. Case #2 – Maximum Principal Stresses, Cavern 1

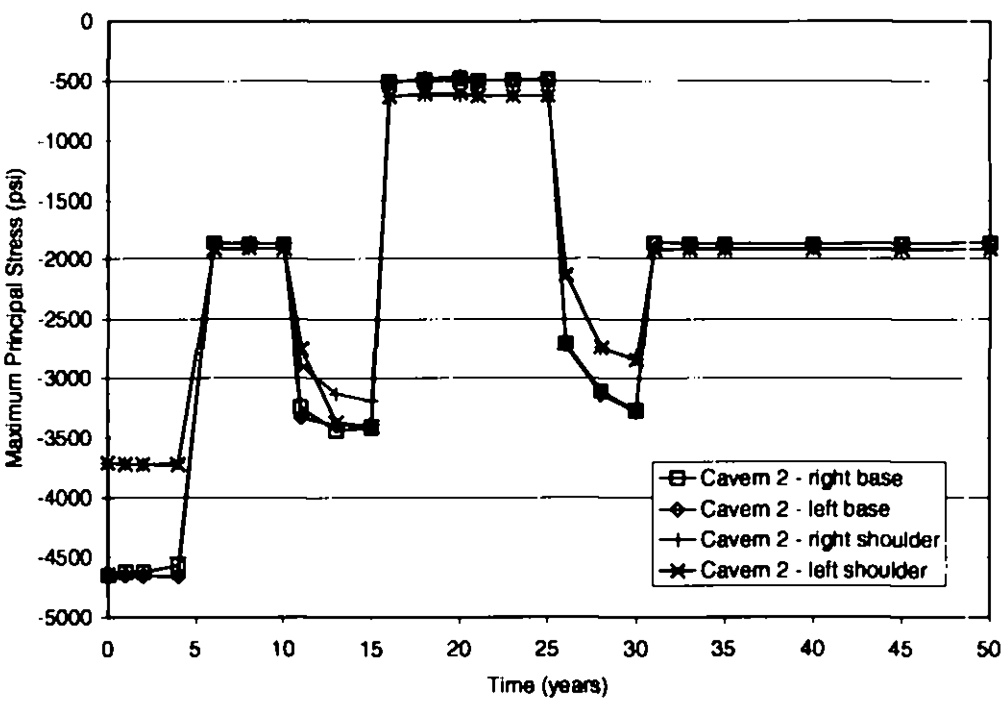

Figure 26. Case #2 – Maximum Principal Stresses, Cavern 2

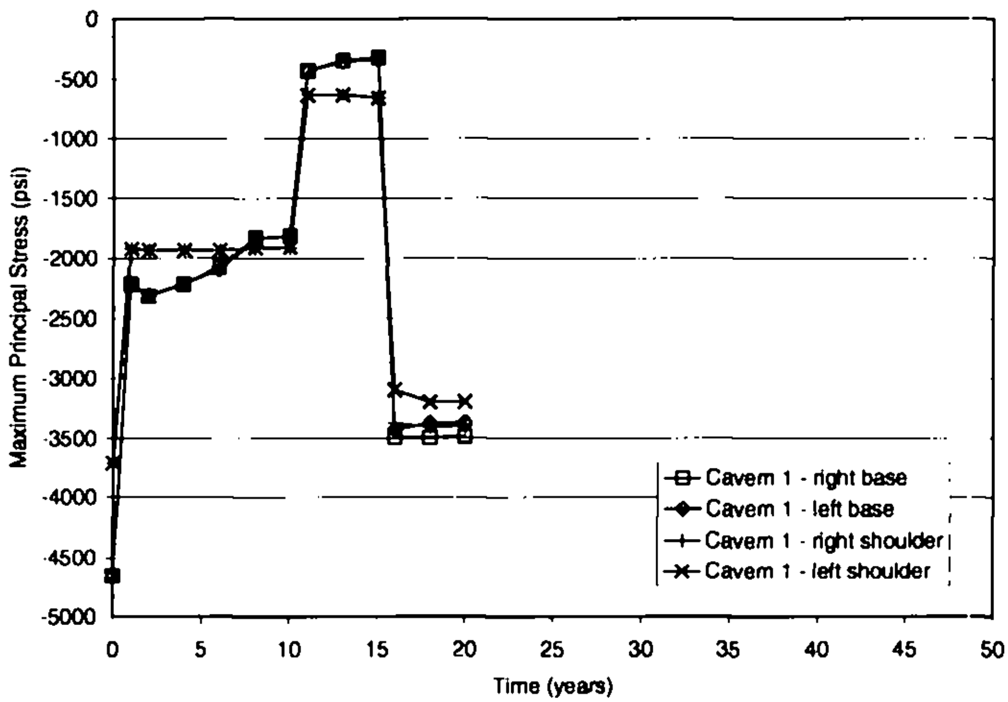

Figure 27. Case #3 – Maximum Principal Stresses, Cavern 1

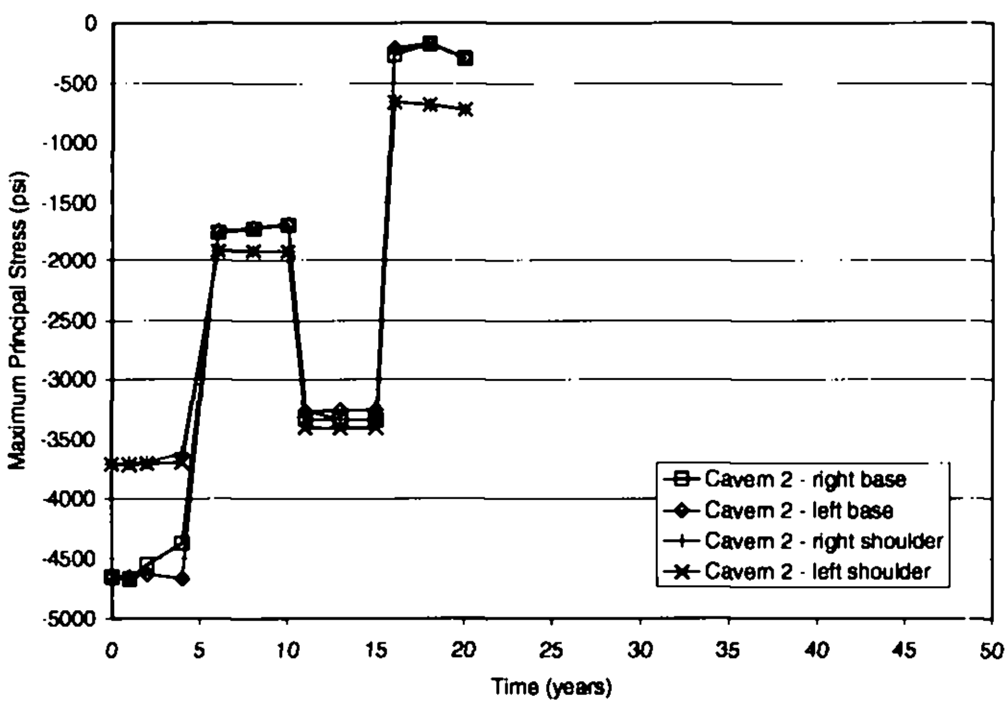

Figure 28. Case #3 – Maximum Principal Stresses, Cavern 2

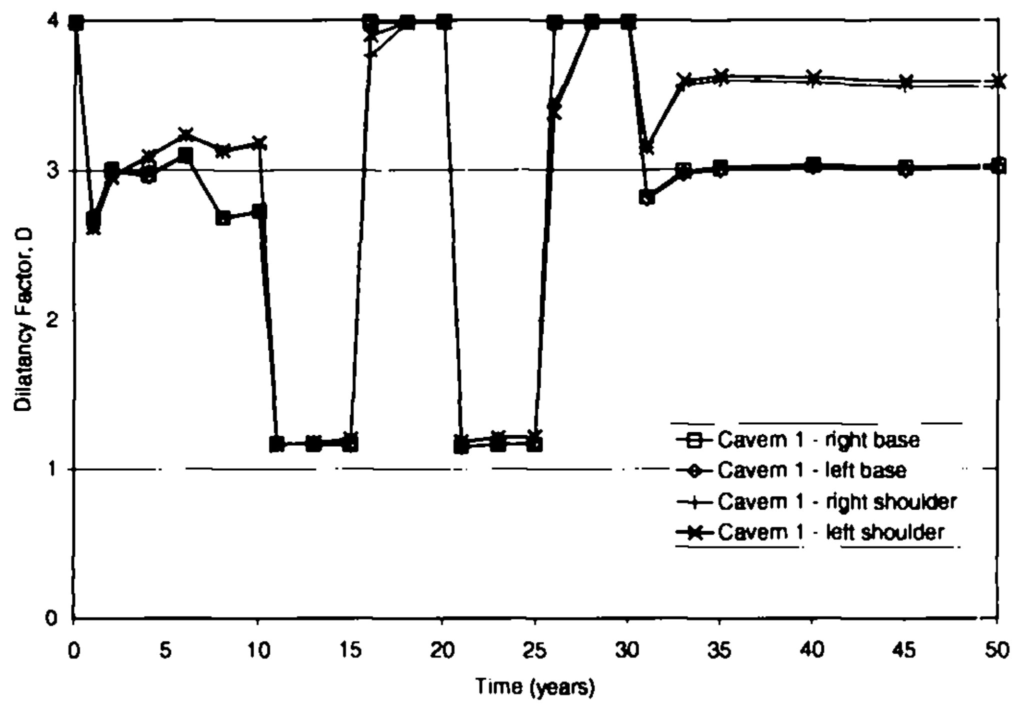

Figure 29. Case #1 – Dilatancy Safety Factor, Cavern 1

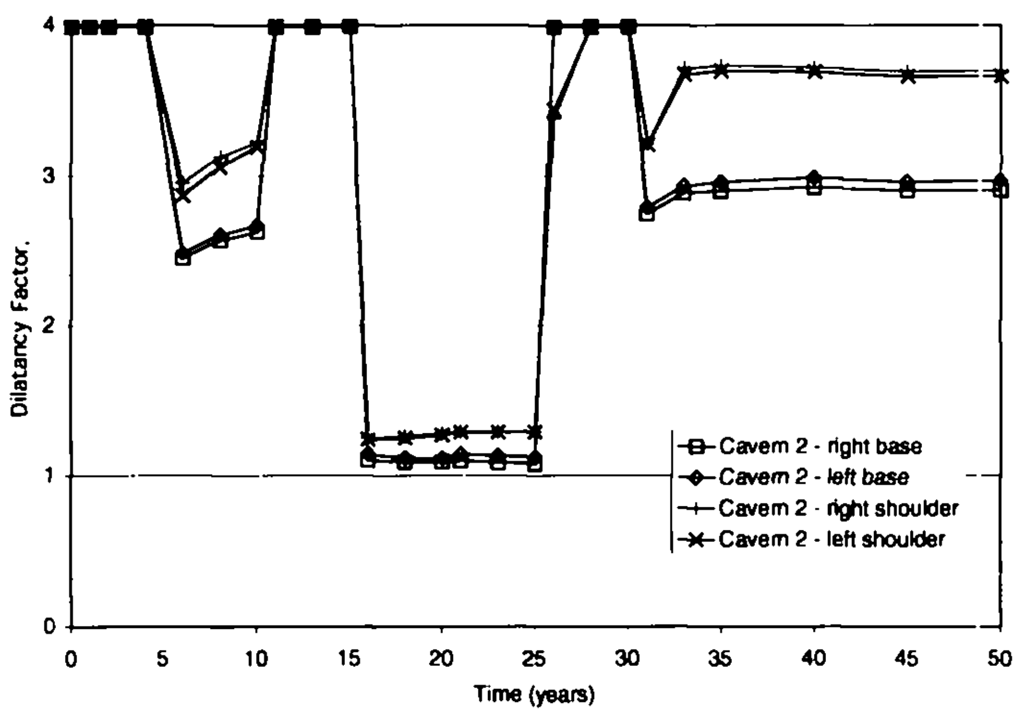

Figure 30. Case #1 – Dilatancy Safety Factor, Cavern 2

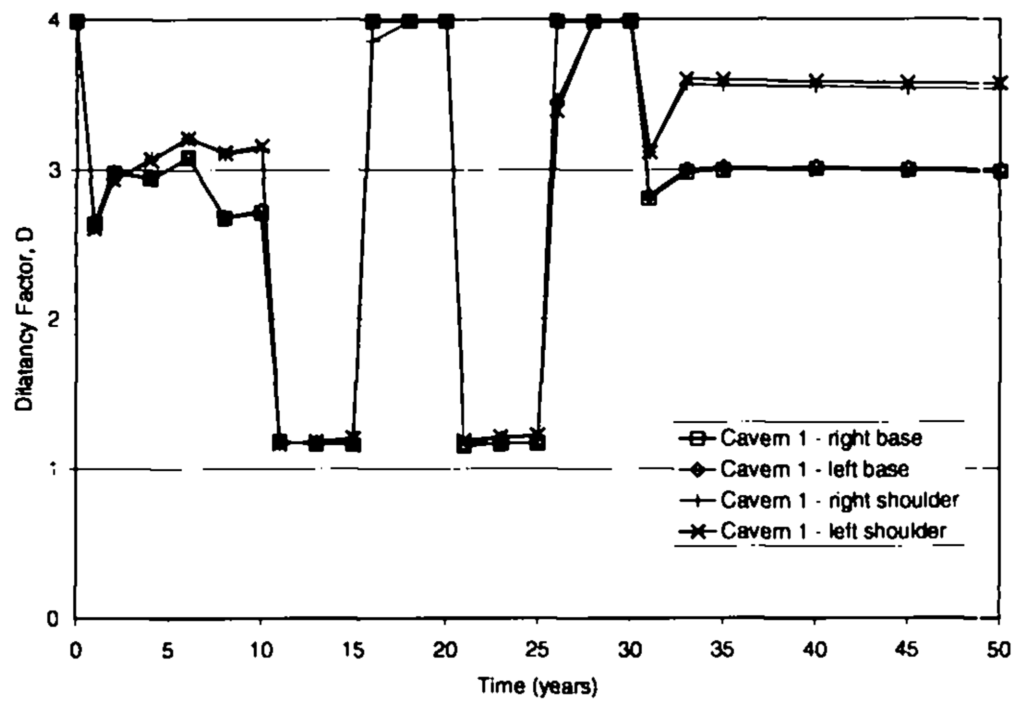

Figure 31. Case #2 – Dilatancy Safety Factor, Cavern 1

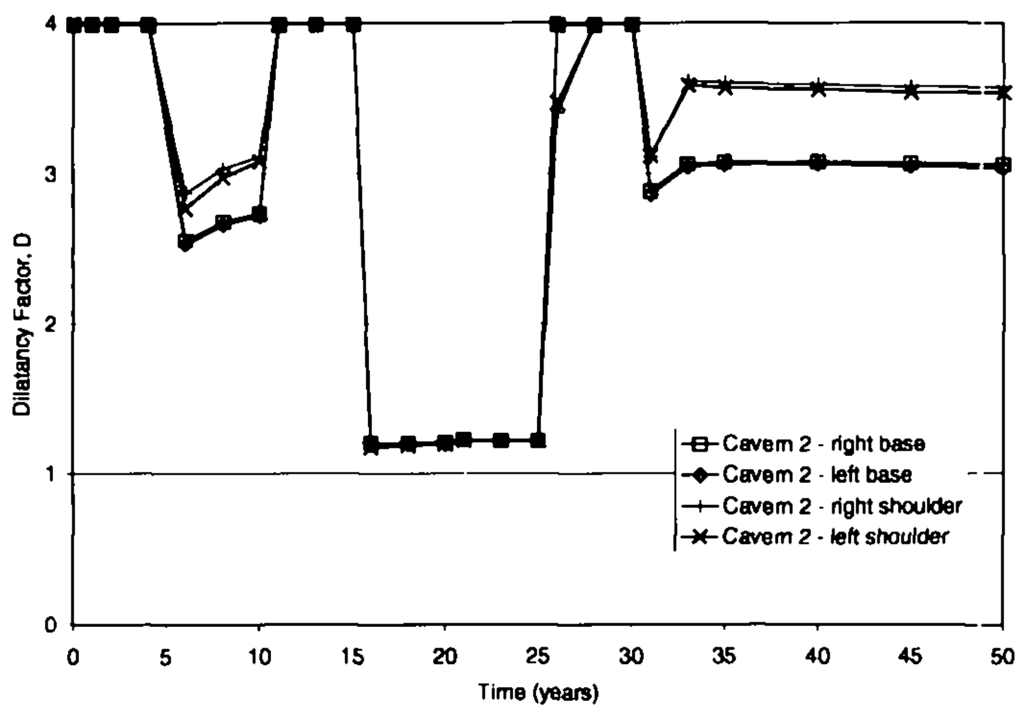

Figure 32. Case #2 – Dilatancy Safety Factor, Cavern 2

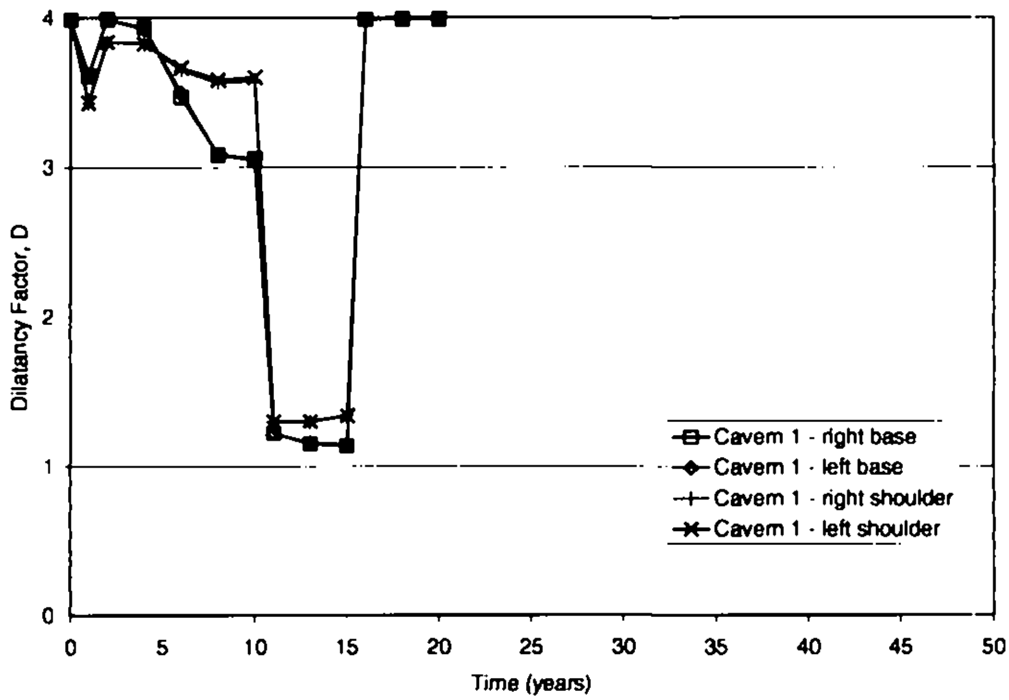

Figure 33. Case #3 – Dilatancy Safety Factor, Cavern 1

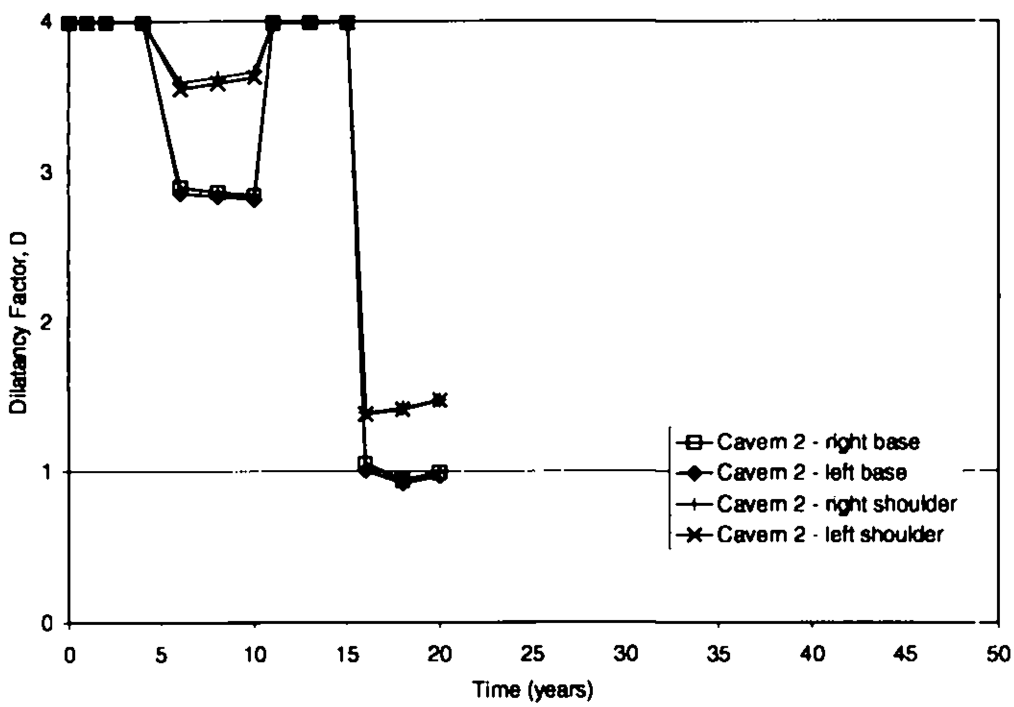

Figure 34. Case #3 – Dilatancy Safety Factor, Cavern 2

Table 4. Peak Values of Principal Stress and Dilatancy

	Maximum Principal Stress (psi)		Minimum Dilatancy Safety Factor, D	
Case	at Shoulder	At Base	at Shoulder	at Base
# 1	-609	-323	1.16	1.08
# 2	-605	-426	1.17	1.15
# 3	-628	-171	1.30	0.92

4 CONCLUSIONS

Three-dimensional finite element analyses were performed for the two gas-filled storage caverns at the Egan field, Jennings dome, Louisiana. The effects of cavern enlargement on surface subsidence, storage loss, and cavern stability were investigated. The finite element model simulated the leaching of caverns to 6 and 8 BCF and examined their performance at various operating conditions. Operating pressures varied from 0.15 psi/ft to 0.9 psi/ft at the lowest cemented casing seat, which is a typical industry standard for referencing gas pressures in caverns. The analysis also examined the stability of the web or pillar of salt between the caverns under differential loading.

The 50 year simulations were performed using JAC3D, a three dimensional finite element analysis code for nonlinear quasistatic solids. The results show that volumetric cavern closures over time due to creep were moderate and subsidence above the cavern field was small and should pose no problem to surface facilities. Cavern closure is predicted to be approximately 15% after 50 years of operation and the resulting subsidence amounts to only 0.16 ft at the surface when using the Jennings salt creep properties. When using the much faster creeping WIPP salt properties, the Cavern closure was about 55% after 20 years and the surface subsidence was about 0.85 feet.

A damage criterion based on the onset of tensile failure and dilatancy was used to investigate cavern stability. Tensile failure was assumed to occur if the maximum principal stress was no longer in compression or is positive. This assumes that the salt has no tensile strength, which is a conservative assumption. In this analysis, no tensile failure of the salt was predicted.

Dilatant behavior reflects the development of microfractures in salt and hence potential increases in permeability. Its onset occurs well before large scale failure. Some localized dilatant damage was predicted near the bottom walls of the caverns when the caverns are operated at minimum pressure and the salt is assumed to creep like WIPP salt (much faster than actually measured in laboratory testing). No dilatant damage was predicted for any of the pressure scenarios in the site specific Jennings salt.

The analysis predicted very little cavern interaction which suggests that the caverns are conservatively spaced. This resulted in no potential for web instability between caverns even when operated at different pressure extremes. In addition, stress perturbations did not extend very far above the roof of the caverns, thus showing the caverns are located sufficiently below the top of the salt. The analyses predict very little difference between Case #1 and #2 (Cavern 2 at 6 versus 8 BCF, respectively) or any significant changes due to the enlargement of Cavern 1 from 6 to 8 BCF. In summary, the predicted damage factors of the Egan caverns suggest stable caverns up through a time period of 50 years.

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Resource Report 6 Detailed Drawings

Critical Energy Infrastructure Information Removed

Resource Report 6 Maps

Non-Internet Public Information Removed

Figure 6.1-1 General Geologic Map of Louisiana

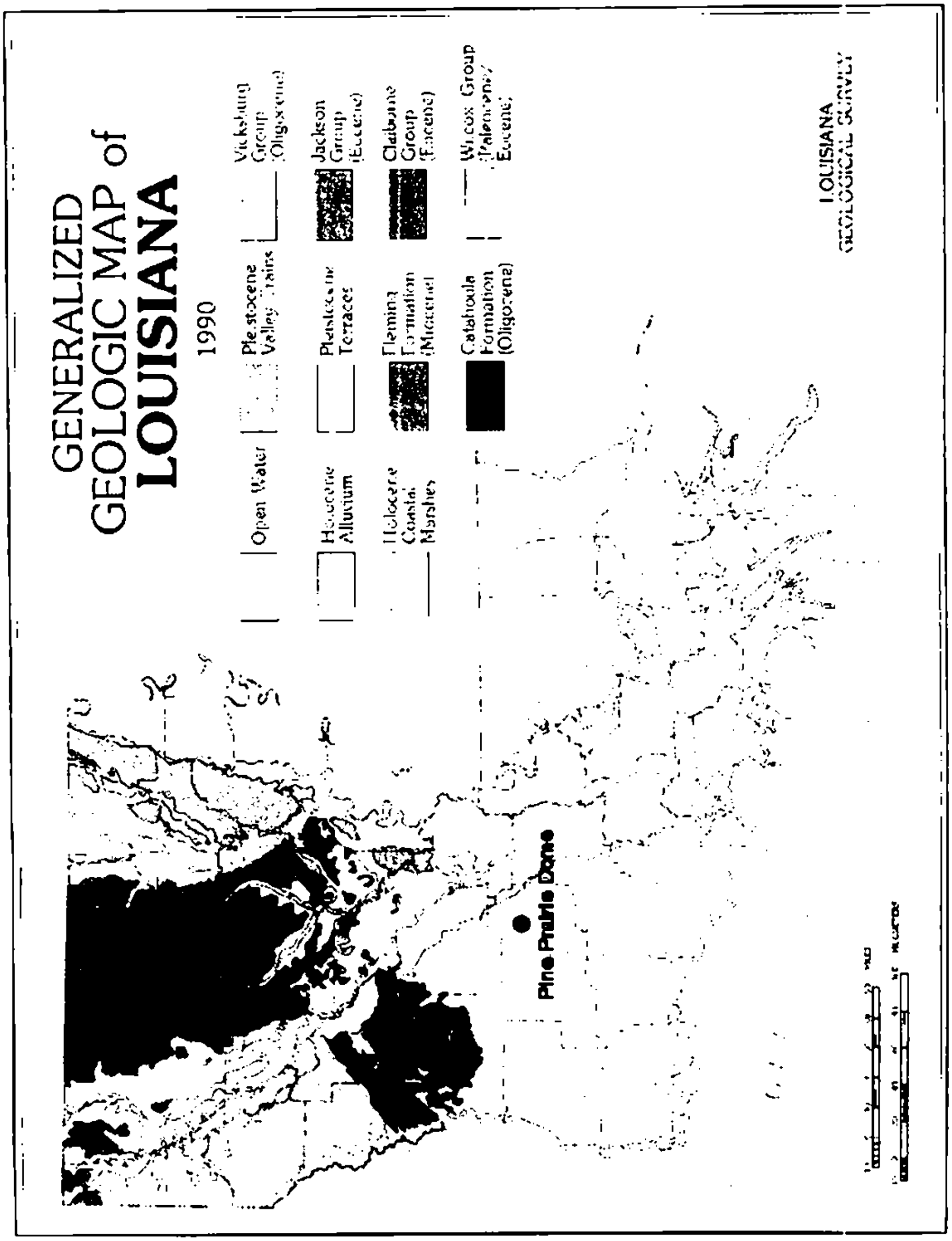


Figure 6.1-2 Extract of Geologic Map of Evangeline Parish

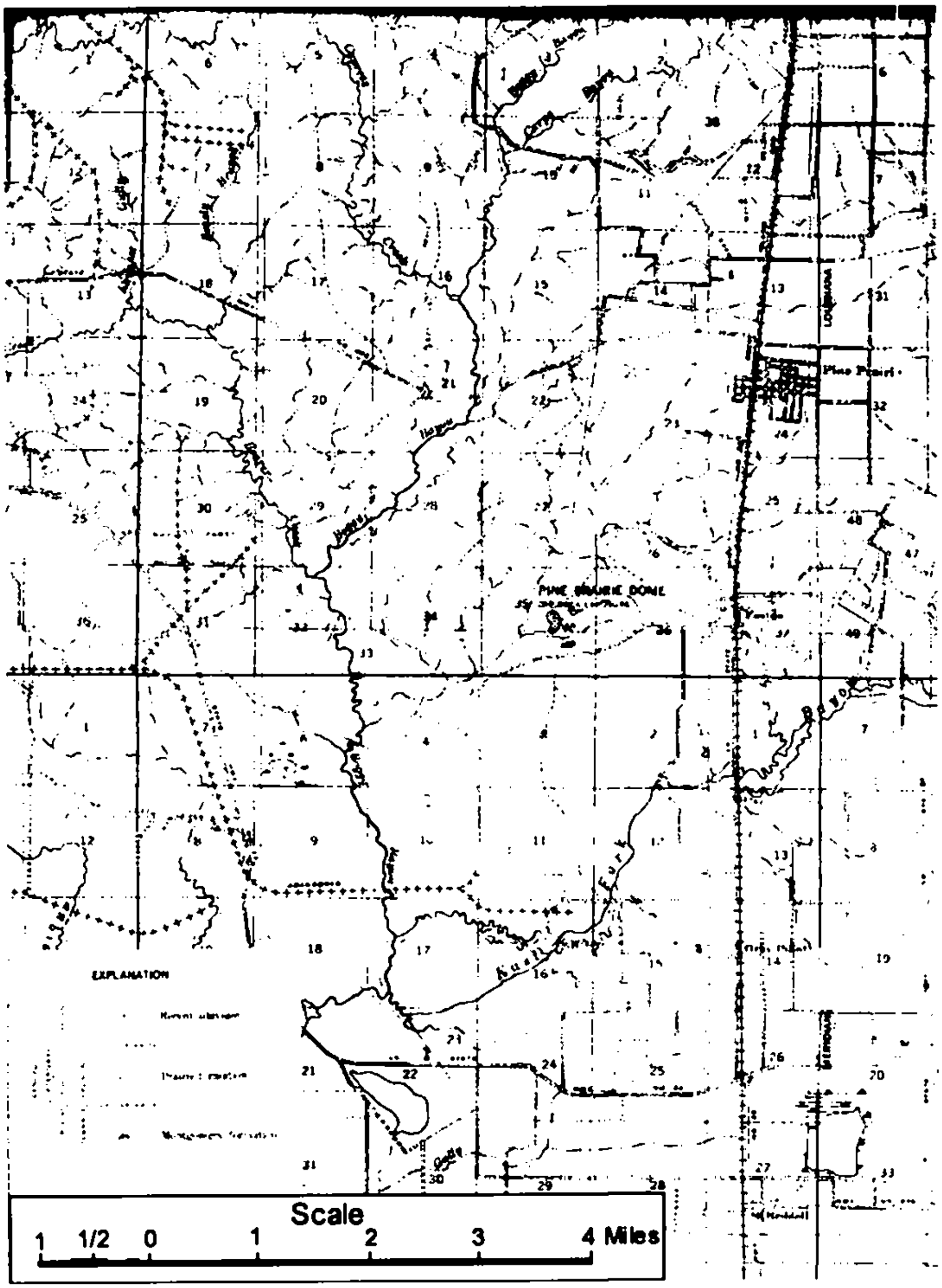


Figure 6.1-3 Top of Salt/Caprock above 7000'

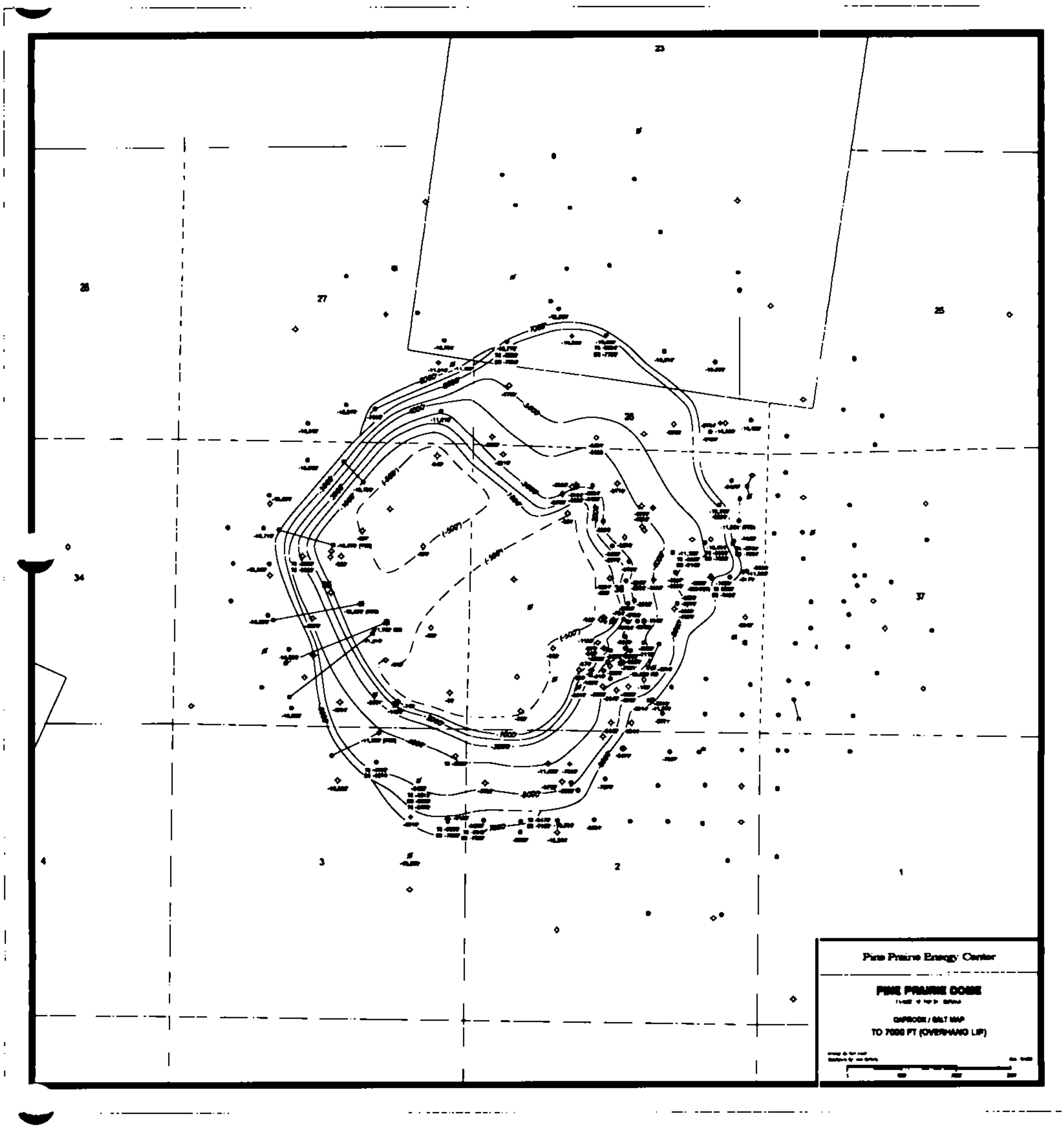
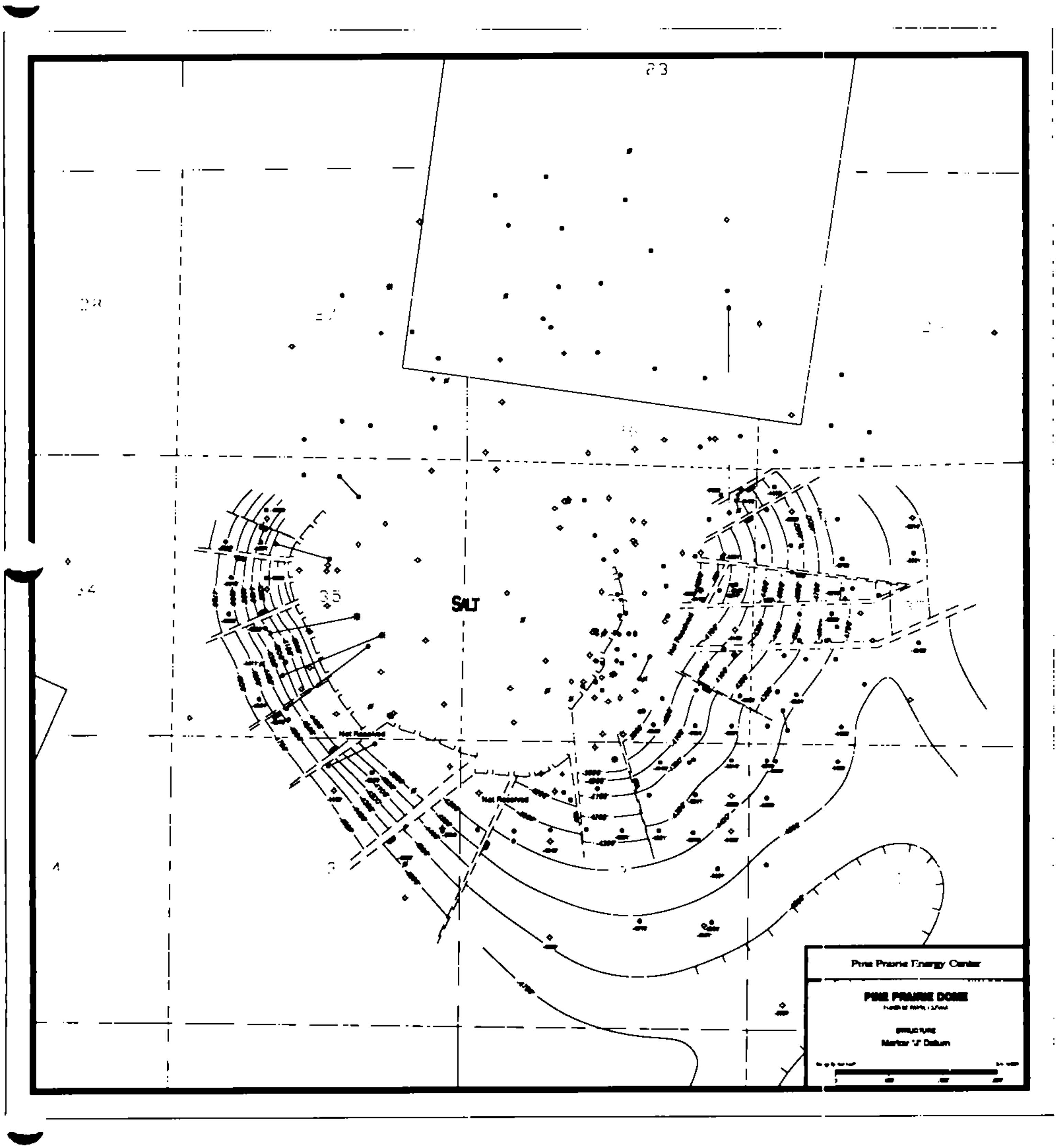

Pine Prairie Energy Center
PINE PRAIRIE DOME
CAPROCK / SALT MAP
TO 7000 FT (OVERHANG LIP)

Figure 6.1-4 Structure Map J Horizon '



23
35
SALT
Not Resolved
Not Resolved
Not Resolved
Pine Prairie Energy Center
PINE PRAIRIE DOME
STRUCTURE
Marker "J" Datum

Figure 6.1-5 Structure map Top of Vicksburg

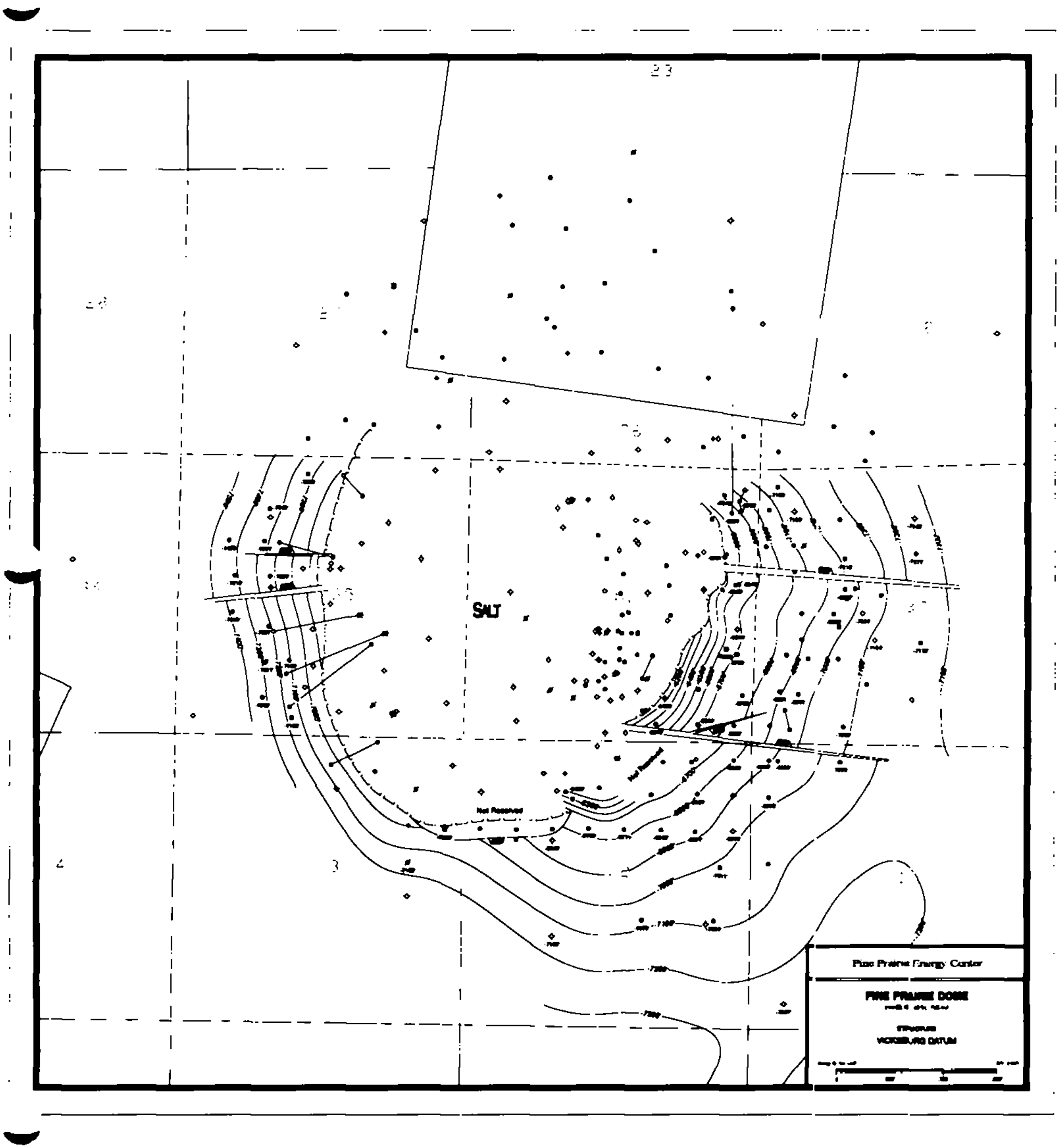

23
26
SALT
Not Received
Not Received
3
4
-7100
-7200
Pine Prairie Energy Center
PINE PRAIRIE DOME
VICKSBURG DATUM

Figure 6.2-1 Generalized Subsurface Fault Map of Louisiana

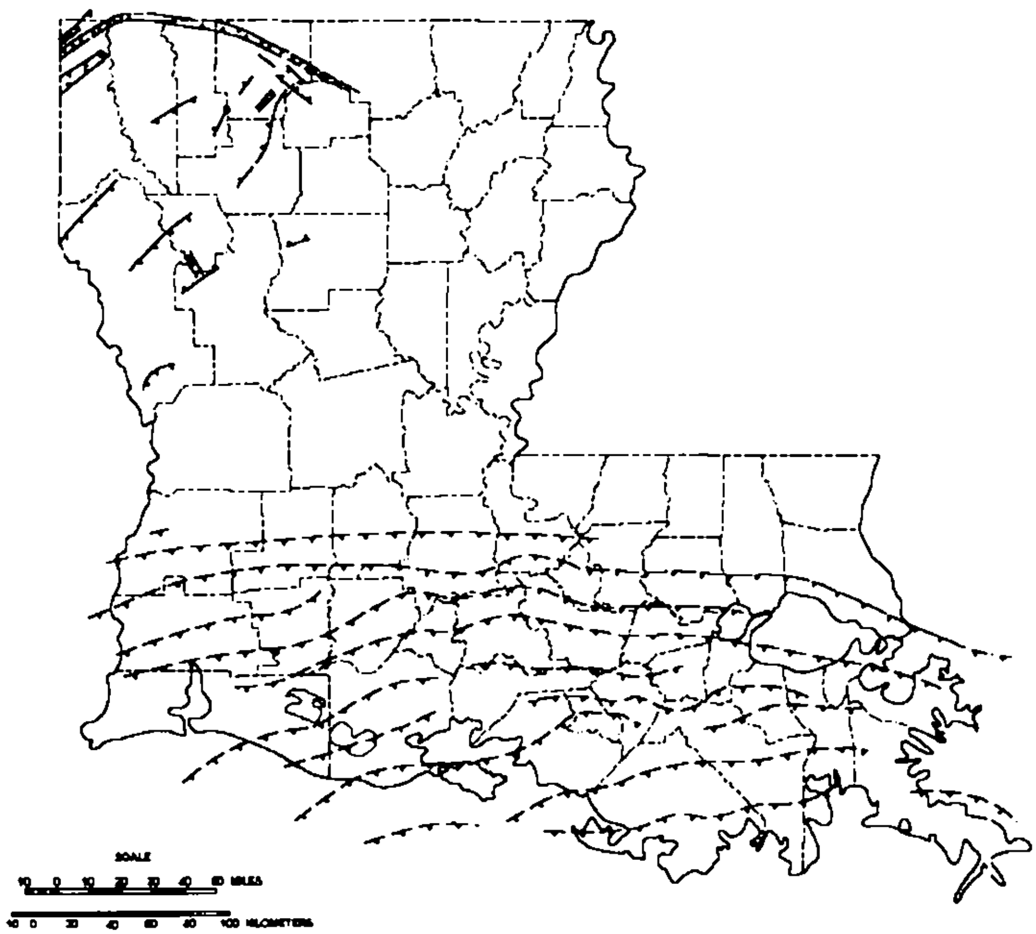


Figure 6.3-8 Predicted Cavern Volume vs. Time

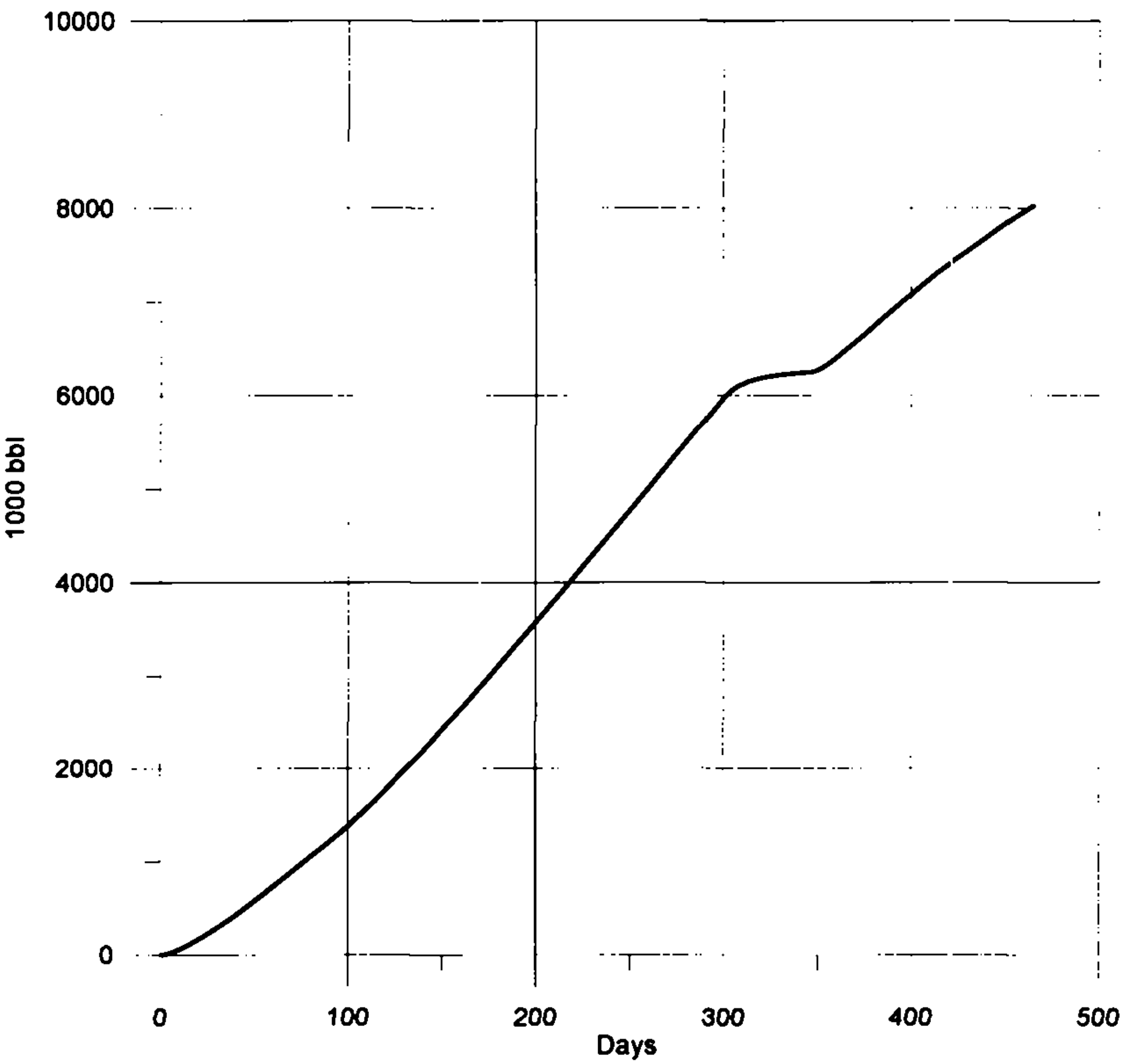
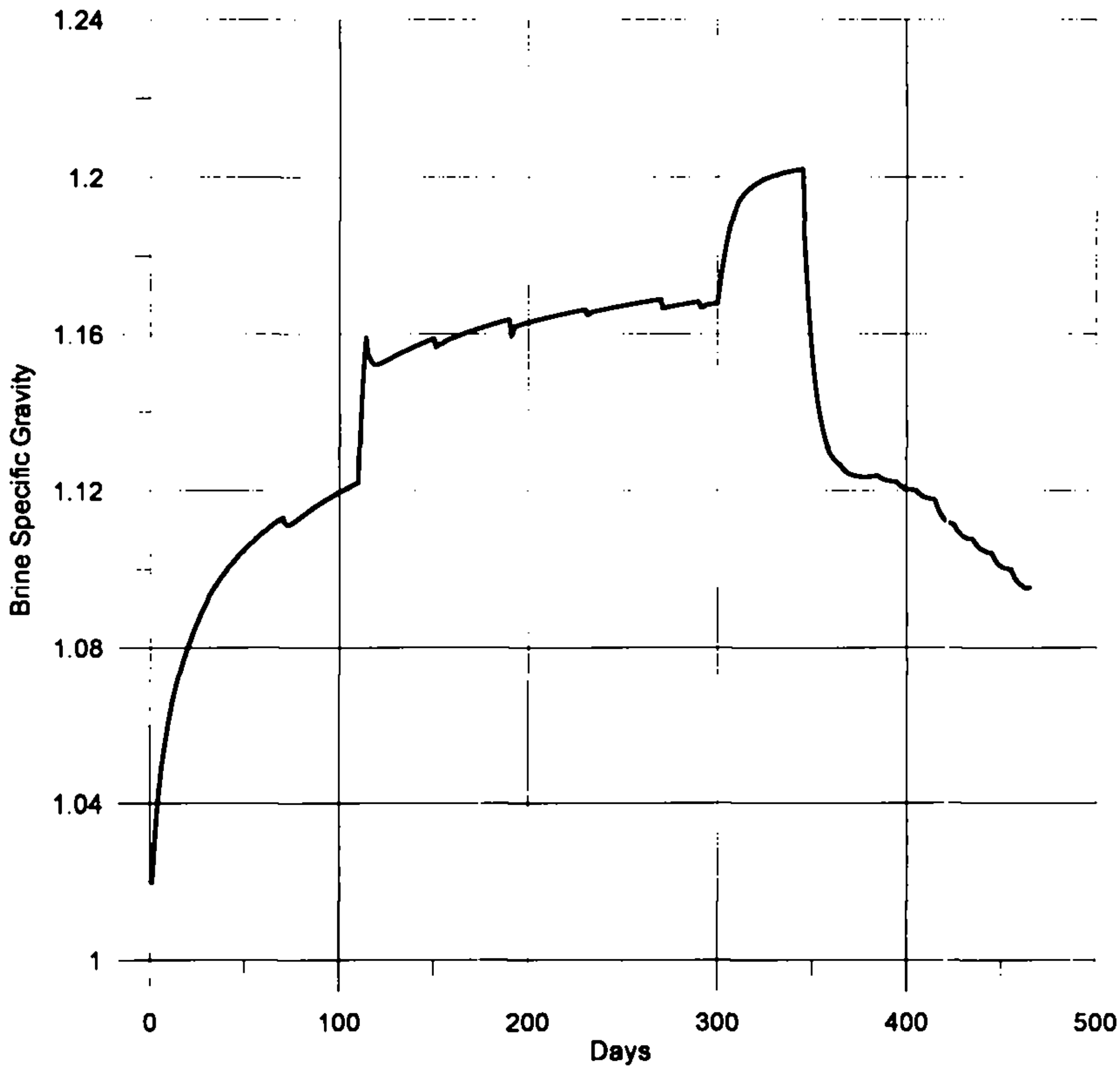


Figure 6.3-11 Predicted Brine Salinity vs. Time



PUBLIC

RESOURCE REPORT 7
SOILS

Pine Prairie Energy Center Storage Project
Evangeline Parish, Louisiana

July 2004

RESOURCE REPORT 7 – SOILS
FERC ENVIRONMENTAL CHECKLIST

Minimum Filing Requirements	Company Compliance or Inapplicability of Requirement
♦ Identify, describe and group by milepost the soils affected by the proposed pipeline and aboveground facilities. List the soil associations by milepost and describe their characteristics.	Table 7.2 Section 7.3.1 through Section 7.3.5.5.
♦ For aboveground facilities, determine the acreage of prime farmland soils that would be affected by construction and operation. List the soil series; describe their characteristics and percentages within the site. ♦ Indicate the onsite percentage of each series that would be permanently affected. ♦ Indicate which series are considered "prime or unique farmland."	Table 7.1
♦ Describe by milepost potential impacts on soils.	Section 7.2
♦ Identify proposed mitigation to minimize impact on soils and compare with staff's Upland Erosion Control, Revegetation, and Maintenance Plan. Identify any measures of the Plan that are deemed unnecessary, technically infeasible, or unsuitable and describe alternative measures that will ensure an equal or greater level of protection.	Section 7.3

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7.0 RESOURCE REPORT 7 – SOILS

7.1 PROJECT DESCRIPTION

The Pine Prairie Energy Center Storage Project is being proposed in response to the expanding market for high-deliverability, multi-cycle natural gas storage services. The Project will include three salt caverns, each with a storage working capacity of 8.0 billion cubic feet (Bcf). The Gas Storage Caverns will be solution mined in southwestern Louisiana's Pine Prairie Salt Dome and will interconnect with seven key interstate gas transmission pipelines.

7.1.1 GAS STORAGE SITE

The following components of the Project will be located on a 60.57-acre parcel of company-owned land in Evangeline Parish, Louisiana. The property is unimproved and, except for occasional timbering and oil and gas exploration and production, there are no other known uses of the property.

- The Gas Handling Facility will house the compressor station, gas dehydration equipment, and other associated infrastructure necessary to support the direction and routing of gas to and from the Gas Storage Caverns located nearby. (See **Figures 1.1-2C1** *Gas Storage Site*, **1.1-3A1** *Gas Handling Facility Site Layout*, **1.1-9A1** *Gas Handling Facility Site Layout*.)

- Three Gas Storage Caverns will be developed within the Pine Prairie salt dome. (See **Figure 1.1-13A1** *Typical Cavern Well Site Diagram*.)

- The Contractor Fabrication Area will be a temporary element of the Project. It will be located at the Gas Storage Site and will be relocated within the site from Cavern Site 2 to Cavern Site1 during construction to accommodate construction and operation of the individual Gas Storage Caverns.

- Service Corridors will provide personnel and vehicular access to, as well as pipeline, utility and transmission services between, the Gas Handling Facility and the Gas Storage Cavern Sites.

7.1.2 BRINE DISPOSAL AND RAW WATER WITHDRAWAL SITE

The Brine Disposal and Raw Water Withdrawal Site will be constructed approximately 2 miles southwest of the Gas Storage Site. (See **Figure 1.1-2D1** *Brine Disposal and Raw Water Withdrawal Site* and **Figure 1.1-4A1** *Primary Brine Disposal and Raw Water Withdrawal Site Layout*.)

- Four Raw Water Wells will be developed to service the solution mining operations. (See **Figure 1.1-14A1** *Typical Raw Water Well Site Diagram*.)

- Four Brine Disposal Wells will be developed to dispose of brine produced in the salt cavern solution mining process. (See **Figure 1.1-15A1** *Typical Brine Disposal Well Site Diagram.*)

- The corridors connecting the Brine Disposal Wells and the Raw Water Wells provide personnel and vehicular access, and pipeline, utility and transmission services, to the well sites. These corridors will include all service roads, road entries from Ambrose Road, pipelines, pipeways and power lines (see **Figure 1.1-4**).

7.1.3 GAS TRANSMISSION PIPELINES

A system of gas transmission pipelines will link the Project with six mainline gas transmission pipelines. The backbone of this system is a 34-mile segment of an existing 24-inch high-pressure gas pipeline known as the Louisiana Chalk Gathering System, which PPEC has the option to purchase and intends to convert for use as part of the Project. A second 24-inch high-pressure gas pipeline will be constructed immediately adjacent to portions of the existing Louisiana Chalk Gathering System segment in or contiguous to the existing ROW.

- The Mid Pipeline Corridor will be approximately 6.36 miles long. (See **Figures 1.1-10B1 – 10B3** *Detailed Route and Wetland Alignment Sheet, Mid Pipeline Corridor.*)

- The North Pipeline Corridor, which was created by the construction of the Louisiana Chalk Gathering System, will extend approximately 17.80 miles from the Mid Pipeline Corridor connection to the Tennessee Gas Metering Site. (See **Figures 1.1-8A1 – 8A7** *Footprint of Pipeline Alignment and Facilities, North Pipeline Corridor.*) It extends a very short distance into Rapides Parish.

- The South Pipeline Corridor is an existing pipeline corridor that was created by the construction of the Louisiana Chalk Gathering System. This 16.49-mile pipeline corridor will link the Mid Pipeline Corridor with gas transmission pipelines to the south and southeast of the Gas Storage Site. (See **Figures 1.1-10A1 – 10A6** *Detailed Route and Wetland Alignment Sheet, South Pipeline Corridor.*) This pipeline corridor will extend a short distance into Acadia Parish.

- The East Lateral Pipeline Corridor, approximately 3.17 miles long, will service the ANR SE Metering Site and ultimately terminate at the Florida Gas Transmission Metering Site. (See **Figures 1.1-10C1 – 10C2** *Detailed Route and Wetland Alignment Sheet, East Lateral Pipeline Corridor.*) This short corridor is located in Acadia Parish.

7.1.4 METER AND REGULATOR SITES, AND INTERCONNECTS

Seven Meters and Regulators, located at six Meter and Regulator Sites, will be connected to the 24-inch pipelines extending to and from the Gas Handling Facility to facilitate custody transfer measurement to and from their associated pipeline interconnects. One of the Meter and Regulator Sites will be located in Rapides Parish at the terminus of the North Pipeline Corridor, and two will be located in Acadia Parish along and at the terminus of the East Lateral Pipeline Corridor. The other three Meter and Regulator Sites will be located in Evangeline Parish.

Figures 1.1-2A1, 1.1-2A2 and **1.1-2A3** illustrate the Project location on a regional geographic basis and **Figures 1.1-8A1, 1.1-8A2 1.1-8A3, 1.1-8A4, 1.1-8A5, 1.1-8A6** and **1.1-8A7** provide the location on U.S. Geological Survey (USGS) topographic quad maps. Appendix A provides a detailed description of the temporary and permanent land requirements associated with construction of the Project.

7.2 SOIL ASSOCIATIONS AND SERIES

The soil association and soil series descriptions were compiled from information presented in the *Soil Survey of Evangeline Parish, Louisiana, Soils Survey of Acadia Parish, Louisiana and Soil Survey of Rapides Parish, Louisiana.* The soil associations and soil series underlying each Project component, as identified in the Parish soil surveys, are described below.

Figures 7.2-1A1 through 1A7 *Soil Map of Evangeline Parish,* **7.2-1A8** *Soil Map of Acadia Parish* and **7.2-1A9** *Soil Map of Rapides Parish* provide the soil associations and soil series underlying each Project component. Important soil characteristics, limitations of the soil association and series at each Project component site, and the percentage of each soil series permanently impacted by each Project component as compared to the total Project area are presented in Table 7-1.

All soil series occurring within the project footprint have a texture of silt loam. Therefore, landscape position as it affects the frequency and duration of flooding and/or soil saturation is the primary determinant of whether the soils meet the criteria for hydric soils.

Most of the soils in the upland areas and in lower areas having a convex surface are not hydric soils, including the Crowley silt loam and the Vidrine silt loam that constitute the Crowley-Vidrine complex (Cv). Other nonhydric soil series within the project footprint include the Acadia silt loam (AcB), Duralde silt loam (DuB), and Mamou silt loam (MaB).

Soils occurring on flat or concave surfaces, as well as moderately fine- to fine textured soils found in areas that are frequently flooded, typically have indicators of hydric soils. Hydric soils occurring within the project footprint include the Basile silt loam (Bw), Mowata silt loam (Mt), Midland (MbA), and Wrightsville silt loam (Wv).

Interpretation of most soil mapping units is straightforward, conforming to the hydric soil-nonhydric soil designations identified above (e. g., the Duralde silt loam is a nonhydric soil, and the Mowata silt loam is a hydric soil). However, the soil mapping unit called the "Wrightsville-Vidrine complex" is more complicated. Areas mapped as this complex are known as pimple mounds, which are mounds of various sizes extending one to two feet above an otherwise flat land surface. The soil of the mound area is the Vidrine soil series (nonhydric), while the soil of the flat land surface is the Wrightsville series (hydric). This commonly-occurring soil mapping unit forms a mosaic on the land surface, in which the elevated areas are nonwetlands and the areas of flat land surface are wetlands, also exhibiting indicators of hydrophytic vegetation and wetlands hydrology.

7.3 PROJECT COMPONENTS

All components of the Project are found within the following soil series:

- Acadia silt loam series,
- Basile series,
- Crowley series,
- Duralde silt loam,
- Mamou silt loam series,
- McKamie series,
- Midland silty clay loam,
- Mowata silt loam series,
- Muskogee series,
- Vidrine series, and
- Wrightsville series.

The series generally consist of silty loams. The soils that actually overlie the subject sites are typically silty loams. The soils in the subject area are generally flat or gently sloping with slopes ranging from 0% to 8%.

7.3.1 GAS STORAGE SITE SOIL SERIES

The Muskogee-McKamie complex and Duralde silt loams comprise the majority of the soils affected by the Gas Storage Site. These complexes consist of silt or very fine-grained sand loams.

The Muskogee-McKamie complex is characterized by moderately to well-drained soils located on narrow escarpments. Slopes range from 3% to 8% and have experienced erosion. The Muskogee soils are wet for a short period after a rain because permeability is slow. In a representative profile, the Musogee surface layer is a grayish-brown silt loam six inches thick. The subsoil, to a depth of 22 inches, is yellow brown silty clay loam. Below a depth of 22 inches, it is gray and yellowish-brown clay mottled with red. Generally, the content of nitrogen, phosphorous and potassium is very low. The soil is strongly acidic. Runoff is rapid. Available water capacity is high. The Muskegee soils in Evangeline Parish are mapped only with McKamie soils.

The well-drained McKamie soils have a dark-gray very fine sandy loam or silt loam surface layer. The subsoil is red clay. Generally, the content of nitrogen, phosphorous and potassium is very low. The soil is very strongly acidic in the surface layer and strongly acidic in the subsoil grading to neutral. Permeability is very slow and runoff is rapid. Available water capacity is moderate.

About 85% of the acreage is woodland. Other uses of the land are for crops and pasture. The supply of moisture available to plants is inadequate during dry periods in some years. The principle limitations are the erosion hazard and low fertility.

The Duralde series consists of somewhat poorly drained soils that are loamy throughout the profile. These soils are mainly gently sloping (1% to 3% slopes), but they also occur in very small mounds. The Duralde series is wet for extended periods because permeability is slow in the lower part of the subsoil. The surface layer is dark grayish-brown silt loam. The subsurface layer is yellowish-brown silt loam, and the subsoil is dark-brown silty clay loam mottled with grayish brown and yellowish brown. Generally, the content of nitrogen, phosphorous, potassium and calcium is very low. The soil is medium acidic to very strongly acidic in the surface layer and upper part of the subsoil and grades to neutral in the lower part. Runoff is medium. Available water capacity is high.

About 90% of the acreage is wooded. A small percentage has been cleared for crops and pasture. The soil is saturated in winter and spring, but lacks adequate moisture for plants during dry periods in some years. The principle limitations for crops are low fertility, wetness and the erosion hazard.

7.3.1.1 Gas Handling Facility Soil Series

The Muskogee-McKamie complex and Duralde silt loams comprise the majority of the soils affected by the Gas Handling Facility. These complexes consist of silt or very fine grained sand loams and are described in detail above.

7.3.1.2 Cavern 1, Cavern 2, Cavern 3, and Future Cavern 4 Soil Series

The Muskogee-McKamie complex comprises the majority of the soils affected by the caverns. This complex consists of silt loams that are described in detail above.

7.3.1.3 Contractor Fabrication Area

The Contractor Fabrication Area will affect the Muskogee-McKamie complex, which is described in detail in Section 7.3.1.

7.3.1.4 Service Corridors

The Service Corridors will affect either the Duralde silt loam or the Muskogee-McKamie complex. Both of these soils are described in greater detail in Section 7.3.1.

7.3.2 BRINE DISPOSAL AND RAW WATER WITHDRAWAL SITE

The land to be occupied by the Brine Disposal and Raw Water Withdrawal Site is composed of the Duralde series and the Wrightsville-Vidrine complex. These complexes consist of silty clays to loams. The Duralde series is described above in Section 7.3.1.

The Wrightsville-Vidrine complex is level to nearly level, poorly to somewhat poorly drained soils located adjacent to major streams in the southern half of Evangeline Parish.

The Wrightsville soil is in broad, flat areas and is the intermound part of the complex. In a representative profile the surface layer is gray silt loam three inches thick. The subsurface layer is light-gray silt loam 15 inches thick. The upper portion of the subsoil is light olive gray silty clay. The lower part is gray silty clay loam. Generally it is very low in nitrogen and phosphorous and low in potassium. It is strongly acidic to moderately alkaline in the subsoil. Available water capacity is moderate.

The Vidrine soil is on mounds and small ridges. It is wet for extended periods because permeability is very slow in the subsoil. This soil has a grayish-brown silt loam surface layer. The upper part of the subsoil is yellowish-brown silt loam and the lower part is grayish-brown silty clay mottled with red. The soil is generally very low in nitrogen and phosphorous and low in potassium. It is strongly acidic in the surface layer and grades to neutral in the lower part of the subsurface layer. Surface runoff is slow to medium and available water capacity is moderate.

About 70% of the acreage is woodland, but an increasing amount is being cleared for crops and pasture. The soils are saturated in winter and early spring, but lack adequate moisture for plants during dry periods in some years. The principle limitations are wetness and low fertility.

7.3.2.3 Service Corridor

The service corridor is located about half in the Duralde series, which is described in Section 7.3.1, and half in the Wrightsville-Vidrine complex, which is described above in Section 7.3.2.

7.3.3 PIPELINE CORRIDORS

7.3.3.1 Mid Pipeline Corridor

The Mid Pipeline Corridor is comprised of three segments and will be approximately 6.36 miles long.

- The first segment of the Mid Pipeline Corridor will be approximately 1.92 miles in length and will extend from the Gas Handling Facility to the Brine Disposal and Raw Water Withdrawal Site.

  The soil occurring in the first segment of the Mid Pipeline Corridor extending from the Gas Handling Facility to the Brine Disposal and Raw Water Withdrawal Site is composed of the Wrightsville-Vidrine Complex and the Duralde series which are described above in Section 7.3.2. The segment closest to the Gas Handling Facility is located in the Wrightsville-Vidrine complex. The segment closest to the Brine Disposal and Raw Water Withdrawal Site is located in the Duralde series. Each soil complex/series runs for about 1 mile.

- In the second segment, the two 24-inch bi-directional natural gas pipelines will continue from the Brine Disposal and Raw Water Withdrawal Site for approximately 0.36 mile to the ANR ML2 Meter and Regulator Site.

  The soil occurring in the second segment of the Mid Pipeline Corridor extending to the ANR ML2 metering site is also composed of the Wrightsville-Vidrine complex and the Duralde series which is described above in Section 7.3.2. Each soil complex/series runs for about 0.20 mile.

- *In the third segment, the two 24-inch bi-directional pipelines will continue from the ANR* ML2 Meter and Regulator Site 4.08 miles further to the North & South Pipeline Corridor connection.

  The soil occurring in the third segment of the Mid Pipeline Corridor extending to the North & South Pipeline Corridor connection is composed of the Wrightsville-Vidrine Complex, the Basile-Wrightsville complex, the Muskogee-McKamie complex, the Midland silty clay loam, and the Acadia silt loam. These soils are generally gently sloping (0-3%) silt loams.

The Wrightsville-Vidrine Complex is described in detail in Section 7.3.2.

The Basile-Wrightsville complex is composed of nearly level soils, along long narrow flood plains at low elevations in the southern half of the parish. They are wet for extended periods because they are frequently flooded and have a high water table.

The poorly drained Basile soil makes up about 60% of the acreage. In a representative profile, the surface layer is gray silt loam 16 inches thick. The subsurface is light-gray silt loam six inches thick. The subsoil, to a depth of 50 inches, is silty clay loam. It is gray mottled with yellowish-brown in the upper 10 inches and is light olive gray below. The Basile is very strongly acidic in the surface layer and neutral to moderately alkaline in the subsoil. It is generally very low in nitrogen and phosphorous content and low in potassium. Permeability is slow and runoff is very slow.

The poorly drained Wrightsville soil makes up about 30% of the acreage. The surface layer is commonly gray silt loam, but ranges to gray silty clay loam over-wash as much as 15 inches thick. The subsoil is gray or light olive-gray silty clay mottled with yellowish brown. This soil is medium acidic in the surface layer and very strongly acidic to alkaline in the subsoil. Generally it is very low in nitrogen and phosphorous content and low in potassium. Permeability is very slow and runoff is slow. Available water capacity is moderate.

Most of the acreage is wooded. Flooding commonly lasts 3 to 14 days in winter and spring. Moisture is adequate for plants in most years. The major limitations are frequent flooding, wetness and low fertility.

The Muskogee-McKamie complex is described in detail in Section 7.3.1.

The Midland silty clay loam is in broad, slightly concave areas in the southern part of Evangeline parish. It is wet for extended periods because runoff is slow and permeability is very slow in the clayey subsoil. The surface layer is dark-gray silty clay loam 5 inches thick. The subsoil is gray to brown-gray clay mottled with brown and yellowish brown. Generally the content of nitrogen and phosphorous is very low and the potassium content is low. The soil is medium acidic at the surface and grades to very strongly acidic below. Available water capacity is moderate.

Most of the acreage is used for crops and pasture. The soil is saturated in winter and spring and water accumulates on the surface after a rain. The moisture available to plants, however, is inadequate during dry periods in most years. The principle limitations are wetness and low fertility.

The Acadia silt loam is a very gently sloping (1% to 3%) soil in long narrow areas adjacent to drainages in the southern half of the parish. It is wet for extended periods after rains because permeability is very slow in the clayey subsoil. The surface layer is a gray silt loam 16 inches thick. The subsurface is light gray silt loam 6 inches thick. The subsoil, to a depth of 50 inches, is silty clay loam. It is gray mottled with yellowish brown in the upper 10 inches and is light olive gray below. Available water capacity is moderate. Generally the content of nitrogen and phosphorous is very low and the content of potassium is low. The surface layer is medium acidic to very strongly acidic, and the subsoil is strongly to very strongly acidic. Runoff is medium.

About 75% of the acreage is wooded. A small percentage of the acreage has been cleared for crops and pasture. The soil is saturated in winter and early spring, but lacks adequate moisture for plants during dry periods late in summer and fall in some years. The major limitations are low fertility, the erosion hazard and wetness.

7.3.3.2 North Pipeline Corridor

The North Pipeline Corridor will extend approximately 17.80 miles from the Mid Pipeline Corridor connection to the Tennessee Gas Metering Site. There will be no additional construction along this corridor except for the TGP M&R site located at the northern end of the corridor. The TGP M&R site is discussed below in Section 7.3.5.1.

7.3.3.3 South Pipeline Corridor

The South Pipeline Corridor will extend south from the Mid Pipeline Corridor connection to the Transco Metering Site, through the Texas Gas Transmission Metering Site to the Texas Eastern Transmission Metering Site, then south to the East Lateral Pipeline Corridor connection for a total length of 16.4 miles.

The South Pipeline Corridor is located along the following series/complexes, in alphabetical order:

- Acadia silt loam
- Basile – Wrightsville Complex
- Crowley-Vidrine Complex
- Mamou silt loam

- Mowata silt loam

The soils found along the South Pipeline Corridor are generally silt loams.

The details of the Acadia silt loam and the Basile – Wrightsville Complex are discussed above in Section 7.3.3.1.

The Crowley-Vidrine Complex are nearly level, poorly drained to somewhat poorly drained soils on broad, slightly convex areas in the southwestern part of Evangeline Parish. The Crowley soils make up about 65% of the acreage and the Vidrine soils make up about 30%.

The Crowley soils are wet for extended periods because runoff is slow and permeability is very slow in the clayey subsoil. The surface layer is dark grayish-brown silt loam 8 inches thick. The subsurface layer is grayish-brown silt loam 12 inches thick. The subsoil is grayish silty clay mottled with red and yellowish brown to a depth of more than 50 inches. Generally the content of nitrogen and phosphorous is very low and that of potassium is low. This soil is strongly acidic in the surface layer and grades to neutral in the lower subsoil. Available water capacity is moderate.

The Vidrine soil is on smooth mound areas and micro-ridges. It is wet for significantly long periods because of the slowly permeable clayey subsoil. The surface layer is grayish-brown silt loam. The upper part of the subsoil is yellowish-brown silt loam and the lower part is grayish-brown silty clay mottled with red. Generally the content of nitrogen and phosphorous is very low and that of potassium is low. The soil is strongly acidic in the surface layer and grades to neutral in the lower subsoil. Permeability and runoff are slow. Available water capacity is high.

Most of the acreage is in crops and pasture. The soils are saturated in winter and early spring, but lack adequate moisture for plants during dry periods in some years. The principle limitations are wetness and low fertility.

The Mamou silt loam is at higher elevations in the southwestern part of Evangeline Parish. Slopes range from 1% to 3%. It is wet for extended periods of time because permeability is slow. The Mamou's surface layer is grayish-brown silt loam 6 inches thick. The subsurface layer is yellowish-brown silt loam mottled with gray. It is about 5 inches thick. The silty clay subsoil is mottled red and dark gray in the upper part and yellowish brown in the lower part. Below a depth of 26 inches it is mottled yellowish-brown loam. The nitrogen, phosphorous and potassium content is low. The surface layer is slightly acidic to neutral. Runoff is medium. The available water capacity is high.

Most of the Mamou acreage is used for crops and pasture. The soil is saturated for short periods in the winter and spring, but lacks adequate moisture for plants during dry periods in some years. The principle limitations are low fertility, the erosion hazard and wetness.

Mowata silt loam is in broad, concave areas in the southern part of Evangeline Parish. It becomes waterlogged after a rain and is wet for extended periods because runoff is slow and permeability is very slow in the claypan subsoil. The surface and subsurface layers are gray silt loam and have a combined thickness of 23 inches. The subsoil is dark-gray silty clay above a depth of 33 inches and gray silty clay loam below. The nitrogen and phosphorous content is very low and the potassium content is low. The soil is medium acidic in the surface layer and strongly acidic below. Available water capacity is moderate.

Most of the Mowata acreage is used for crops and pasture. The soil is saturated in winter and early spring and water accumulates after a rain. Soil moisture, however, is inadequate during dry periods in most years. The principle limitations are wetness and low fertility.

The details of the Wrightsville-Vidrine Complex are described above in Section 7.3.2

7.3.3.4 East Lateral Pipeline Corridor

The East Lateral Pipeline Corridor will extend east from the South Pipeline Corridor Connection and will terminate at the Florida Gas Transmission Metering Site after a distance of 3.17 miles.

The East Lateral Pipeline Corridor is located in Acadia Parish and runs through the Acadiana silt loam, Basile and Brule soils, Crowley silt loam, Iota silt loam, and Kinder-Vidrine silt loams.

The majority of the 1.4 miles on the west end of the East Lateral Pipeline Corridor is located in the Crowley silt loam. This includes the contractor's temporary yard at the junction of the existing pipeline and the East Lateral Pipeline Corridor (Section 7.3.5.7) and the ANR South M&R site (Section 7.3.5.6).

The Crowley is a silt loam with 0 to 1% slopes. It is a level to nearly level, somewhat poorly drained stream terrace located on broad, slightly convex ridges. This soil has naturally medium fertility. Runoff is very low to medium, and permeability is very slow. A perched water table is at a depth of 0.5 to 1.5 feet.

The Crowley surface soil in Acadia Parish is a dark grayish brown silt loam. The subsurface layer is characterized as a light brownish gray silt loam. The subsoil layer is grayish to brownish silty clay.

Most of the acreage is cropland. Other uses include pasture and crayfish farming.

The Kinder-Vidrine is a silt loam with 0 to 1% slopes. The Kinder soils are level to nearly level and the Vidrine soils are nearly level to gently sloping. The Kinder-Vidrine silt loam is poorly drained. It is composed of stream terraces. The Kinder soils are located on broad flats and depressions on the terraces. The Vidrine soils are located on convex, circular mounds. Both soils have naturally low fertility. Runoff is low and permeability is slow. A perched water table is at a depth of 0 to 2 feet.

Both the Kinder and the Vidrine surface layers are a dark grayish brown silt loam. The Kinder subsurface layer is characterized as a light brownish gray silt loam. The Vidrine does not contain a subsurface layer. The subsoil layer is grayish to brownish silty clay.

Most of the Kinder-Vidrine acreage is woodland. Other uses include cropland, pasture and crayfish farming.

The Iota is a silt loam with 3 to 8% slopes. It is a moderately sloping to sloping, well drained soil located on uplands. This soil has naturally low fertility. Runoff is very high, and permeability is very slow.

The Iota surface layer in Acadia Parish is a brown silt loam. The subsurface layer is characterized as a pale brown silt loam. The Kinder subsoil layer is a variegated gray, reddish brown and light brownish gray silty clay. The Vidrine subsoil layer is a dark grayish brown, light yellowish brown, and gray silty clay.

Most of the Iota acreage is woodland, although it is also used as pasture.

The Basile and Brule soils have a 0 to 3% slopes. The Basile soils are level to nearly level and the Brule soils are nearly level to very gently sloping. The soils are poorly drained. These soils are located in floodplains. The Basile soil is in swales and the Brule is located on low convex ridges. These soils have a naturally low to medium fertility. Runoff is very low to ponded, and permeability is moderate.

The Basile surface layer is a dark grayish brown silt loam. The Brule surface layer is a dark gray silty clay loam. The Basile subsurface layer is characterized as a grayish brown silt loam. The Brule subsurface layer is characterized as a dark grayish brown silty clay loam. The Basile subsoil layer is light brownish gray silty clay loam. The Brule subsoil layer is brown to yellowish brown or gray silt loam.

Most of the acreage is woodland. Other uses include wildlife and pasture.

The Acadiana is a silt loam with 1 to 3% slopes. It is a gently sloping, moderately well drained soil on stream terraces located on convex side slopes. This soil has naturally low fertility. Runoff is medium, and permeability is very slow.

The Acadiana surface layer in Acadia Parish is a dark grayish brown silt loam. The subsurface layer is characterized as a light yellowish brown silt loam. The subsoil layer is a variegated gray, reddish brown and light brownish gray silty clay.

Most of the Acadiana acreage is woodland and pasture, although other uses include cropland, home sites and recreation.

7.3.3.5 TGT Lateral Pipeline Corridor

The TGT Lateral Pipeline Corridor is underlain by the Crowley-Vidrine Complex and the Mowata silt loam. The Crowley-Vidrine complex and the Mowata silt loam are both described in detail in Section 7.3.3.3.

Table 7-1 Soil Associations and Series Potentially Impacted by the Project

Project Component	Soil Series	Erosion Potential	Soil Fertility	Drainage Characteristics	Hydric	Prime Farmland	Land Disturbed Temporarily During Construction (acres)	Land Permanently Affected (acres)
Gas Handling Facility Site								
Gas Handling Facility	Muskogee-McKamie complex	Severe	Low	Moderately well drained and well drained	No	No	4.93	4.01
	Duralde series	Severe	Low	Somewhat poorly drained	No	No	4.94	4.02
Cavern 1, 2, and 3	Muskogee-McKamie complex	Severe	Low	Moderately well drained and well drained	No	No	4.74	0.84
Service Corridor	Muskogee-McKamie complex	Severe	Low	Moderately well drained and well drained	No	No	6.10	3.90
	Duralde series	Severe	Low	Somewhat poorly drained	No	No	0.30	0.30
Temporary Pipe Fabrication Area	Muskogee-McKamie complex	Severe	Low	Moderately well drained and well drained	No	No	0.00*	0.00*
SUBTOTAL							**21.01**	**13.07**

* Addressed as portion of Gas Storage Facility.

Table 7-1 Soil Associations and Series Potentially Impacted by the Project (continued)

Project Component	Soil Series	Erosion Potential	Soil Fertility	Drainage Characteristics	Hydric	Prime Farmland	Land Disturbed Temporarily During Construction (acres)	Land Permanently Affected (acres)
Primary Brine Disposal And Raw Water Withdrawal Site								
Four Water Wells	Duralde series	Severe	Low	Somewhat poorly drained	No	No	1.44	0.08
Four Brine Injection Wells	Duralde series	Severe	Low	Somewhat poorly drained	No	No	3.20	1.12
Service Corridor	Duralde series	Severe	Low	Somewhat poorly drained	No	No	5.35	0.51
	Wrightsville – Vidrine Complex	Slight	Low	Poorly drained and somewhat poorly drained	Yes/No	No	0.01	0.01
Balance of 60 - acre Project Site	Muskogee-McKamie complex	Severe	Low	Moderately well drained and well drained	No	No	33.50	0.00
	Duralde series	Severe	Low	Somewhat poorly drained	No	No	3.91	0.00
Pipeline Corridors								
South Pipeline Corridor	Acadia silt loam	Moderate	Low	Somewhat poorly drained	No	No	1.73	0.64
	Basile-Wrightsville complex	Slight	Low	Poorly drained	Yes	No	2.97	1.55
	Crowley-Vidrine complex	Slight	Low	Poorly to somewhat poorly drained	No	No	62.65	20.49
	Mamou silt loam	Moderate	Low	Somewhat poorly drained	No	No	1.67	0.92
	Mowata silt loam	Slight	Low	Poorly drained	Yes	No	43.70	15.93

Table 7-1 Soil Associations and Series Potentially Impacted by the Project (continued)

Project Component	Soil Series	Erosion Potential	Soil Fertility	Drainage Characteristics	Hydric	Prime Farmland	Land Disturbed Temporarily During Construction (acres)	Land Permanently Affected (acres)
Pipeline Corridors								
Mid Pipeline Corridor	Duralde series	Severe	Low	Somewhat poorly drained	No	No	16.36	8.15
	Wrightsville – Vidrine Complex	Slight	Low	Poorly drained and somewhat poorly drained	Yes/No	No	50.28	25.14
	Basile-Wrightsville complex	Slight	Low	Poorly drained	Yes	No	6.78	3.39
	Muskogee-McKamie complex	Severe	Low	Moderately well drained and well drained	No	No	3.36	1.65
	Midland silty clay loam	Slight	Low	Poorly drained	Yes	No	1.34	0.67
	Acadia silt loam	Moderate	Low	Somewhat poorly drained	No	No	7.12	3.56
East Lateral Pipeline Corridor	Acadiana silt loam	Moderate	Low	Moderately well drained	No	No	3.58	1.25
	Basile and Brule soils	Slight	Low to Medium	Poorly drained	Yes/No	No	2.24	1.31
	Crowley silt loam	Moderate	Medium	Somewhat poorly drained	No	No	17.45	5.17
	Iota silt loam	Severe	Low	Well drained	No	No	2.42	0.72
	Kinder-Vidrine silt loams	Moderate	Low	Poorly drained	No	No	10.46	3.06

Table 7-1 Soil Associations and Series Potentially Impacted by the Project (continued)

Project Component	Soil Series	Erosion Potential	Soil Fertility	Drainage Characteristics	Hydric	Prime Farmland	Land Disturbed Temporarily During Construction (acres)	Land Permanently Affected (acres)
Pipeline Corridors								
TGT Lateral	Crowley-Vidrine complex	Slight	Low	Moderately well drained and well drained	No	No	5.91	1.75
	Mowata silt loam	Slight	Low	Poorly drained	Yes	No	2.88	0.80
North Pipeline Corridor							0.00*	0.00*
Meter and Regulator Sites and Interconnects								
TGP M & R & Interconnect	Malbis fine sandy loam	Moderate	Low	Moderately well drained	No	No	0.54	0.54
	Guyton complex	Slight	Low	Poorly drained	No	No	0.53	0.53
ANR ML2 M & R & Interconnect	Wrightville-Vidrine complex	Slight	Low	Poorly and somewhat poorly drained	Yes/No	No	0.59	0.59
TGT/TRANSCO M & R & Interconnect	Crowley-Vidrine complex	Slight	Low	Poorly to somewhat poorly drained	No	No	1.38	1.38
TETCO M & R & Interconnect	Mamou silt loam	Moderate	Low	Somewhat poorly drained	No	No	0.65	0.65
ANR SE M & R & Interconnect	Crowley silt loam	Slight	Medium	Somewhat poorly drained	No	No	0.46	0.46
FGT M & R & Interconnect	Acadiana silt loam	Moderate	Low	Moderately well drained	No	No	0.86	0.86

* Addressed as portion of Gas Storage Facility.

Table 7-1 Soil Associations and Series Potentially Impacted by the Project (continued)

Project Component	Soil Series	Erosion Potential	Soil Fertility	Drainage Characteristics	Hydric	Prime Farmland	Land Disturbed Temporarily During Construction (acres)	Land Permanently Affected (acres)
Contractors' Temporary Yards								
Contractors's Temporary Yard No. 1	Crowley silt loam	Slight	Medium	Somewhat poorly drained	No	No	5.40	0.00
Contractors' Temporary Yard No. 2	Mamou silt loam	Moderate	Low	Somewhat poorly drained	No	No	10.20	0.00
	Crowley-Vidrine complex	Slight	Low	Poorly to somewhat poorly drained	No	No	4.40	0.00
Contractors' Temporary Yard No. 3	Mowata silt loam	Slight	Low	Poorly drained	Yes	No	10.50	0.00
	Crowley-Vidrine complex	Slight	Low	Poorly and somewhat poorly drained	No	No	0.60	0.00
Contractors' Temporary Yard No. 4	Wrightville-Vidrine complex	Slight	Low	Poorly and somewhat poorly drained	Yes/No	No	1.61	0.00
Contractors' Temporary Yard No. 5	Wrightville-Vidrine complex	Slight	Low	Poorly and somewhat poorly drained	Yes/No	No	4.90	0.00
	Crowley-Vidrine complex	Slight	Low	Poorly and somewhat poorly drained	No	No	5.90	0.00
TOTAL							***359.84***	***115.95***

7.3.4 METERING AND REGULATOR SITES AND INTERCONNECTS

Seven meters at six metering sites will be connected to the Gas Handling Facility Site to facilitate custody transfer measurement to and from their associated pipeline interconnects (see Table 1-2). Each metering site will be serviced by a 24-inch bi-directional natural gas pipeline interconnect.

7.3.4.1 TGP Metering and Regulator Site and Interconnect

The Tennessee Gas Pipeline Metering and Regulator Site and Interconnect is located in Rapides Parish, north of the Gas Handling Facility. The majority of the TGP Metering Site and Regulator and Interconnect is underlain by the Malbis fine sandy loam. This is a very gently to gently sloping (1 to 5% slope), moderately well drained, loamy soil on uplands. This soil has naturally low fertility. Runoff is medium, and water and air move moderately slow through the soil. A seasonal high water table is at a depth greater than 6 feet. Roots penetrate easily. The part of the subsoil that contains plinthite perches water for short periods during winter and spring. Slope and hazard of erosion are the main limitations.

Most of the acreage is wooded. A small portion of the acreage is in pasture.

The northeast corner of the metering site is underlain by the Guyton complex. This complex is on alluvial plains of streams that drain the uplands, therefore it is frequently flooded. It consists of poorly drained loamy soils. Slopes are 0 to 1%.

The surface layer is grayish-brown silt loam about 3 inches thick. The subsurface layer is light brownish-gray silt loam about 14 inches thick. The subsoil to a depth of 80 inches is grayish-brown silty clay loam mottled with yellowish brown.

This complex has low natural fertility. Runoff is slow and water moves slowly through the soil. A seasonal high water table is encountered at a depth of 0 to 1.5 feet from December through April. This complex is often flooded because of runoff received following rains during the winter and spring. It is dry during summer and fall. Flooding, low strength, and wetness are the main limitations.

Most of the acreage is in mixed hardwoods and pine trees. This complex is not suited to crops or to most pasture plants, because of flooding.

7.3.4.2 ANR ML2 Metering and Regulator Site and Interconnect

The ANR ML2 Metering and Regulator Site and Interconnect is underlain by the Wrightville-Vidrine complex, which is described in detail in Section 7.3.2.

7.3.4.3 TGT/TRANSCO Metering and Regulator Site and Interconnect

The TGT/TRANSCO Metering and Regulator Site and Interconnect is underlain by the Crowley-Vidrine complex, which is described in detail in Section 7.3.3.3.

7.3.4.4 TETCO Metering and Regulator Site and Interconnect

The TETCO Meter and Regulator Site and Interconnect is underlain by the Mamou silt loam, which is described in detail in Section 7.3.3.3.

7.3.4.5 ANR SE Metering and Regulator Site and Interconnect

The ANR SE Metering and Regulator Site and Interconnect is entirely located in the Crowley silt loam, which is described in detail above in Section 7.3.3.4.

7.3.4.6 FGT Metering and Regulator Site and Interconnect

The FGT Metering and Regulator Site and Interconnect is underlain by the Acadiana silt loam, which is described in detail in Section 7.3.3.4.

7.3.5 CONTRACTORS' TEMPORARY YARDS

7.3.5.1 Contractors' Temporary Yard No. 1

This facility is entirely located in the Crowley silt loam, which is described in Section 7.3.3.4.

7.3.5.2 Contractors' Temporary Yard No. 2

This facility is located in the Mamou silt loam and the Crowley-Vidrine complex. The Mamou silt loam is described in Section 7.3.3.3 and the Crowley-Vidrine complex is described in Section 7.3.3.3.

7.3.5.3 Contractors' Temporary Yard No. 3

This facility is located in the Mowata silt loam, which is described in detail in Section 7.3.3.3, and the Wrightsville-Vidrine complex, which is described in detail in Section 7.3.2.

7.3.5.4 Contractors' Temporary Yard No. 4

This facility is entirely located in the Wrightsville-Vidrine complex, which is described in detail in Section 7.3.2.

7.3.5.5 Contractors' Temporary Yard No. 5

Approximately the northern half of the facility is located in the Wrightsville-Vidrine complex and the southern half is located in the Crowley-Vidrine complex. The Wrightsville-Vidrine complex is described in detail in Section 7.3.2 and the Crowley-Vidrine complex is described in Section 7.3.3.3.

7.4 POTENTIAL PROJECT IMPACTS ON SOILS

Construction activities have the potential to adversely affect soil characteristics, thereby limiting the restoration potential of areas disturbed by land-clearing activities, well development, the movement of heavy equipment, and restoration activities. Potential soil impacts in the Project area include loss of vegetation and subsequent soil erosion, soil compaction and damage to soil structure as a result of construction vehicle traffic, and structural damage to wet soils and soils with poor drainage. Table 7-1 provides soil limitations of the soil associations and series affected by each Project component.

Short-term increases in erosion can occur as a result of the removal of vegetation during clearing and grading activities and the subsequent exposure of topsoil to wind action and precipitation. Soil series that exhibit high erosion potential in the Project area are listed in Table 7-1. Procedures listed in the Erosion and Sediment Control Plan (E&SCP) will be followed for these areas and will reduce the potential impacts of erosion (see Appendix B).

Other impacts to soils that may result from construction of the Project facilities include rutting and compaction of soils due to transport of heavy equipment. These impacts may be more likely when soils are saturated or moist. Soils with the potential for compaction and rutting from heavy equipment usage were identified from the Evangeline Parish, Acadia Parish and Rapides Parish soil surveys. Soil associations and soil series with somewhat poorly drained characteristics potentially susceptible to compaction or rutting are also listed in Table 7-1.

7.5 MEASURES TO MINIMIZE AND MITIGATE PROJECT IMPACTS ON SOILS

The proposed Project will have temporary short-term impact on most of the soils only during construction. A description of the construction methods that PPEC will use to minimize any long-term effects, which will occur mainly at the Gas Storage Site and the Metering and Regulator Sites, can be found in Resource Report 1. PPEC will closely follow the Project E&SCP (a copy of which can be found in Appendix B). Temporary Erosion Control for the proposed Project will include the use of a sediment fence, hay bales or a combination of the two.

Table 7-2 Detailed Milepost Chart

Mile Post	Soil Series/Complex
EAST LATERAL	
0.00 EL - 1.42 EL	Crowley silt loam, 0 to 1% slopes
1.42 EL - 1.94 EL	Kinder-Vidrine silt loam, 0 to 1% slope
1.94 EL - 2.07 EL	Iota silt loam, 3 to 8% slopes
2.07 EL - 2.11 EL	Basile and Brule soils, 0 to 3% slopes
2.11 EL - 2.18 EL	Iota silt loam, 3 to 8% slopes
2.18 EL - 2.43 EL	Basile and Brule soils, 0 to 3% slopes
2.43 EL - 2.49 EL	Acadiana silt loam, 1 to 3% slopes
2.49 EL - 2.66 EL	Kinder-Vidrine silt loam, 0 to 1% slope
2.66 EL - 2.72 EL	Acadiana silt loam, 1 to 3% slopes
2.72 EL - 2.79 EL	Basile and Brule soils, 0 to 3% slopes
2.79 EL - 2.88 EL	Acadiana silt loam, 1 to 3% slopes
2.88 EL - 3.03 EL	Kinder-Vidrine silt loam, 0 to 1% slope
3.03 EL - 3.17 EL	Acadiana silt loam, 1 to 3% slopes
MID CORRIDOR	
0.00M - 0.17 M	Wrightsville-Vidrine Complex
0.17 M - 0.21 M	Acadia silt loam, 1 to 3% slopes
0.21 M - 0.24 M	Basile-Wrightsville Complex, frequently flooded
0.24 M - 0.48 M	Acadia silt loam, 1 to 3% slopes
0.48 M - 0.53 M	Wrightsville-Vidrine Complex
0.53 M - 0.62 M	Midland silty clay loam
0.62 M – 098 M	Wrightsville-Vidrine Complex
0.98 M - 1.11 M	Basile-Wrightsville Complex, frequently flooded
1.11 M - 1.22 M	Wrightsville-Vidrine Complex
1.22 M - 1.34 M	Basile-Wrightsville Complex, frequently flooded
1.34 M - 1.43 M	Wrightsville-Vidrine Complex
1.43 M - 1.63 M	Basile-Wrightsville Complex, frequently flooded
1.63 M - 4.22 M	Wrightsville-Vidrine Complex
4.22 M - 4.78 M	Duralde silt loam, 1 to 3% slopes
4.78 M - 5.05 M	Wrightsville-Vidrine Complex
5.05 M - 5.52 M	Duralde silt loam, 1 to 3% slopes
5.52 M - 5.87 M	Wrightsville-Vidrine Complex
5.87 M - 6.05 M	Duralde silt loam, 1 to 3% slopes
6.05 M - 6.30 M	Muskigee-McKamie Complex (MuD2)
6.30 M - 6.36 M	Duralde silt loam, 1 to 3% slopes
TEXAS GAS LATERAL	
0.00 T- 0.42 T	Crowley-Vidrine Complex
0.42 T - 0.64 T	Mowata Silt Loam
0.64 T - 0.70 T	Crowley-Vidrine Complex
SOUTH CORRIDOR	
5.25 S - 5.36 S	Mamou silt loam, 1 to 3% slopes
5.36 S -5.58 S	Crowley-Vidrine Complex
5.58 S -5.89 S	Mowata silt loam
5.89 S -6.16 S	Crowley-Vidrine Complex
6.16 S -6.37 S	Mowata silt loam

Mile Post	Soil Series/Complex
6.37 S -7.12 S	Crowley-Vidrine Complex
7.12 S -7.16 S	Mowata silt loam
7.16 S -7.89 S	Crowley-Vidrine Complex
SOUTH CORRIDOR	
7.89 S -7.99 S	Mowata silt loam
7.99 S -8.11 S	Crowley-Vidrine Complex
8.11 S -8.20 S	Mowata silt loam
8.20 S -8.29 S	Wrightsville-Vidrine Complex
8.29 S -8.37 S	Basile-Wrightsville Complex, frequently flooded
8.37 S -8.91 S	Wrightsville-Vidrine Complex
8.91 S -9.05 S	Mowata silt loam
9.05 S -9.13 S	Wrightsville-Vidrine Complex
9.13 S -9.16 S	Mowata silt loam
9.16 S -9.30 S	Crowley-Vidrine Complex
9.30 S -9.45 S	Mowata silt loam
9.45 S -10.26 S	Crowley-Vidrine Complex
10.26 S -10.43 S	Mowata silt loam
10.43 S -10.46 S	Crowley-Vidrine Complex
10.46 S -11.43 S	Mowata silt loam
11.43 S -11.55 S	Crowley-Vidrine Complex
11.55 S -11.80 S	Mowata silt loam
11.80 S -11.97 S	Wrightsville-Vidrine Complex
11.97 S -12.02 S	Basile-Wrightsville Complex, frequently flooded
12.02 S -12.39 S	Wrightsville-Vidrine Complex
12.39 S -12.45 S	Acadia silt loam, 1 to 3% slopes
12.45 S -12.56 S	Basile-Wrightsville Complex, frequently flooded
12.56 S -12.62 S	Acadia silt loam, 1 to 3% slopes
12.62 S -13.02 S	Wrightsville-Vidrine Complex
13.02 S -13.17 S	Crowley-Vidrine Complex
13.17 S -13.22 S	Mowata silt loam
13.22 S -13.56 S	Crowley-Vidrine Complex
13.56 S -13.60 S	Mowata silt loam
13.60 S -14.06 S	Crowley-Vidrine Complex
14.06 S -14.54 S	Mowata silt loam
14.54 S -15.16 S	Crowley-Vidrine Complex
15.16 S -15.21 S	Mamou silt loam, 1 to 3% slopes
15.21 S -15.24 S	Basile-Wrightsville Complex, frequently flooded
15.24 S -15.45 S	Wrightsville-Vidrine Complex
15.45 S -16.08 S	Mowata silt loam
16.08 S -16.37 S	Crowley-Vidrine Complex
16.37 S -16.49 S	Wrightsville-Vidrine Complex
NORTH @ TGP Meter Site	
17.80 N	Ruston Fine Sandy Loam, 1 to 3% slopes
17.80 N	Malbis Fine Sandy Loam, 1 to 5% Slopes
17.80 N	Guyton Complex, Frequently Flooded

7.6 REFERENCES

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PUBLIC

RESOURCE REPORT 8

LAND USE, RECREATION AND AESTHETICS

Pine Prairie Energy Center Storage Project
Evangeline Parish, Louisiana

July 2004

RESOURCE REPORT 8 – LAND USE, RECREATION AND AESTHETICS FERC ENVIRONMENTAL CHECKLIST

Filing Requirements	Company Compliance or Inapplicability of Requirement
1. Classify and quantify land use affected by: ♦ Pipeline construction and permanent rights-of-way; ♦ Extra work/staging areas; ♦ Access roads; ♦ Pipe and contractor yards; and ♦ Aboveground facilities.	**Appendix A** Land Requirements and Existing Land Use
2. Identify by milepost all locations where the pipeline ROW would at least partially coincide with existing ROW, adjacent to existing ROWs, and outside of existing ROW.	**Table 8-2** New and Existing ROWs Along Proposed Pipelines
3. Provide detailed typical construction ROW cross-section diagrams showing information such as widths and relative locations of existing ROW, new permanent ROW and temporary construction ROW.	**Figures 1.2-1A1, 1.2-2A1 – A3, 1.2-3A1 - A7, 1.3-1A1 – A4, and 1.3-2A1 – A3**
4. Summarize the total acreage of land affected by construction and operation of the project.	**Table 8-1** Summary of Acreage Impacted By Project
5. Identify by milepost all planned residential or commercial/business development and the time frame for construction. ♦ Identify all planned development crossed or within 0.25 mile of proposed facilities.	**§ 8.3.2** Planned Residential Areas
6. Identify by milepost special land uses.	**§ 8.4** Public Land, Recreation and Other Designated Areas
7. Identify by beginning milepost and length of crossing all land administered by Federal, state, or local agencies, or private conservation organizations.	**§ 8.4** Public Land, Recreation and Other Designated Areas
8. Identify by milepost all natural, recreational, or scenic areas and all registered natural landmarks crossed by the project. ♦ Identify areas within 0.25 mile of any proposed facility.	**§ 8.4** Public Land, Recreation and Other Designated Areas
9. Identify all facilities that would be within designated coastal zone management areas.	N/A – because the Project is located outside of a Coastal Zone Management Area
10. Identify by milepost all residence that would be within 50 feet of the construction right-of-way or extra work area.	**§ 8.3** Residential Areas
11. Identify all designated or proposed candidate National or State Wild and Scenic Rivers crossed by the project.	**§ 8.4** Public Land, Recreation and Other Designated Areas
12. Describe any measures to visually screen aboveground facilities, such as compressor stations.	**§ 8.5** Visual Resources
13. Demonstrate that applications for ROW or other proposed land use have been or soon will be filed with Federal land-managing agencies with jurisdiction over land that would be affected by the project.	N/A – The Project does not involve any federal, state or Indian administered or owned lands
14. Identify all buildings within 50 feet of the construction right-of-way or extra work areas.	**§ 8.3.1** Existing Residences
15. Describe the management and use of all public lands that would be crossed.	**§ 8.4** Public Land, Recreation and Other Designated Areas
16. Provide a list of landowners by milepost or tract number that corresponds to information on alignment sheets.	**Appendix D** Landowner List
17. Provide a site-specific plan for residences within 50 feet of construction.	**Appendix B** Erosion and Sediment Control Plan

TABLE OF CONTENTS

TABLES

8.0 RESOURCE REPORT 8 – LAND USE, RECREATION AND AESTHETICS

8.1 SITE DESCRIPTION

The Pine Prairie Energy Center Storage Project is a high deliverability, natural gas storage facility designed for injection, storage and withdrawal of natural gas in salt caverns. The Gas Storage Site will be located on a 60.57-acre parcel of company-owned land approximately 15 miles north of Eunice and approximately 1 mile west of Easton, in Section 36, Township 3 South, Range 1 West in Evangeline Parish, LA. The Brine Disposal and Raw Water Withdrawal site will be located on an approximately 10-acre parcel of land to be acquired by PPEC. The precise dimensions of this parcel are being established through negotiations with the affected landowners; it will fall entirely within a larger area of approximately 30 acres that PPEC and its consultants have evaluated. This site is located approximately 1.92 miles southwest of the Gas Storage Site. Pipeline and related metering and regulation facilities associated with the Project will extend for relatively short distances into Rapides Parish (to the north of the proposed Gas Storage Site) and Acadia Parish (to the south of the Gas Storage Site).

The property to be occupied by the Gas Storage Site and the Brine Disposal and Raw Water Withdrawal Site is unimproved land consisting primarily of pine forest, native grasses and shrubs. With the exception of occasional timbering, there are no known current uses of the property.

8.2 LAND REQUIREMENTS OF PROPOSED FACILITIES

Table 8-1 summarizes the total acreage of land affected by construction and operation of the Project. A detailed description of the temporarily and permanently impacted land types is located in Appendix A.

8.2.1 GAS STORAGE SITE

The following components of the Project will be located on a 60.57-acre parcel of company-owned land in Evangeline Parish, Louisiana.

8.2.1.1 Gas Handling Facility

The Gas Handling Facility will consist of the Compressor Station, gas dehydration equipment, and other associated infrastructure necessary to support the direction and routing of gas to and from the Gas Storage Caverns located nearby. (See **Figures 1.4-1A2** *Map of Survey (Gas Storage Site and Gas Handling Facility*, **1.1-3A1** *Gas Storage Site - Aerial*, **1.1-9A1** *Gas Handling Facility Layout.*) The main compressor building will be approximately 65 x 343 x 25 ft eve height. An estimated 9.88 acres will be temporarily impacted by construction of the Gas Handling Facility, of which 8.03 acres will be permanently impacted (see Table 8-1).

8.2.1.2 Gas Storage Caverns

Three Gas Storage Caverns will be developed within the Pine Prairie salt dome. (See Figure **1.1-13A1** *Typical Gas Storage Cavern Well Site Diagram.*) Each cavern will initially require a matted area for drilling operations measuring 200 ft x 323 ft plus an adjacent area measuring 150 ft x 30 ft (1.58 acres each). Once the cavern wells are drilled and completed, a 110 ft x 110 ft area will be permanently maintained at each site (0.28 acre each). An estimated 4.74 acres will be temporarily impacted by construction of the Caverns 1, 2 and 3, of which 0.84 acre will be permanently impacted (see Table 8-1).

8.2.1.3 Pipe Fabrication Area

The Contractor's Fabrication Area (200 x 323 feet) will be a temporary element of the Project (See **Figure 1.1-3A1**). It will first be located at the Gas Storage Cavern 2 site while Gas Storage Cavern 1 is being constructed. After Gas Storage Cavern 1 is completed, the Contractor's Fabrication Area will be relocated to the Gas Storage Cavern 1 site, where it will remain for the duration of construction activities. The Contractor's Fabrication Area will occupy the same space as one cavern area; therefore, an estimated 1.58 acres will be temporarily impacted and there will be no additional permanent impacts.

8.2.1.4 Service Corridor

Service Corridors will provide personnel and vehicular access, as well as pipeline, utility and transmission services, between the Gas Handling Facility and the Gas Storage Caverns. An estimated 6.40 acres will be temporarily impacted along the Service Corridors, of which 4.20 acres will be permanently impacted (see Table 8-1).

8.2.2 BRINE DISPOSAL AND RAW WATER WITHDRAWAL SITE

The Brine Disposal and Raw Water Withdrawal Site will be constructed on a tract of approximately 10 acres to be located 1.92 miles southwest of the Gas Storage Site. (See **Figure 1.1-4A1** *Brine Disposal and Raw Water Withdrawal Facility Site -Aerial.*)

8.2.2.1 Raw Water Wells

Four Raw Water Wells will be developed to service the solution mining operations. Each well will initially require a matted area for drilling operations measuring 125 ft x 125 ft (0.36 acre). A 30 ft x 30ft area (0.02 acre) will be permanently maintained around each well for wellhead piping and operation of associated components. An estimated 1.44 acres will be temporarily impacted by the construction of the four Raw Water Withdrawal Wells, and 0.08 acres will be permanently impacted (see Table 8-1).

8.2.2.2 Brine Disposal Wells

Four Brine Disposal Wells will be developed to dispose of brine produced in the salt cavern solution mining process. Each well will initially require a matted area for drilling operations measuring 145 ft x 210 ft plus a 28 ft x 150 ft matted area (0.80 acre). Upon completion of drilling, a 110 ft x 110 ft area (0.28 acre) will be permanently maintained around each well. An estimated 3.20 acres will be temporarily impacted by construction of the four Raw Water Withdrawal Wells, and 1.12 acres will be permanently impacted (see Table 8-1).

8.2.2.3 Service Corridors

The Service Corridors connecting the Brine Disposal Wells and the Raw Water Wells will provide personnel and vehicular access, as well as pipeline, utility and transmission services, to the well sites. These corridors will include all service roads, road entries from Ambrose Road, pipelines, pipe-ways and power lines. An estimated 5.36 acres will be temporarily impacted along the Service Corridors, and 0.52 acre will be permanently impacted.

Table 8-1 Summary of Acreage Impacted by Project

Proposed Facilities	Total Length (miles) Size (acres) or Number of Sites	Temporarily Impacted (acre)	Permanently Impacted (acre)
Gas Storage Site			
♦ Gas Handling Facility	1	9.88	8.03
♦ Gas Storage Caverns Sites	3	4.74	0.84
♦ Contractor's Fabrication Area	1	1.58	0.00
♦ Service Corridors	1	6.40	4.20
Subtotal		22.60	13.07
Brine Disposal and Raw Water Withdrawal Well Site			
♦ Water Withdrawal Wells	4	1.44	0.08
♦ Brine Disposal Wells	4	3.20	1.12
♦ Service Corridors	1	5.36	0.52
Subtotal		10.00	1.72
Mid Pipeline Corridor (including Temporary Extra Work Space)	6.36 miles	85.24	42.56
North Pipeline Corridor	17.80 miles	0.25	0.00
South Pipeline Corridor (including Temporary Extra Work Space)	27.73 miles	133.08	30.66
East Lateral Pipeline Corridor (including Temporary Extra Work Space)	3.17 miles	36.15	11.51
TGT Lateral Pipeline Corridor	0.70 miles	8.79	2.55
Meter and Regulator Sites and Interconnects			
♦ Meter and Regulator Sites	6	42.70	4.28
♦ Interconnects (including Temporary Extra Work Space)	7	9.60	0.00
Contractors' Temporary Yards	5	43.51	0.00
TOTAL		**391.92**	**109.35**

8.2.3 GAS TRANSMISSION PIPELINES

The third major component of the proposed Project is a system of gas transmission pipelines linking the Project with seven mainline gas transmission pipelines. (**Figure 1.1-6A1** *Corridor Intersection Site*, **Figure 1.1-6A2** *East Lateral Pipeline Tie-in*, and **Figure 1.1-6A3** *TGT Tie-in*.) Table 8-2 identifies the locations where a pipeline will be constructed in or adjacent to an existing transmission ROW.

8.2.3.1 Mid Pipeline Corridor

The Mid Pipeline Corridor will connect the Gas Handling Facility with the North Pipeline Corridor and the South Pipeline Corridor (the corridors by which the Project will initially be interconnected with the six transmission pipelines at the Meter and Regulator Site and Interconnections discussed later in this Resource Report). This corridor will be approximately 6.36 miles long.

- The first segment of the Mid Pipeline Corridor will be approximately 1.92 miles in length and will extend from the Gas Handling Facility to the Brine Disposal and Raw Water Withdrawal Site. This segment will house two 24-inch bi-directional natural gas pipelines, one 16-inch raw water withdrawal pipeline and one 16-inch brine disposal pipeline.

- In the second segment, the two 24-inch bi-directional natural gas pipelines will continue from the Brine Disposal and Raw Water Withdrawal Site for approximately 0.36 mile to the ANR ML2 Meter and Regulator Site.

- In the third segment, the two 24-inch bi-directional pipelines will continue from the ANR ML2 Meter and Regulator Site 4.08 miles further to the North & South Pipeline Corridor connection.

The Mid Pipeline Corridor will be constructed in a 100-foot wide ROW (50 feet permanent, 50 feet temporary, with extra temporary work space at specific road and bayou crossings). The corridor will be approximately 6.36 miles long. Disturbed acreage along the Mid Pipeline Corridor will include 85.24 acres of temporary ROW, and 42.56 acres of permanent ROW, of which 30.66 acres is permanent wooded impact.

8.2.3.2 North Pipeline Corridor

The North Pipeline Corridor will link the Mid Pipeline Corridor with existing interstate gas transmission pipelines at Metering and Interconnect Sites located north of the Gas Storage Site. (See **Figures 1.1-8A1 – 8A7** *Footprint of Pipeline, Alignment and Facility, North Pipeline Corridor*.) It will consist of an existing 24-inch bi-directional natural gas pipeline (with an existing 30-foot wide permanent ROW) that extends approximately 17.80 miles from the Mid Pipeline Corridor connection to the Tennessee Gas Meter and Regulator Site. This existing pipeline is a portion of the former Louisiana Chalk Gathering System (see Table 8-2). It is primarily located in Evangeline Parish, but it extends for a short distance into Rapides Parish.

Disturbed acreage along the North Pipeline Corridor will include less than 0.25 acres of temporarily impacted land; however, zero acres will be permanently impacted since the existing ROW will be used (see Table 8-1).

8.2.3.3 South Pipeline Corridor

The South Pipeline Corridor is an existing pipeline corridor that was created by the construction of the Louisiana Chalk Gathering System. (See **Figures 1.1-10A1 – 10A6** *Detailed Route and Wetland Alignment Sheet, South Pipeline Corridor*). It will link the Mid Pipeline Corridor with gas transmission pipelines to the south and southeast of the Gas Storage Site. The South Pipeline Corridor will be composed of:

- **A new 11.24-mile long, 24-inch bi-directional pipeline that will loop and be installed immediately adjacent to the existing 24-inch pipeline**

  The new 24-inch bi-directional pipeline will extend from the Mid Pipeline Corridor connection, south past the Transco Meter and Regulator Site and the Texas Gas Transmission Meter and Regulator Site, and will end at the Texas Eastern Transmission Meter and Regulator Site. The new pipeline will be constructed within a 100-foot wide ROW that consists of the existing 30-foot permanent easement (or servitudes), plus 70 feet of temporary work space, with extra temporary work space at specific road and bayou crossings. This will vary in some areas because of the configuration of the existing easement, but the total workspace will not exceed 100 feet, except at specific road and bayou crossings.

- **An existing 16.49-mile long, 24-inch bi-directional pipeline**

  The existing 24-inch pipeline continues south from the Texas Eastern Transmission Meter and Regulator Site for approximately 5.25 miles to the proposed East Lateral Pipeline Corridor connection. Existing ROW will be used for the installation of the new 24-inch pipeline, except where an additional 10 feet of width is required for about 6,981 feet of the ROW, and a new 30 feet of width is required for 7,913 feet of the ROW.

The South Pipeline Corridor is located primarily in Evangeline Parish, but it also extends a short distance into Acadia Parish. Disturbed acreage along the South Pipeline Corridor will include 133.08 acres of temporary ROW and 48.60 acres of permanent ROW, of which 6.40 acres is permanent wooded impact (see Table 8-1).

8.2.3.4 East Lateral Pipeline Corridor

The new 24-inch bi-directional natural gas pipeline in the East Lateral Pipeline Corridor will link the South Pipeline Corridor to transmission pipeline interconnects south and southeast of the Gas Storage Site. (See **Figures 1.1-10C1 – 10C2** *Detailed Route and Wetland Alignment Sheet, East Lateral Pipeline Corridor*.) Extending east from the South Pipeline Corridor Connection (located approximately 5.25 miles south of the Texas Eastern Transmission Interconnection), the 3.17-mile East Lateral Pipeline Corridor will service the ANR SE Metering Site and will terminate further east at the Florida Gas Transmission Metering Site. The pipeline will be constructed in a 100-foot wide ROW (30 feet permanent, 70 feet temporary, with extra temporary workspace at specific road and bayou crossings).

Disturbed acreage along the East Lateral Pipeline Corridor will include 36.15 acres of temporary ROW and 11.51 acres of permanent ROW, of which 3.41 acres is permanent wooded impact. (see Table 8-1).

8.2.3.5 TGT Lateral Pipeline Corridor

Disturbed acreage along the TGT Lateral Pipeline Corridor will include 8.79 acres of temporary ROW, which will be reduced to 2.55 acres of permanent ROW.

8.2.4 METER AND REGULATOR SITES AND INTERCONNECTS

Seven Meters and Regulators, located at six Meter and Regulator Sites, will be connected to the 24-inch pipelines extending to and from the Gas Handling Facility to facilitate custody transfer measurement to and from their associated pipeline interconnects. One of the Meter and Regulator Sites will be located in Rapides Parish at the terminus of the North Pipeline Corridor, and two will be located in Acadia Parish along and at the terminus of the East Lateral Pipeline Corridor. The other three Meter and Regulator Sites will be located in Evangeline Parish.

Sites will vary from 100 ft x 200 ft to 200 ft x 200, ft depending on location and equipment requirements. The ROW width will be 100 feet (30 permanent, 70 feet temporary, with extra work space at specific road and bayou crossings) and will total approximately 4,200 linear feet. An estimated 5.50 acres will be temporarily impacted by construction of the Meter and Regulator Sites and Interconnects, and 4.28 acres will be permanently impacted.

8.2.5 CONTRACTORS' TEMPORARY YARDS

It is anticipated that a total of five Contractors' Temporary Yards will be required along the pipeline corridors to store equipment and provide a fabrication area. It is estimated that Yard 1 will have a temporary impact on 5.4 acres of land, Yard 2 will temporarily impact 14.6 acres, Yard 3 will temporarily impact 11.1 acres, Yard 4 will temporarily impact 1.61 acres and Yard 5 will temporarily impact 10.8 acres. In total, an estimated 43.51 acres will be temporarily impacted by the construction of the five yards, but zero acres will be permanently impacted.

Table 8-2 New and Existing ROW Along Proposed Pipelines

Interconnecting Pipeline	New ROW (Milepost)	Existing ROW (Milepost)	Adjacent ROW (Milepost)
Pipeline connecting Gas Handling Facility and Gas Storage Caverns	4.44M – 6.36M		
Mid Pipeline Corridor	4.08M - 6.36M		0.0M - 4.08M
North Pipeline Corridor		0.00N - 17.39N	
South Pipeline Corridor		0.00S – 16.49S	5.25S – 16.49S
East Lateral Pipeline Corridor	0.00E – 0.85EL		0.85E – 3.17EL
TGT Lateral	0.00T – 0.70T		

8.3 RESIDENTIAL AREAS

8.3.1 EXISTING RESIDENCES

The proposed Project is located in a sparsely populated, rural area with scattered farm and non-farm residences. The route has been developed to minimize work near existing residences. The route will pass within 50 feet of only one year-round residence. The home is located adjacent to the existing South Pipeline Corridor. Any potential impacts to residents will involve short-term, site-specific impacts from construction noise and dust, construction equipment use of local roads, and work activities at road crossings.

8.3.2 PLANNED RESIDENTIAL AREAS

The majority of the Project is located in a rural area of Evangeline Parish, with one Meter and Regulator and Interconnect Site in Rapides Parish, and two Meter and Regulator and Interconnect Sites and part of the East Pipeline Lateral are in Acadia Parish. There are no currently proposed planned residential or commercial properties or projects on any of the land to be affected by construction, or the surrounding area.

8.4 PUBLIC LAND, RECREATION AND OTHER DESIGNATED AREAS

Land in this category includes lands identified for special scenic, recreational or cultural purposes or those that have received a special land use designation. These lands include but are not limited to:

- National or state parks and forests, Native American Indian reservations, wilderness areas, wildlife management areas, nature preserves, national trails, registered natural landmarks, and flood control land;
- Land used for designated recreational or conservation purposes,
- Land of historical or cultural significance;

- Landfills, hazardous waste sites, quarries, mines, or other special uses; and
- National scenic rivers, State scenic rivers and designated scenic areas or roads.

There are currently no existing or proposed categories of land described above that would be affected by the Project.

8.4.1 AGENCY AND LANDOWNER CONSULTATIONS

Agencies and landowners were contacted as appropriate to gather information regarding public lands, recreation areas and other special land use designated areas. Contacts made in preparation of the Resource Reports are included in Appendix C (Correspondence).

8.4.2 IMPACT AND MITIGATION

In the absence of public lands, recreation and other designated areas, no mitigation for impacts to these areas is proposed. Hunting is a popular activity in Evangeline, Acadia and Rapides Parishes. Discussions will be held with any affected landowners and hunting clubs prior to any hunting season if construction will be taking place during the season, to minimize any potential short term impacts. In addition, a safety awareness and training program will be developed and implemented prior to construction.

8.5 VISUAL RESOURCES

There are no visually sensitive areas along the proposed pipeline routes or within ½ mile of the proposed aboveground facilities. All above ground facilities have been sited at locations far removed and screened from the nearest residences.

PUBLIC

RESOURCE REPORT 9
AIR AND NOISE QUALITY

Pine Prairie Energy Center Storage Project
Evangeline Parish, Louisiana

July 2004

RESOURCE REPORT 9 – AIR AND NOISE QUALITY
FERC ENVIRONMENTAL CHECKLIST

Filing Requirements	Company Compliance or Inapplicability of Requirement
1. Describe existing air quality in project vicinity. Identify criteria pollutants that may be emitted above EPA-identified significance levels.	§ 9.2.3.2 National Ambient Air Quality Stds. (NAAQS)
2. Quantify existing noise levels at noise sensitive areas and at other areas covered by relevant state and local noise ordinances. Measure or estimate the existing ambient sound environment. Include a plot plan that identifies the locations and duration of noise measurements.	§ 9.3.5 Existing Noise Levels Plot plan – Attachment 9-1, Figure 1
3. Quantify existing and proposed emissions of compressor equipment, plus construction emissions, including Nox and CO, and the basis for these calculations.	Table 9.1 Summary of Potential Air Emissions
4. Summarize anticipated air quality impacts for the project.	Table 9.1 Summary of Potential Air Emissions
5. Describe proposed compressor units, including manufacturer, model number, horsepower and energy source.	§ 9.2.2 Process Description
6. Identify any nearby noise-sensitive area by distance and direction from the proposed compressor unit building/enclosure.	Table 9-2 Sound Survey Summary Results
7. Identify any applicable state or local noise regulations. Specify how the facility will meet the regulations.	§ 9.3.2 & 9.3.7
8. Calculate the noise impact at noise-sensitive areas of the proposed compressor unit modifications or additions, specifying how the impact was calculated, including manufacturer's data and proposed noise control equipment.	Attachment 9-1 Hoover & Keith Report
9. Provide copies of application for state air permits and agency determinations, as appropriate.	Appendix E
10. For major sources of air emissions, provide copies of applications for permits to construct (and operate, if applicable) or for applicability determinations under regulations for the prevention of significant air quality deterioration and subsequent determinations.	Appendix E
11. Describe measures and manufacturer's specifications for equipment proposed to mitigate impact to air and noise quality, including emission control systems, installation of filters, mufflers, or insulation of piping and building, and orientation of equipment away from noise-sensitive areas.	§ 9.3.7 Proposed Mitigation Measures

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RESOURCE REPORT 9 – AIR AND NOISE QUALITY

9.1 PROJECT DESCRIPTION

This resource report addresses the Air and Noise quality impacts associated with the proposed Pine Prairie Energy Center Storage Project (the Project). The Project is a high deliverability, natural gas storage facility designed for injecting and storing natural gas in salt caverns and for the withdrawal of stored gas from these caverns for delivery to various gas transmission pipelines. The gas storage caverns will be solution mined in the Pine Prairie Salt Dome, located in southwestern Louisiana in Evangeline Parish.

The Project will consist of surface and subsurface components:

- A Gas Handling Facility
- Three Gas Storage Caverns
- Four Raw Water Wells
- Four Brine Disposal Wells
- Four Pipeline Corridors
- Six Meter and Regulator Sites, and Interconnects
- Required Utilities and Roadways

9.1.1 GAS STORAGE SITE

The natural gas storage-related elements of the Project – the central compression facilities and related gas handling equipment – will be located at the Gas Storage Site, which will include the Gas Storage Cavern Area and the Gas Handling Facility. The Gas Storage Site will be located on a 60.57-acre parcel of company-owned land in Evangeline Parish, LA.

The Gas Storage Site is made up of three tracts of land:

1. The Gas Handling Facility will be located at the south end, and Cavern Wellhead Site 1 will be located at the north end of **Tract C**.

2. Cavern Wellhead 2 and Cavern Wellhead 3 will be located in the west-central and east-central portions of **Tract B**.

3. The future expansion Cavern Wellhead 4 will be located in the north-central section of **Tract A**.

9.1.1.1 Gas Handling Facility

An 8.03-acre Gas Handling Facility will be established within the 60.57-acre Gas Storage Site. It will be permanently fenced and maintained for construction and operation of the Gas Handling

Facility, the Leaching and Disposal Facilities, Contractor Fabrication Area and Permanent Roads (see **Figures 1.1- 1A3** *Project Location and Route Map*, **1.1-2A2** *Entire Project Overview*, **1.1-9A1** *Gas Handling Facility Layout* and **1.4-1A2** *Map of Survey – Gas Storage Site & Gas Handling Facility*).

The Gas Handling Facility will house the Compressor Station, gas dehydration equipment, and other associated infrastructures necessary to support the direction and routing of gas to and from the storage caverns located nearby. The main compressor building will house six 8,000 horsepower (hp) Caterpillar G16CM34 (or equal) gas engine driven Ariel JGV/6 (or equal) reciprocating compressors along with ancillary support equipment.

9.1.1.2 Gas Storage Caverns

Three Gas Storage Caverns will be developed within the Pine Prairie salt dome using the solution mining method. (See **Figures 1.1-3A1** *Gas Storage Site – Aerial* and **1.1-13A1** *Typical Gas Storage Cavern Well Site Diagram*) The tops of the caverns will be approximately 3,900 feet below the ground surface, with the caverns extending down to approximately 5,700 feet. Four definitive phases have been scheduled to develop the Project:

- **Phase 1** – Gas Storage Cavern 1 will be developed to a working gas capacity of up to 6.0 Bcf. Phase 1 will also incorporate the required pipeline infrastructure and incremental compression.

- **Phase 2** - Gas Storage Cavern 2 will be developed to a working gas capacity of 6.0 Bcf. Phase 2 will also incorporate the required additional pipeline infrastructure and incremental compression.

- **Phase 3** - Both Gas Storage Cavern 1 and 2 will be solution mined using the Solution Mining Under Gas (SMUG) process (described in Resource Report 6) to add an additional quantity of working gas capacity to each of the caverns to bring each cavern up to a total working gas capacity of 8.0 Bcf.

- **Phase 4** - Gas Storage Cavern 3 will be developed to a working gas capacity of 8.0 Bcf. Phase 4 will also incorporate the required additional pipeline infrastructure and incremental compression.

The Project will be configured so it can accommodate a fifth Phase in the future (adding Gas Storage Cavern Well 4 and additional incremental compression equipment) for an ultimate working gas capacity of 32 Bcf.

9.1.2 BRINE DISPOSAL AND RAW WATER WITHDRAWAL SITE

The second major component of the Project – the Brine Disposal and Raw Water Withdrawal Site - will be located on a 10-acre parcel of land. PPEC will drill and complete four raw water wells in the Evangeline Formation, and will use water drawn from this formation in its solution mining activities. PPEC will also develop four deep injection to dispose of brine produced in the salt cavern solution mining process.

9.1.3 GAS TRANSMISSION PIPELINES

The third major component of the proposed Project is a system of gas transmission pipelines linking the Project with seven mainline gas transmission pipelines. This system consists, in part, of a 34-mile segment of an existing 24-inch high-pressure gas pipeline known as the Louisiana Chalk Gathering System. PPEC has procured an option to purchase this pipeline segment (along with certain facilities and associated ROW and servitudes) and will exercise this option before starting construction of the Project. PPEC will construct a second 24-inch high pressure gas pipeline immediately adjacent to the existing 24-inch pipeline for much of the length of the South Pipeline Corridor.

9.1.4 METER AND REGULATOR SITES, AND INTERCONNECTS

Seven Meters and Regulators, located at six Meter and Regulator Sites, will be connected to the 24-inch pipelines extending to and from the Gas Handling Facility to facilitate custody transfer measurement to and from their associated pipeline interconnects. One of the Meter and Regulator Sites will be located in Rapides Parish at the terminus of the North Pipeline Corridor, and two will be located in Acadia Parish along and at the terminus of the East Lateral Pipeline Corridor. The other three Meter and Regulator Sites will be located in Evangeline Parish.

9.2 AIR QUALITY

9.2.1 REGIONAL CLIMATE AND EXISTING AIR QUALITY

The topography of the area consists of gently rolling hills at the northern-most metering site and relatively flat land throughout the rest of the Project area. Much of the land surface, however, has been laser-leveled to maximize the ability to add or remove water from fields to facilitate rice and crawfish cultivation activities. Therefore, relatively little of the natural topography remains.

Evangeline Parish has a warm, humid, subtropical climate characterized by relatively high rainfall. An average rainfall of more than four inches occurs in every month except September and October. The Gulf of Mexico has a moderating effect on the climate. The maximum temperature is at least 90° F on more than 80% of the days in July and August, but temperatures higher than 100° F are rare. Winters are usually mild. Extremely cold weather seldom lasts more than 3 or 4 days at a time.

9.2.2 PROCESS DESCRIPTION

The Pine Prairie Energy Center will receive sweet natural gas via pipeline. This gas will be routed through filter/separators and compressed for injection into the Gas Storage Caverns. Additionally, the facility will provide for the withdrawal of natural gas from each cavern for delivery to the sales pipeline. The majority of compression is required during the injection phase of the storage cycle, but a limited amount of compression is also required during the withdrawal phase. Compression will be provided by six Caterpillar G16-CM34 lean-burn, natural gas-fired engines. The rated horsepower for each engine is 8,033 hp.

During withdrawal, high-pressure natural gas is reduced from cavern pressure to the surface facility operating pressure. Following pressure reduction and filtration, the gas is processed through the TEG dehydration plant, which consists of three dehydration units. Wet gas flows to a TEG contactor, where a counter flowing stream of lean tri-ethylene glycol absorbs entrained water vapor. Dry natural gas leaves the dehydration unit for metering into the sales pipeline. Water laden TEG (rich TEG) is sent to a distillation unit for regeneration. Depending on the water vapor content of the Gas Storage Cavern gas, a portion of the gas may by-pass the dehydration system to be blended with dry, dehydrated gas downstream of the TEG contactor. This blending allows the Gas Handling Facility to efficiently process gas to meet pipeline quality specifications, reduces still vent emissions to the condenser/oxidizers, and reduces fuel consumption and exhaust emissions from the reboilers. Each dehydration unit will have a maximum gas processing capacity of 250 Mmscf/d, for a total plant capacity of 750 Mmscf/

9.2.3 AIR QUALITY REGULATORY REQUIREMENTS

The Clean Air Act (CAA) of 1970, 42 USC §§ 7401 et seq., as amended in 1977 and 1990 and 40 CFR Parts 50-99 are the basic Federal statutes and regulations governing air emissions. The provisions that are potentially relevant to this project are the Air Quality Control Region (AQCR) designations, National Ambient Air Quality Standards (NAAQS), Prevention of Significant Deterioration (PSD), New Source Review (NSR), New Source Performance Standards (NSPS), Maximum Achievable Control Technology Standards (MACT), and Title V Operating Permits. In addition, the Project will be subject to state regulations administered by the Louisiana Department of Environmental Quality (LDEQ).

9.2.3.1 Air Quality Control Region (AQCR)

The project is located in the Southern Louisiana-Southeast Texas Interstate Air Quality Control Region. AQCRs are designated as Classes I, II and III.

- Class I AQCRs are pristine wilderness areas. The Project and associated facilities will not be located in a Class I area, nor will they be located within 100 kilometers of a Class I area.

- The Project site is in a Class II AQCR.

- The Class III designation is intended for heavily industrial zones, and has to be specifically requested. In order to qualify, it must meet all the requirements outlined in 40 CFR Part 51.166. A request for Class III designation is not needed.

9.2.3.2 National Ambient Air Quality Standards (NAAQS)

The EPA has established NAAQS for six "criteria" air pollutants: Ozone, Nitrogen Oxide (NO_x), Carbon Monoxide (CO), Sulfur Oxides (SO_x), Particulate Matter (PM_{10}), and Lead. The NAAQS are set at a level where the air quality is protective of human health and the environment. All areas in the U.S. have been checked against the NAAQS and are classified as one of the following

- ***Non-attainment:*** any area that does not meet the NAAQS for the specific pollutant. Adjacent areas whose ambient air quality may be affected also have the potential of being classified as non-attainment areas;
- ***Attainment:*** any area that meets the NAAQS for the specified pollutant; or
- ***Unclassifiable:*** any area that cannot be classified on the basis of available information.

The proposed Project area is in attainment with the NAAQS.

The Louisiana Ambient Air Quality Standards for criteria pollutants are the same as the federal standards. Evangeline Parish is classified as attainment for all criteria pollutants. There are no existing, significant air pollutant-emitting sources in the Project area.

9.2.3.3 Prevention of Significant Deterioration (PSD) Requirements

Procedures have been established for federal pre-construction review of certain large projects located in attainment areas. The review process is intended to prevent the new sources from causing air quality to deteriorate beyond acceptable levels. The emission threshold for "major stationary sources" varies under PSD regulations according to the type of facility. A gas handling facility that includes compressors would be subject to PSD review if it constitutes a new major stationary source for an attainment pollutant. As defined by 40 CFR Parts 51.166(b)(1)(1)(b), the Project would be considered major under PSD if it emits, or has the potential to emit, 250 tons per year or more of any criteria pollutant.

The emission estimates for the Project (see Table 9-1) indicate that it will not trigger PSD requirements. Control devices will be installed, where appropriate, and in some instances operational limits (e.g. hours of operation) will be established to ensure that the limits imposed by the PSD Major Source definition are not exceeded.

9.2.3.4 New Source Performance Standards (NSPS)

NSPS are established as another method to control emissions, thereby helping to ensure continued attainment with the NAAQS or to help bring a non-attainment area into attainment. The potential NSPS that could be applicable to the Project include the following:

- Subpart Dc is applicable to fuel-fired heat transfer equipment with heat input capacity of 10 MMBTU/hr or more. This standard is potentially applicable to the tri-ethylene glycol reboiler; however the reboilers' maximum heat input capacity is less than 10 MMBTU/hr, and so is not applicable to this project.

- Subpart KKK is applicable to equipment leaks of VOCs at onshore natural gas processing plants. The standard is not applicable since no natural gas processing plant will be included in the Gas Handling Facility.

- Subpart LLL is applicable to SO_2 emissions from onshore natural gas processing. This standard applies to facilities that separate the H_2S and CO_2 contents from sour natural gas. Sour natural gas will not be handled at the Project. Since the proposed Project is not an onshore natural gas processing facility, Subpart LLL does not apply.

- Subpart Kb is applicable to VOC storage tanks with capacities greater than or equal to 10,000 gallons. Four VOC tanks with capacities greater than 10,000 gallons will be used at the Gas Handling Facility; consequently, Subpart Kb will be applicable.

9.2.3.5 Maximum Available Control Technology (MACT)

The Project could be subject to the National Emission Standards for Hazardous Air Pollutants from Natural Gas Transmission and Storage Facilities as found in 40 CFR, Part 63, Subpart HHH. These MACT standards apply to facilities that:

- Transport or store natural gas prior to entering a pipeline to a local distribution company or to a final end user if there is no local distribution company, and
- Are considered a major source for hazardous air pollutants (HAP) (10 tons per year (tpy) individual HAP, 25 tpy aggregate).

The three glycol dehydration units are a potentially affected source at the Gas Handling Facility because they have the potential to emit benzene, toluene, ethylbenzene and xylene (BTEX). These chemical compounds are classified as HAPs and are also volatile organic compounds. Under MACT emission control requirement, HAP emissions must be reduced by 95% or greater in all gases vented to the control device. This MACT standard should not apply to the proposed Project because the Gas Handling Facility is not estimated to be a major HAP source.

The other potentially affected emission source would be the compressor engines, which have the potential to emit formaldehyde. The EPA is currently developing a MACT standard for fuel-fired reciprocating engines that address formaldehyde emissions. The emissions from the proposed engines to be used in the Project were speciated for the individual HAPs. The results of this analysis show that the total HAP emissions from the dehydrators and engines are below the major source definition of 10 tpy individual and 25 tpy aggregate, and so the MACT would not apply.

9.2.3.6 Title V Operating Permit

The Title V Permit program, as described in 40 CFR Part 70, requires major sources of air emissions to obtain federal operating permits. The operating permit establishes conditions for the operation of applicable emission sources of air pollution. In addition, the permit defines the compliance demonstration and recordkeeping and reporting requirements. When determining the need for a Title V Operating Permit in attainment areas, such as Evangeline Parish, the major source threshold is:

- 100 tons per year of any criteria pollutant, and
- 10 tons per year of any individual HAP or 25 tons per year for aggregated HAPs.

Because the Gas Handling Facility is estimated to be a major source of NO_x and CO emissions, a Title V Operating Permit application will need to be filed with the LDEQ.

9.2.3.7 Risk Management Program (RMP)

The RMP is federal regulation designed to prevent the release of hazardous materials from accidents and minimize impacts when releases do occur. The regulation contains a list of substances and threshold quantities for determining applicability of the regulation to a facility. If a facility stores, handles or processes one or more substance on this list and at a quantity equal to or greater than specified in the regulation, it must prepare and submit a risk management plan.

With the exception of natural gas constituents (e.g., methane, ethane, propane, etc.), no regulated substances will be handled or stored in quantities greater than the applicability threshold. Natural gas pipelines do not fall under RMP regulations if they are covered by DOT or a state natural gas safety program certified by DOT. In addition, RMP regulations do not cover storage of natural gas incidental to transportation (e.g., gas taken from a pipeline during non-peak periods and placed in storage fields, then returned to the pipeline when needed). Consequently, a risk management plan is not required. The facility will maintain awareness of hazardous issues and meet the goal of the General Duty Clause.

9.2.4 APPLICABLE STATE AIR REQUIREMENTS

The LDEQ has been delegated authority by the EPA to manage the air quality permitting program and the MACT standards for HAPs. LDEQ requirements generally follow the EPA regulations.

9.2.5 POTENTIAL IMPACTS ON AIR QUALITY AND MITIGATION MEASURES

9.2.5.1 Construction-Related Air Emissions

There are a limited number of vehicles that will be associated with the construction of the Gas Handling Facility and the Brine Disposal and Raw Water Withdrawal Site and the various pipeline facilities. The air pollutant emissions that result from the operation of these vehicles and the generation of fugitive dust during construction activities are expected to be minor and temporary at all sites within the Project.

Vehicular exhaust and crankcase emissions from gasoline and diesel engines will comply with applicable EPA mobile source emission regulations (40 CFR Part 85). This will be done by using equipment manufactured to meet these specifications, thereby limiting the potential emissions. Fugitive dust may be produced during construction. Where appropriate, dust suppression methods, such as watering, will be used to minimize these potential impacts.

The compressor building will be designed in accordance with applicable local and state codes. The final configuration of the compressor building will be a pre-engineered, metal structure approximately 65 x 343 x 25 ft high. Insulation will be provided to reduce sound emissions from the compressor equipment as design dictates. The building will incorporate a 12-foot wide roll-up door at each end of the building to allow for loading and unloading of maintenance equipment.

9.2.5.2 Operations-Related Air Emissions

There are two emission sources associated with each TEG distillation unit: 1) combustion exhaust stacks for the gas-fired reboilers and 2) condenser still vents for venting distillation vapors from the regeneration of rich TEG. Each reboiler is used to heat rich TEG to approximately 400° F in order to vaporize absorbed water. The regenerated, lean TEG is routed back to the contactor to continue the dehydration process. Vapors from the still vents typically contain significant quantities of volatile organic compounds (VOCs) in addition HAPs such as benzene, toluene, methylbenzene and xylene. Still vent vapors from each dehydration unit at Pine Prairie will be sent to one of three condenser/oxidizers. In addition, flash tank off-gas is routed to the fuel system of each reboiler, or to the firebox.

Estimated emission levels for the compressor station and associated equipment are shown in Tables 9-1. The total emissions of each pollutant will be below the major source thresholds for PSD, but NO_x and CO will be above the threshold for the Title V Operating Permit Program. The emission data presented in Table 9-1 are based on manufacturer-supplied emission factors supplemented with EPA default emission factors obtained from AP-42 and assume continuous operation of the compressor engines, but limit the overall hours of operations of the compressor engines and the dehydrators. These operating limits are applied to the equipment cumulatively. For example, the compressors can individually operate up to 24 hours per day, but collectively the operation of the engines has a specific annual hp-hour limit given in the permit.

Specific details on each emission source, such as the hours of operation, fuel use and emission factors, are presented in the Air Permit Application that is included in Appendix E.

Table 9-1 Summary of Potential Emissions

Source	Operating %	VOC tpy	NO_x tpy	CO tpy	SO_2 tpy	PM_{10} tpy	Comments
Caterpillar G16CM34 (6)	*	7.932	226.22	64.58	0.654	0.102	85% load
Blowdowns		0.109					
Emergency Diesel Engine	1.19	0.087	0.816	0.176	0.054	0.058	
Line Heaters (3)	8	0.039	0.810	0.681	0.009	0.063	
TEG Reboilers (3)	21.83	0.183	3.765	3.105	0.036	0.285	
TEG Still Vents (3)	21.83	N/A	N/A	N/A	N/A	N/A	Emissions sent to oxidizer
Thermal Oxidizers (3)	21.83	6.711	14.262	122.29	0.129	0.216	99% efficiency
Fugitive Emissions	100	0.38					
Flash Emissions	100	18.31					
Tanks	100	0.50					
Loading Emissions	100	0.784					
Totals		**35.035**	**245.87**	**190.83**	**0.882**	**0.724**	

* Note: Each engine will be permitted to operate up to 24 hours/day, although collectively they cannot operate on a 12-month rolling basis for more than the hp-hr limit that will be established in the air permit. The emissions summarized in Table 9.1 reflect the accumulated operation of all six engines.

9.2.6 DETERMINATIONS AND PERMITS

The Project will require a permit to construct an air pollution source from LDEQ. However, because the site is located in an area that is attainment with all NAAQS, and criteria air pollutants emissions are below the threshold for applicability of PSD, the permit application is not subject to PSD review.

Louisiana regulations require that a Permit be obtained before starting work. The submitted permit (Appendix E) is both a construction and an operating permit. The permit application includes a complete analysis of all the emissions, emission rates and operating conditions.

9.3 NOISE QUALITY

9.3.1 GENERAL

There are several metrics used for quantifying and regulating environmental noise, although the most common metrics used by federal, state and municipal agencies is the A-weighted (A-wt.) sound level. The A-wt. sound level is a single-figure sound rating, expressed in decibels, which correlates to the human perception of loudness of sound. The dBA level is commonly used to measure industrial and environmental noise since it is easy to measure and provides a reasonable indication of the human annoyance value of the noise.

Because noise levels can vary over a given time period, they are further quantified using the Equivalent Sound Level (Leq) and Day-Night Sound Level (Ldn). The Equivalent Sound Level (Leq) can be considered an average sound level measured during a period of time, including any fluctuating sound levels during that period. The Ldn is an energy average of the measured daytime Leq (Ld) and the measured nighttime Leq (Ln) plus 10 dB. The 10-dB adjustment to the Ln is intended to compensate for nighttime sensitivity. Ld is the equivalent A-weighted sound level, in decibels, for a 15 hour time period, between 07:00 and 22:00 hours (7:00 a.m. and 10:00 p.m.). Ln is the equivalent A-weighted sound level in decibels for a 9 hour time period, between 22:00 and 07:00 (10:00 p.m. and 7:00 a.m).

9.3.2 EXISTING REGULATORY ENVIRONMENT

FERC guidelines (18 CFR § 157.206-(b)(5)]) require that the noise attributable to any new compressor unit addition or modification not exceed an Ldn of 55 dBA at the nearest noise sensitive area (school, hospitals or residence) unless such noise sensitive areas are established after facility construction. The EPA has identified an Ldn of 55 dBA as being the maximum sound level that will not adversely affect public health and welfare by interfering with speech and other activities in outdoor areas, with an adequate margin of safety (USEPA, 1974). The State of Louisiana does not regulate ambient noise levels (LDEQ 2004), nor are there currently any applicable county or local noise regulations.

9.3.3 SITE DESCRIPTION

The proposed Gas Storage Site and related Brine Disposal and Raw Water Withdrawal Site are located in Evangeline Parish, Louisiana, approximately 18 miles north of Eunice, Louisiana. The land surrounding these proposed sites is primarily rural and is typically used for oil and gas production.

The proposed Project has two areas that contain surface facilities that were included in the noise survey:

- The Gas Storage Site, including the Gas Handling Facility, which will include compression, gas dehydration equipment, and other associated infrastructure necessary to support the direction and routing of gas to and from the Gas Storage Caverns located nearby (see Figure 1.1-9A1).

- The Brine Disposal and Raw Water Withdrawal Site, approximately 1.92 miles southwest of the Gas Storage Site (see Figure 1.1-4A1).

9.3.4 AMBIENT SOUND SURVEY AND NOISE IMPACT ANALYSIS

Hoover & Keith Inc. has performed an Ambient Sound Survey and Noise Impact Analysis for the Pine Prairie Energy Center Gas Storage Project. See Hoover & Keith Report No. 1842, dated July 7, 2004, which is included in its entirety as Attachment 9-1. The sound survey and noise impact analysis was performed to:

- Document the existing acoustic environment prior to the Project's operation and locate the nearby noise-sensitive areas (NSAs) around the site of the two sites that will host noise-producing facilities (the Gas Handling Facility and the Brine Disposal and Raw Water Withdrawal Site;

- Estimate the sound contribution of the proposed facility at the nearby NSAs during the drilling portion of construction of the Project;

- Estimate the sound contribution of the proposed Gas Handling Facility at the nearby NSAs during normal operation of the facility equipment; and,

- Determine noise mitigation measures to ensure that applicable sound level criteria are not exceeded due to the operation of the proposed facilities.

9.3.5 EXISTING NOISE LEVELS

Hoover & Keith conducted a sound survey to determine the existing noise levels in the vicinity of the Project on June 15, 2004. Table 9-2, which was taken from the Hoover & Keith report and follows, summarizes the existing noise levels.

Table 9-2 Sound Survey Summary Results

Meas. Position	Description of NSA and Sound Measurement Location	Meas'd. L_d (dBA)	Calc'd L_{dn} (dBA)
Pos. 1	NSA #1: Houses 2300 ft. ENE of the Compressor Bldg.	42.9	49.3
Pos. 2	NSA #2: House 2320 ft. ESE of the Compressor Bldg.	36.9	43.3

9.3.6 POTENTIAL IMPACTS ON NOISE QUALITY

The potential sound level impacts associated with the Project will consist of short-term impacts due to construction and long-term impacts due to facility operation.

9.3.6.1 Short-Term Impacts (Construction)

The most prevalent sound source during construction is anticipated to be the internal combustion engines used to provide mobility and operating power to construction equipment. The sound level impacts on the NSAs from construction operations will depend on the type of equipment used, the equipment mode of operation, the length of time that the equipment is in use, the amount of equipment used simultaneously and the distance between the sound source and the NSA. All of these factors will be constantly changing throughout the construction period, making an estimate of the sound levels and quantification of construction impacts difficult.

For the noisier pieces of typical construction equipment, a distance of approximately 800 feet between the noise sensitive area and the construction equipment should result in a sound level of 65 dBA or less, which is not considered a substantial sound impact during daylight hours. The intermittent, short-term nature of the construction noise and the distance between the noise sensitive areas and the proposed construction areas suggests that impacts from construction noise will be acceptable.

9.3.6.2 Long-Term Impacts (Operational)

The Hoover & Keith noise impact analysis considers the noise produced during operation of the Gas Handling Facility and the Brine Disposal and Raw Water Withdrawal Site that could impact the sound contribution at the nearby NSAs. Hoover & Keith noise impact analysis estimates the sound contribution for the following conditions:

- Sound level contribution of the facility at the closest NSA during operation of the Gas Handling Facility;
- Total estimated noise level of the facility at NSA #1 (i.e., estimated noise level of the facility plus measured ambient noise level).

The predicted sound contribution of the facilities at the nearby NSAs was performed for the closest NSA (i.e., NSA #1) since the sound contribution at the other NSAs should be equal to or less than the sound contribution at the closest NSA.

Tables 9-3 shows a summary of the estimated sound level impacts at NSA #1, which is 2,300 feet away from the Gas Handling Facility during the drilling portion of the operation and the daily operation of the Facility. The results of the noise impact analysis indicate that the noise attributable to the Project should be lower than the FERC sound level requirements of 55 dBA Ldn at the nearby NSAs.

Table 9-3 Summary of Noise Quality Analysis

Type of Operation	Meas'd Ambient L_d (dBA)	Calc'd Ambient L_{dn} via Meas'd L_d (dBA)	Est'd L_{dn} Of the Facility (dBA)	Total Est'd L_{dn} (Facility + Ambient Noise)	Potential Noise Increase
Drilling Operations	42.9	49.3	50.8	53.1	3.8 dB
Daily Operation of Facility	42.9	49.3	50.3	52.9	3.5 dB

9.3.7 PROPOSED MITIGATION MEASURES

Hoover & Keith Report No. 1842, dated July 70, 2004, contains detailed noise control measures for the significant sound sources of the proposed Project facilities along with the pertinent assumptions that may affect the noise emitted by these facilities. A copy of the report can be found in Attachment 1. The detailed noise control measures will address the following equipment, shown by way of example and not by way of limitation:

- Noise generated by the engine-compressor units that penetrates the building;
- Noise radiated from outdoor piping located between the units and gas coolers;
- Noise radiated from outdoor gas piping and associated piping components;
- Noise of each engine exhaust, including noise of the outdoor exhaust piping;
- Noise generated by each engine air intake system;
- Noise of the outdoor jacket-water (JW) cooler for each engine;
- Noise radiated by the 2500 hp raw water injection pumps operating at full load;
- Noise generated by the 1000 hp brine injection pumps operating at full load;
- Noise of typical oil field drill rig operating at full load;
- Noise of the outdoor line heaters, if employed; and
- Other miscellaneous "smaller" motor-driven pumps and equipment.

PPEC has committed to implement the detailed noise control measures suggested in Hoover & Keith Report No. 1842, dated July 7, 2004, which is included as Attachment 9-1. The noise control measures for the Brine Disposal and Raw Water Withdrawal Site are summarized in Table 9-4 and the controls for the Gas Storage Facility are summarized in Table 9-5.

Table 9-4
Summary of Noise Control Measures at Brine Disposal and Raw Water Facility

SYSTEM	CONTROL
Other "Smaller" Motor-Driven Pumps and Substation	Noise controls are not expected to be necessary for equipment associated with the substation.

Table 9-5 Summary of Noise Control for Gas Handling Facility

SYSTEM	CONTROL
Building Structure	♦ The walls and roof will be constructed of exterior steel of 18 gauge and an interior layer of 6-inch thick unfaced mineral wool covered with a 26 gauge perforated metal liner. ♦ Personnel entry doors will seal well with the doorframe and be self-closing. ♦ The large access openings will be a minimum 20-ga. Insulated type. ♦ Windows, louvers or skylights will not be installed.
Building Ventilation	♦ Noise associated with each building air-supply fan will not exceed 60 dBA at 50 feet. ♦ Each air-supply fan will include a metal boot enclosing the fan; a minimum 3-feet length exterior silencer and a weather hood lined with acoustical insulation.
Engine Exhaust System	♦ The exhaust system for each Caterpillar will be designed to meet the dynamic sound insertion loss values specified in Attachment 1.
Additional Aboveground Gas Piping	♦ Noise control measures are not expected to be necessary.
Engine Air Intake System	♦ The air intake system of each engine will include a filter/cleaner system that meets the DIL values specified in Attachment 1.
Engine Jacket Water Cooler	♦ The water jacket for each engine will not exceed 62 dBA at 50 feet from the cooler perimeter at full operating conditions.
Gas Intercooler and Aftercooler	♦ The sound level of each gas intercooler and aftercooler will not exceed 65 dBA at 50 feet from the cooler perimeter at full operating conditions
Pressure Reduction System	♦ The primary gas pressure-reducing valves and gas flow-control valves associated with the Pressure Reduction System will incorporate a Fisher WhisperTrim Type I or WhisperFlow type of "low-noise" cages or an equivalent type of "low-noise" valve trim system.
Brine Disposal and Raw Water Injection Pumps	♦ Each motor-driven pump will be designed not to exceed a sound level of 95 dBA at 3 feet from the pump perimeter at the rated operating conditions. This may require that the electric motor be a "low-noise" type of motor.
150 hp and 100 hp Pumps	♦ Each of the motor-driven pumps will be designed not to exceed a sound level of 90 dBA at 3 feet from the pump perimeter at the rated operating conditions.

9.3.8 POST-CONSTRUCTION SOUND SURVEY

After operation of the facility commences, a Post-Construction Sound Survey will be performed at the Gas Handling Facility to ensure that the L_{dn} level at the nearby NSAs due to the operation of the facility does not exceed an L_{dn} of 55 dBA. The results of the Post-Construction Sound Survey will be submitted to the Commission within 90 days of facility startup.

ATTACHMENT 9-1

HOOVER & KEITH REPORT NO.1842
DATED JULY 7, 2004
RESULTS OF AN AMBIENT SOUND SURVEY
AND
NOISE IMPACT ANALYSES OF THE PROPOSED PINE PRAIRIE ENERGY CENTER GAS STORAGE FACILITY & PROPOSED DRILLING PORTION OF THE OPERATION

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PINE PRAIRIE ENERGY CENTER (GAS STORAGE FACILITY): RESULTS OF AN AMBIENT SOUND SURVEY AND NOISE IMPACT ANALYSES OF THE PROPOSED GAS STORAGE FACILITY & PROPOSED DRILLING PHASE OF PROJECT CONSTRUCTION.

REPORT SUMMARY

This report provides the results of the noise impact analyses of the **Pine Prairie Energy Center**, a grass roots gas storage facility to be located in Evangeline Parish, Louisiana.

The intent of the noise impact analyses is to predict the sound level contribution from the proposed natural gas storage facility and determine noise control measures to meet applicable sound level criteria. Also included are the results of the recent ambient sound survey (performed June 15, 2004) at the proposed site of the Gas Storage Facility and the Brine Disposal and Raw Water Withdrawal Site.

The following table summarizes the noise quality analysis for the facility at the closest NSA (i.e., NSA #1) for the drilling portion of the Project's construction.

Closest NSA and Direction from Anticipated Location of Compr. Bldg.	Approx. Distant of NSA to Anticipated Location of Compr. Bldg.	Meas'd Ambient L_d (dBA)	Calc'd Ambient L_{dn} via Meas'd L_d (dBA)	Est'd L_{dn} Of the Facility (dBA)	Total Est'd L_{dn} (Facility + Ambient Noise)	Potential Noise Increase
NSA #1 (ENE)	2300 feet	42.9	49.3	50.8	53.1	3.8 dB

The following table summarizes the noise quality analysis for the facility at the closest NSA (i.e., NSA #1), assuming operation of the equipment associated with the Gas Storage Facility.

Closest NSA and Direction from Anticipated Location of Compr. Bldg.	Approx. Distant of NSA to Anticipated Location of Compr. Bldg.	Meas'd Ambient L_d (dBA)	Calc'd Ambient L_{dn} via Meas'd L_d (dBA)	Est'd L_{dn} Of the Facility (dBA)	Total Est'd L_{dn} (Facility + Ambient Noise)	Potential Noise Increase
NSA #1 (ENE)	2300 feet	42.9	49.3	50.3	52.9	3.5 dB

(Continued next page)

The results of the noise impact analysis indicates that if the recommended and/or anticipated noise control measures are successfully implemented, the noise attributable to the facilities associated with the Pine Prairie Energy Center should be lower than the typical FERC sound level requirement of **55 dBA** (L_{dn}) at the nearby NSAs. In addition, the Gas Storage Facility operations and drilling phase construction operations should have "minimum noise impact" on the surrounding environment. "Minimum noise impact" implies that the noise of the facility should not interfere with public activity or be an annoyance outdoors.

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1.0 INTRODUCTION

The results of the noise impact analyses of the proposed **Pine Prairie Energy Center** gas storage facility are presented. Also included are the results of an ambient sound survey (performed June 15, 2004) at the site. The purpose of the sound survey and noise impact analyses is four-fold:

(1) Document the existing acoustic environment prior to the Project facilities' operation and locate the nearby noise-sensitive areas (NSAs) around the site of the facilities;

(2) Estimate the sound contribution of the proposed facility at the nearby NSAs during the drilling portion of construction of the Project, both at the Gas Handling Facility Site and the Brine Disposal and Raw Water Withdrawal Site;

(3) Estimate the sound contribution of the proposed Gas Handling Facility at the nearby NSAs during normal operation of the facility equipment; and,

(4) Determine noise mitigation measures to ensure that applicable sound level criteria are not exceeded due to the operation of the proposed facility.

2.0 TYPICAL SOUND LEVEL METRICS AND TERMINOLOGY

There are several metrics used for quantifying and regulating environmental noise although the most common metric used by state/municipal agencies is the A-weighted (A-wt.) sound level. Some state/municipal noise regulations also include permissible octave-band sound pressure levels in addition to maximum permissible A-wt. sound levels. There are also other methods and metrics, such as L_{eq} or L_{dn}, which are used for estimating sound level and correlating a human reaction to an intruding sound.

A summary of the definitions/terminology discussed in the report and typical metrics used to measure and regulate environmental noise is provided in the **Appendix** (pp. 23). To gain an understanding and comparison of the level of measured or predicted facility noise, a chart is provided in the **Appendix** (p. 25) that shows examples of sound levels for typical activities and expected community reaction to noise.

3.0 SITE/FACILITY DESCRIPTION

3.1 Site Description

Figure 1 (p. 13) is an area layout around the facility that shows the closest NSAs around the facility and the chosen sound measurement positions utilized for the site sound survey. The proposed facility is located in Evangeline Parish, Louisiana, approximately 18 miles north of Eunice, Louisiana. The land surrounding the proposed site is primarily rural and is typically used for oil and gas production. The closest NSA (i.e., residence) to the proposed compressor building is located approximately 2300 feet east northeast of the site.

3.2 Description of the Proposed Facility

Figure 2 (p. 14) shows the anticipated layout of buildings and equipment for the Gas Handling Facility. The Gas Handling Facility is designed for injection, storage, and withdrawal of natural gas from pipeline compressor suction pressures as low as 500 psig to compression injection pressures as high as 3100 psig. The facility is designed for a maximum flow rate of 1.2 MMSCFD during gas injection, 2.4 MMSCFD during gas withdrawal and, upon completion of the construction proposed in the Project's certificate application, will have a gas cavern storage capacity of 24 BCF. The facility includes two general areas: Gas Storage Facility (i.e., gas injection, storage plant) located on Ambrose Road and one Brine Disposal and Raw Water Withdrawal Facility (i.e., water well and brine-disposal wells and associated facilities), located on Ambrose Road, to the southwest of the Gas Storage Facility. The noise resulting from the operation of the facility is primarily related to the equipment associated with the Gas Storage Facility during operation and the equipment to be used in the drilling of the wells to be located at the Brine Disposal and Raw Water Withdrawal Facility, and the gas cavern wells to be located at the Gas Storage Site.

3.2.1 Gas Storage Facility

The Gas Storage Facility, which will inject natural gas into storage caverns, withdraw stored gas and direct gas to and from interconnecting pipelines, will include six (6) engine-driven reciprocating gas compressor units. Each unit will consist of a Caterpillar Model G16-CM34 engine (rated at 8000 HP, 750 rpm) driving an Ariel Model JGV/6 reciprocating compressor (8000 HP). The engine-driven compressors are to be installed inside a single insulated metal building. The following describes the expected engine-driven compressors, auxiliary equipment and other notable items associated with the Gas Storage Facility:

- Compressor building (including engine, compressor, & L.O. cooler)

- An outdoor utility (jacket-water) cooler for each engine/compressor unit
- An outdoor gas intercooler and aftercooler for each unit
- An exhaust system for each engine exhaust
- An air intake filter system for each unit
- Aboveground gas piping, including suction headers and discharge headers, and other piping system components (e.g., valves, two horizontal filter/separators, six interstage scrubbers)
- A pressure reduction system utilized during gas withdrawal, noting that equipment associated with injection would not operate during withdrawal
- Outdoor line heaters
- TEG circulation pumps
- Main / Utility Building with Instrumentation Air Compressors
- Electrical substation and MCC area
- Miscellaneous Storage Tanks and small transfer pumps

The Gas Storage Facility Site also contains the following above ground equipment that is necessary to develop the gas caverns (i.e., solution mining equipment).

- Four (4) 2500 HP electric motor-driven Raw Water Injection multistage centrifugal pumps, located outdoors.
- Four (4) 1000 HP electric motor-driven Brine Water Injection multistage centrifugal pumps, located outdoors.
- Three (3) 200 HP motor-driven centrifugal raw water booster pumps.
- Raw water and brine liquid storage tanks.
- Typical oil drilling rig with all necessary packaged generator sets.

3.2.2 Brine Disposal and Raw Water Withdrawal Facility

The following describes the equipment that will be located at the Brine Disposal and Raw Water Withdrawal Facility:

- four small 200 HP motor-driven pumps, transformers, etc.

4.0 MEASUREMENT METHODOLOGY AND LOCATIONS/CONDITIONS

4.1 Sound Measurement Locations

Two (2) locations for measuring the ambient sound levels at the NSAs near the Gas Storage Facility and one (1) location near the site of the Gas Storage Facility are reported. Additionally, sound levels near the Brine Disposal and Raw Water Withdrawal

Site (near Ambrose Rd.) are also reported. The following is a description of the NSAs and the selected sound measurement positions:

Pos. 1: Near NSA #1: Houses located on Rock Pit Road, approximately 2300 feet east northeast of the anticipated location of the compressor building. This NSA is considered the closest NSA to the compressor building.

Pos. 2: Near NSA #2: Trailer/House located on Ambrose Road, approximately 2320 feet east southeast of the anticipated location of the compressor building.

Pos. 3: Un-occupied trailer approximately 2500 feet southeast of the anticipated location of the compressor building.

Pos. 4: Near the proposed site of the Gas Storage Facility on Ambrose Road.

Pos. 5: Near the proposed site of the Brine Disposal and Raw Water Withdrawal Facility site near Ambrose Road, southwest of the Gas Storage Facility Site.

4.2 Conditions during the Sound Survey

Mr. Matthew S. Kinch of H&K performed the ambient sound survey during the daytime (i.e., morning and afternoon) on June 15, 2004. During the daytime sound survey tests, the temperature was 84° - 89° F., the wind was 0- 5 mph from the west, the sky was partly cloudy, and the relative humidity was 95% – 100%.

4.3 Data Acquisition and Sound Measurement Equipment

At the reported sound measurement locations, A-wt. equivalent sound level (L_{eq}) measurements and unweighted octave-band sound pressure level (SPL) measurements were taken at approx. five (5) feet above ground. The sound measurements attempted to exclude "extraneous sound" such as the noise contribution of occasional vehicle traffic passing immediately by the sound measurement position or other intermittent sources (e.g., aircraft flying overhead of measurement position). The acoustical measurement system consisted of a Rion Model NA-27 Analyzer/Sound Level Meter (a Type 1 SLM per ANSI Standard S1.4 & S1.11) equipped with an Rion Model UC-53A 1/2-inch condenser microphone/preamplifier with a windscreen. The SLM was calibrated with a Larson Davis model CAL-200 microphone calibrator that was calibrated within 1 year of the test date.

5.0 MEASUREMENT RESULTS

5.1 Measured Ambient Sound Data

Table A (Appendix, p. 16) shows the measured daytime L_{eq} (i.e., L_d) at the NSA measurement locations along with the average of the measured L_d since several samples of the sound level were performed. The calculated L_{dn} is also provided in **Table A**, as calculated from the measured L_d (nighttime measurements were deemed equal to daytime measurements).

Meteorological conditions that occurred during the sound survey are summarized in **Table B** (Appendix, p. 16). The measured unweighted octave-band SPLs and the average of the measured octave-band SPLs at each sound measurement position are provided in **Table C** (Appendix, p. 17).

The following **Table 1** summarizes the measured ambient L_d and the calculated L_{dn} at the closest NSAs around the proposed site of the facility.

Meas. Position	Description of NSA and Sound Measurement Location	Meas'd L_d (dBA)	Calc'd L_{dn} (dBA)
Pos. 1	NSA #1: Houses 2300 ft. ENE of the Compressor Bldg.	42.9	49.3
Pos. 2	NSA #2: House 2320 ft. ESE of the Compressor Bldg.	36.9	43.3

Table 1: Summary of Measured L_d and Calculated L_{dn} at NSA Measurement Positions

5.2 Observations during the Ambient Site Sound Tests

At the nearby NSAs surrounding the storage site (i.e., NSA #1 & NSA #2), the environmental noises that were audible and which contributed to the measured ambient sound levels included the noise associated with distant vehicle traffic (i.e., along Highway 13 to the east of the facility), the noise of birds, the noise of insects, and the noise of nearby natural gas/crude oil compressor stations along Oil Field Road to the northeast of the NSAs.

It is our opinion that the measured sound level data adequately quantifies the existing ambient sound levels around the proposed site of the facility for the meteorological conditions that occurred during the site sound survey.

6.0 SOUND LEVEL CRITERIA

Typically, certificate conditions set forth by the Federal Energy Regulatory Commission (FERC) require that the sound level attributable to a new natural gas compressor facility not exceed an equivalent day-night sound level (L_{dn}) of 55 dBA at the nearby NSAs. For an essentially steady sound source (e.g., gas compressor facility) that can operate continuously over a 24-hour period and controls the environmental sound level, the L_{dn} is approximately 6.4 dB above the measured L_{eq}. Consequently, an L_{dn} of 55 dBA corresponds to an L_{eq} of 48.6 dBA.

There appear to be no applicable local/county noise regulations, and any local noise regulations, if required, will be addressed during the local permitting process.

7.0 NOISE IMPACT ANALYSES

The noise impact analyses consider the noise produced by facility equipment during operation of the Gas Storage Facility and Brine Disposal and Raw Water Withdrawal Facility and during the drilling portion of Project construction activities that could impact the sound contribution at the nearby NSAs. A description of the analysis methodology and source of sound data is provided in the **Appendix** (pp. 21). For this analysis, we have estimated the sound contribution for the following conditions:

- Sound level contribution of the facility at the closest NSA (*i.e.*, NSA #1) during the drilling portion of Project construction activities.
- Total estimated noise level of the Drilling Phase at NSA #1 (*i.e.*, estimated sound level of the drilling operation plus measured ambient noise level).
- Sound level contribution of the facility at the closest NSA (*i.e.*, NSA #1) during operation of the Gas Storage Facility and Brine Disposal and Raw Water Withdrawal Facility.
- Total estimated noise level of the facility at NSA #1 (*i.e.*, estimated sound level of the facility plus measured ambient noise level).

The predicted sound contributions of the Gas Storage Facility at the nearby NSAs was performed only for the closest NSA (i.e., NSA #1) since the facility sound contribution at the other NSAs should be equal to or less than the sound contribution at the closest NSAs.

The potential noise associated with the pressure reduction system has not been included in the analysis since the noise generated by this system would occur when the gas injection equipment is not operating, although recommendations to insure that this pressure reduction system is not a significant noise source have been provided.

7.1 Significant Sound Sources

For the drilling portion noise impact analysis, the following sound sources associated with the operation of the proposed facility are included in the analysis. The analysis assumes that all continuously operated equipment associated with the drilling portion of Project construction would operate.

Drilling Portion of Operation

- Noise radiated by the 2500 HP Raw Water Injection Pumps operating at full load (Note: these pumps are located at the Gas Storage Facility);
- Noise generated by the 1000 HP Brine Injection Pumps operating at full load (Note: these pumps are located at the Gas Plant Facility); and,
- Noise of a typical oil field drilling rig operating at full load.

For the Gas Storage Facility noise impact analysis, the following sound sources associated with the operation of the proposed facility are included in the analysis. The analysis assumes that all continuously operated equipment associated with the Gas Storage Facility and the Brine Disposal and Raw Water Withdrawal Facility would operate.

Gas Storage Facility

- Noise generated by the engines-compressors that penetrates the building;
- Noise of the each engine exhaust, including noise of the outdoor exhaust piping;
- Noise radiated from outdoor gas piping and associated piping components.;
- Noise radiated from outdoor piping located between the units and gas coolers;
- Noise generated by each engine air intake system;
- Noise of the outdoor jacket-water (JW) cooler for each engine;
- Noise of the outdoor gas cooler associated with each compressor unit;
- Noise of the outdoor line heaters, if employed; and,
- Other miscellaneous “smaller” motor-driven pumps and equipment.

Brine Disposal and Raw Water Withdrawal Facility

- Noise associated with the 2500 HP motor-driven Raw Water injection pumps (located at the Gas Storage Facility);
- Noise associated with the 1000 HP motor-driven brine disposal pumps (located at the Gas Storage Facility;

- Noise of the substation and associated equipment (e.g., transformers, etc.);
- Noise of other 150 HP and 100 HP motor-driven pumps; and,
- Other miscellaneous "smaller" motor-driven pumps and equipment.

7.2 Sound Level Contribution

Tables D & E (Appendix, p. 18-20) shows the calculations (i.e., spreadsheet analyses) of the estimated octave-band SPLs and the A-wt. sound level at the closest NSA (i.e., NSA #1) contributed by the significant noise sources associated with the facility for standard day propagating conditions (i.e., no wind, 60 deg. F., 70% R.H.). These spreadsheet analyses include the potential noise reduction due to the anticipated and/or recommended noise control measures for equipment. **Tables D & E** also provide the estimated "total" sound levels at NSA #1 (i.e., sound contribution of the facility plus the measured ambient noise level).

8.0 NOISE CONTROL MEASURES

The following section provides the recommended or anticipated noise control measures for the significant sound sources of the proposed Gas Storage Facility along with other assumptions that may affect the noise produced by the facility.

8.1 Gas Storage Facility

8.1.1 Building Enclosing the Engines/Compressors

We understand that the engines, compressors, & L.O. coolers will be installed inside an insulated metal building. The following describes specific sound requirements and other items related to the components of the compressor building.

Building Structure

The sound contribution of the equipment noise radiated through the compressor building should not exceed **50 dBA** at 300 feet from the building perimeter. This sound level requirement includes, but is not limited to, the following noise sources: (a) the noise of equipment that penetrates the building walls, roof and doors, and (b) the noise generated by supply-air ventilation fans for the building.

The following unweighted sound power levels (PWLs) in dB per octave-band frequency and A-wt. PWL can be assumed for the interior equipment during full-load operation of the facility:

Unweighted PWL in dB per Octave-Band Freq. (Hz) for Interior Equipment

31.5	63	125	250	500	1000	2000	4000	8000	A-Wt.
128	127	128	127	126	126	127	128	126	134

- As a minimum, if an insulated metal building is employed, the walls and roof of the building should be constructed with an exterior skin of 18 gauge metal and the building interior surfaces should be covered with a layer of 6-inch thick unfaced mineral wool (e.g., 6.0-8.0 pcf uniform density) covered with 26-gauge perforated liner. Thermal insulation such as "R-13" or "R-19" type insulation should **not** be substituted for the 6.0-8.0 pcf material.

- Windows, louvers or skylights should not be installed. All voids and openings in the walls and roof of the building resulting from penetrations of ducts, piping, etc. should be patched and sealed.

- Personnel entry doors should seal well with the doorframe and be self-closing.

- The large equipment access openings (i.e., roll-up doors) should be a minimum 20-ga. insulated-type design (e.g., 20-ga. exterior, 20-ga. backskin with insulation core).

Building Ventilation

- The noise associated with each building air-supply fan (with noise control), should not exceed **60 dBA** at 50 feet. As a minimum, each air-supply fan should include a metal boot enclosing the fan; a minimum 3-feet length exterior silencer (i.e., parallel baffle-type design) and a weather hood lined with acoustical insulation.

8.1.2 Aboveground Gas Piping

Noise control measures, such as acoustical pipe lagging, are not expected to be necessary for aboveground piping to meet the noise criteria although noise control measures should be implemented if deemed necessary after installation.

It is recommended that the aboveground piping be isolated and separated from any other metal structure (e.g., walkways, platforms, or steel framework connected to building). Also, it is recommended that the outdoor aboveground piping be inserted underground soon after exiting the compressor building.

8.1.3 Engine Exhaust System

The exhaust system for each engine should include a muffler system that provides the following dynamic sound insertion loss (DIL) values at the rated operating conditions (i.e., DIL values if a single muffler is employed):

DIL Values in dB per Octave-Band Center Freq. For Engine Exhaust

31.5	63	125	250	500	1000	2000	4000	8000
22	32	40	45	45	42	38	32	25

The most effective and recommended method of achieving the above DIL values for the exhaust muffler system is to employ a double-muffler (2-stage) system consisting of two types of mufflers described below.

1. Install an outdoor reactive-type exhaust muffler (e.g., "super-critical" type) that meets the following minimum recommended DIL values:

DIL Values in dB per Octave-Band Center Freq. For Reactive Muffler

31.5	63	125	250	500	1000	2000	4000	8000
20	26	35	35	30	30	28	28	25

2 Install an absorptive-type muffler that is mounted in-line with engine exhaust piping (inside the compressor building) that meets the following minimum recommended DIL values:

DIL Values in dB per Octave-Band Center Freq. For "In-Line" Muffler

31.5	63	125	250	500	1000	2000	4000	8000
2	4	10	14	20	20	20	15	10

If only a single outdoor exhaust muffler is employed, the following are other items of the exhaust system that should be addressed:

- The exhaust piping located between the building & muffler body should be completely covered with an acoustical lagging consisting of a heavy-gauge steel jacketing (min. 20-ga.) along with a 3-inch thick inner layer of insulation.
- The exhaust pipe expansion joint (if located outside the building) & flanges should be covered with a removable/reusable acoustical blanket material. The blanket material usually consists of a core of 2.0-in thick needled fiber

mat (6.0-8.0 lb/ft^3 density) and a liner material of mass-loaded vinyl (1.0-1.25 lb/ft^2 surface weight) that is covered with a coated fiberglass cloth.

8.1.4 Engine Air Intake System

The air intake system of each engine should include an air filter/cleaner system that provides the following recommended DIL values:

DIL Values in dB per Octave-Band Center Freq. (in Hz) for Intake System

31.5	63	125	250	500	1000	2000	4000	8000
5	8	15	20	30	35	35	30	20

Based on recent field sound tests, a CAT "heavy-duty" air filter/cleaner system (i.e., type with "pre-cleaner") should be capable of meeting the above DIL values.

8.1.5 Engine Jacket Water Cooler

The A-wt. sound level of the jacket water cooler for each engine should not exceed **62 dBA** at **50 feet** from the cooler perimeter at the full rated operating conditions (i.e., equivalent to a PWL of **94-95 dBA**). The supplier should provide the estimated A-wt. sound level and the unweighted octave-band SPLs at **50 feet** from the cooler with all fans/motors operating.

8.1.6 Gas Intercooler & Aftercooler

The sound level of each gas intercooler and each gas aftercooler should not exceed **65 dBA** at **50 feet** from the cooler perimeter at the full rated operating conditions (i.e., equivalent to a PWL of approx. **97 - 98 dBA**). The supplier should provide the estimated A-wt. sound level and the unweighted octave-band SPLs at **50 feet** from the cooler with all fans/motors operating.

8.1.7 Heaters and Substation

Noise control measures are not expected to be necessary for the line heaters and the equipment associated with the substation (e.g., transformers) to meet the sound level requirements.

8.1.8 Pressure Reduction System

The primary gas pressure-reducing valves and gas flow-control valves associated with the Pressure Reduction System should incorporate a Fisher WhisperTrim Type I or WhisperFlo type of "low-noise" cages or an equivalent type of "low-noise" valve trim system. Pressure-reducing valves should be capable of meeting a sound level requirement of **90 dBA** (e.g., typically 3-ft. from piping downstream of valve).

If so-called "low-noise" valves other the aforementioned Fisher type valve are being considered, the acoustical consultant familiar with the project should review the proposed valve design or any other potential noise mitigation method being considered.

8.1.9 TEG Regenerator Units

The A-wt. sound level of each TEG regenerator unit should not exceed **62 dBA** at **50 feet** from the skid perimeter for any range of operation (i.e., equivalent to a PWL of **94-95 dBA**). The sound level criteria of **62 dBA** at **50 feet** includes all auxiliary equipment associated with the TEG regenerator units.

8.2 Brine Disposal and Raw Water Withdrawal Facility

8.2.1 Raw Water Injection Pumps

Each motor-driven raw water injection pump should be designed not to exceed a sound level of **95 dBA** at **3 feet** from the pump perimeter at the rated operating conditions (i.e., includes noise of the motor and pump), which is equivalent to an A-wt. PWL of approximately **105 dBA**. This may require that the electric motor be a "low-noise" (i.e., energy efficient) type of motor.

8.2.2 Brine Disposal Pumps

Each motor-driven brine disposal pump should be designed not to exceed a sound level of **92 dBA** at **3 feet** from the pump perimeter at the rated operating conditions (i.e., includes noise of motor and pump), which is equivalent to an A-wt. PWL of approximately **102 dBA**. This may require that the electric motor be a "low-noise" (i.e., energy efficient) type of motor.

8.2.3 150 HP and 100 HP Pumps

Each of the 150 HP and 100 HP motor-driven pumps (e.g., booster pumps and well water pumps) should be designed not to exceed a sound level of **90 dBA** at **3 feet** from the pump perimeter at the rated operating conditions (i.e., includes noise of motor and pump), which is equivalent to an A-wt. PWL of approximately **100 dBA**.

8.2.4 Other "Smaller" Motor-Driven Pumps and Substation

"Smaller" motor-driven pumps (i.e., less than 50 HP) should not to exceed a sound level of **85 dBA** at **3 feet** from the pump perimeter. Noise control measures are not expected to be necessary for equipment associated with the substation (i.e., transformers).

9.0 FINAL COMMENT

The results of the noise impact analysis indicates that If the recommended and/or anticipated noise control measures are successfully implemented, the noise attributable to the facilities associated with the construction and operation of the Pine Prairie Energy Center should be lower than the typical FERC sound level requirement of **55 dBA** (L_{dn}) at the nearby NSAs. In addition, the gas storage facility should have "minimum noise impact" on the surrounding environment. "Minimum noise impact" implies that the noise of the facility should not interfere with public activity or be an annoyance outdoors.

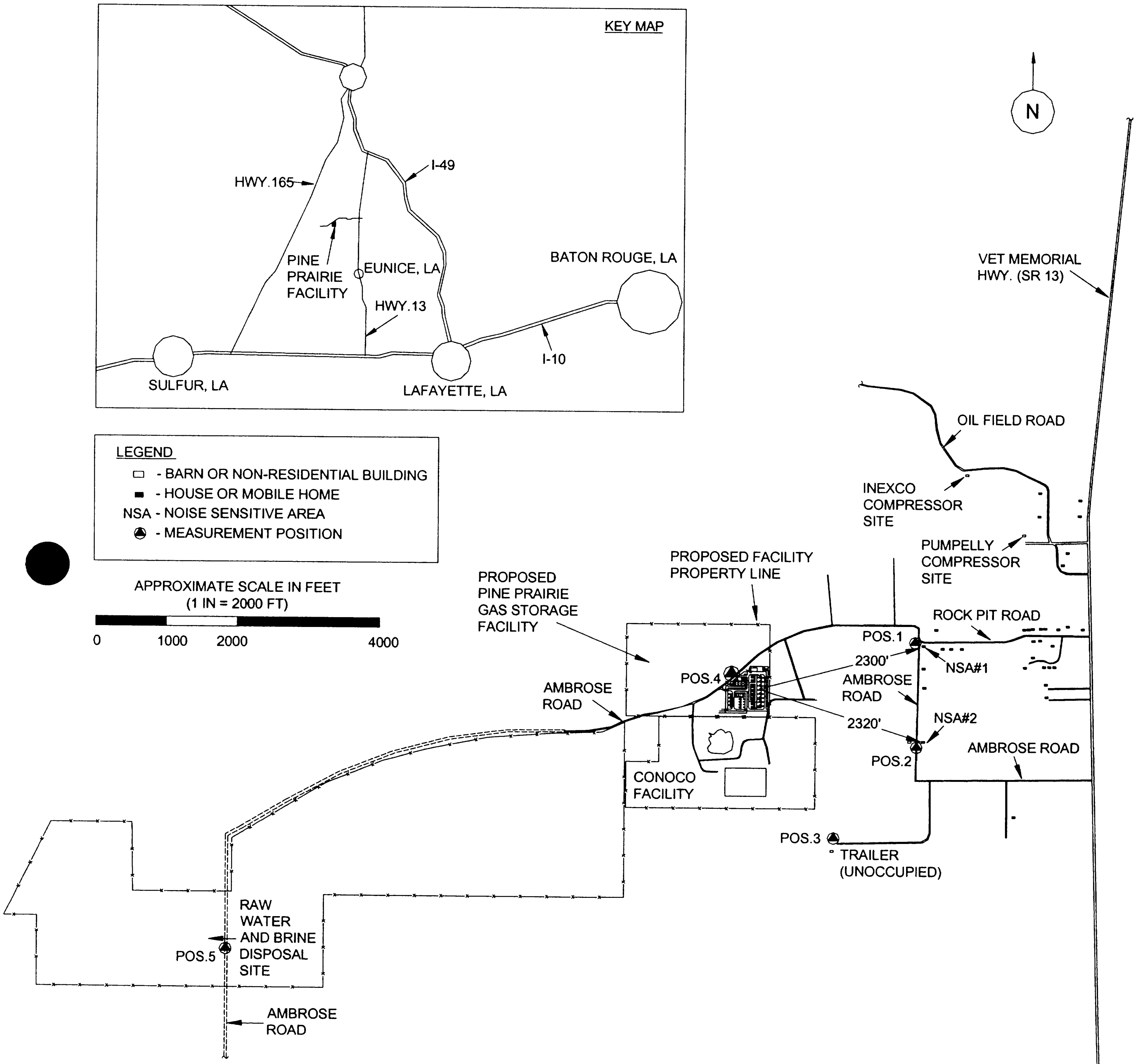

Figure 1: Pine Prairie Gas Storage Facility: Area Layout Showing the Location of the Closest NSAs and the Measurement Positions during Ambient Sound Survey.

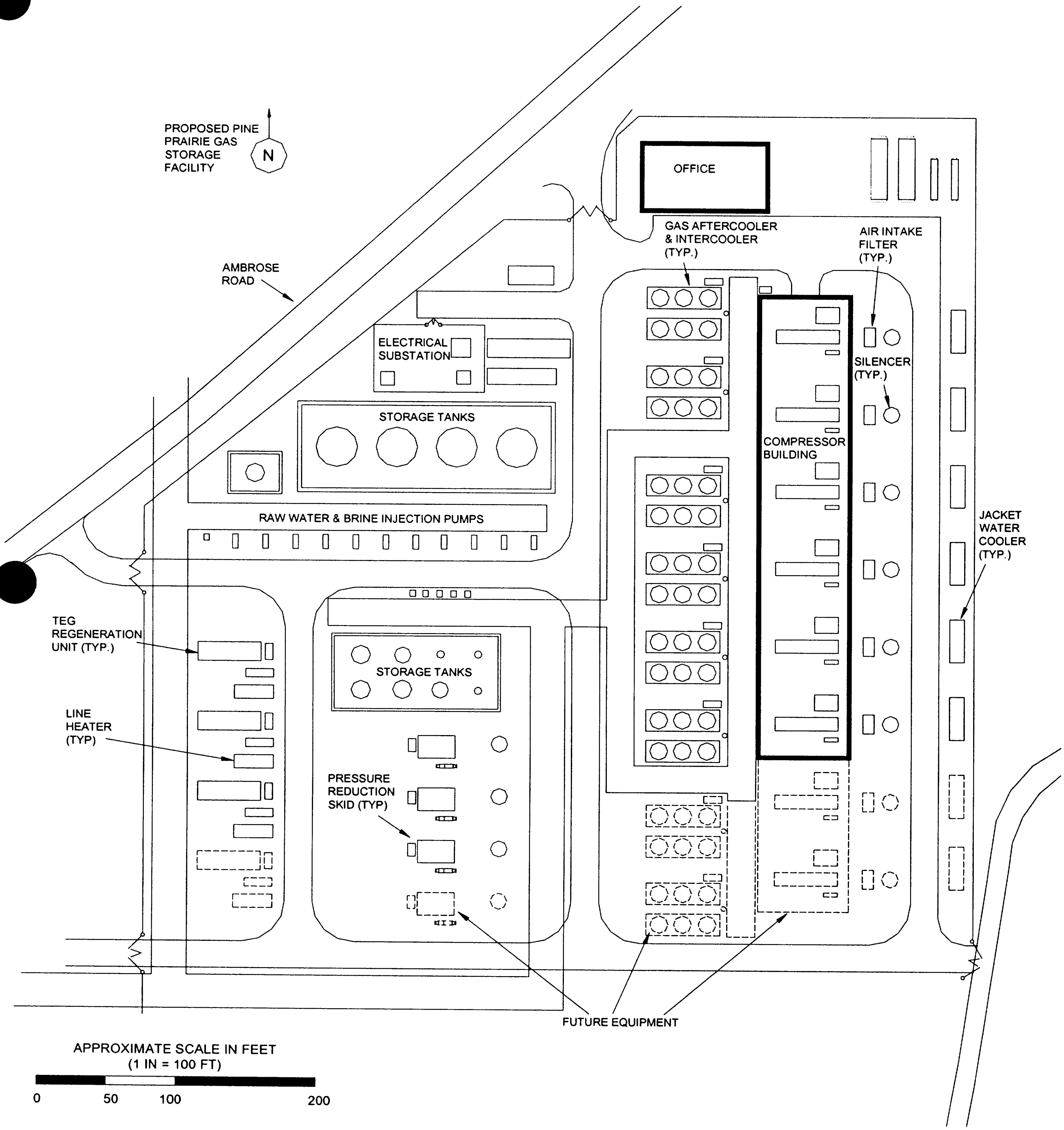

Figure 2: Pine Prairie Gas Storage Facility: Anticipated Layout of Buildings, Equipment and Property Line for the Facility.

APPENDIX

SUMMARY OF THE MEASURED SITE SOUND DATA,

NOISE IMPACT ANALYSIS OF THE PROPOSED FACILITY,

DESCRIPTION OF THE ANALYSIS METHODOLOGY, THE SOURCE OF SOUND DATA, AND SUMMARY OF TYPICAL METRICS & TERMINOLOGY

Measurement Set		Measured A-Wt. Sound Levels (dBA)					
Position	Time of Tests	D-time Leq(Ld)	Avg'd Ld	N-time Leq(Ln)	Avg'd Ln	Calc'd Ldn	Notes/Observations
Pos. 1 Near NSA #1, Houses (Rock Pit Rd.) 2300' ENE of Proposed Compressor Site	11:00 AM - 4:00 PM	43.2 42.2	**42.9**	--	--	**49.3**	Sounds audible included birds, insects, occasional distant traffic to east and nearby natural gas / crude oil pumping stations along Oil Field Rd.
Pos. 2 House (Ambrose Rd.) 2320' ESE of Proposed Compressor Site	11:31 AM 11:33 AM 11:37 AM	37.1 35.4 37.8	**36.9**	--	--	**43.3**	Sounds audible included birds, insects, and occasional distant traffic to east.
Pos. 3 Un-Occupied Trailer SE of Proposed Compressor Site	11:45 AM 11:48 AM 11:51 AM	42.2 43.4 41.3	**42.4**	--	--	**48.8**	Sounds audible included birds, insects, and occasional distant traffic to east.
Pos. 4 Near Site of Proposed Compressor Building	12:02 PM	37.5	**37.5**	--	--	**43.9**	Sounds audible included birds, insects, occasional distant traffic to east and nearby natural gas / crude oil pumping stations along Oil Field Rd.
Pos. 5 Near Site of Proposed Raw Water & Brine Disposal Site	12:18 PM	33.5	**33.5**	--	--	**39.9**	Sounds audible included birds, insects, and occasional distant traffic to east.

Table A: **Pine Prairie Energy Center (LA): Measured Ambient Daytime Sound Levels (Leq) at the Closest NSAs on 15 June 2004 around the Proposed Gas Storage Facility along with the Calculated Equivalent Day-Night Levels (Ldn).**

Measurement Set		Temp.	R.H.	Wind	Wind	Peak	
Position	Date/Time of Testing	(°F)	(%)	Direction	Speed	Wind	Sky Conditions
Pos. 1 - 5 (Daytime)	11:00 AM - 4:00 PM (15 June 2004)	84 - 89	95 - 100	From the West	0- 5 mph	7 - 8 mph	Partly Cloudy

Table B: **Pine Prairie Energy Center (LA): Meteorological Conditions During the Ambient Sound Survey Measurements around the Proposed Site of the Gas Storage Facility on 15 June 2004.**

Measurement Set		Sound Pressure Level (SPL) in dB per Octave-Band Frequency (in Hz)									A-Wt.
Position	Time of Tests	31.5	63	125	250	500	1000	2000	4000	8000	Level
Pos. 1 Near NSA #1, Houses (Rock Pit Rd.) 2300' ENE of Proposed Compressor Site	11:11 AM	60.4	61.9	46.3	36.0	33.6	31.0	35.4	38.8	25.1	43.5
	11:17 AM	60.2	61.5	46.6	34.7	31.5	29.3	33.3	38.0	29.9	42.6
	11:21 AM	59.0	60.9	46.6	38.4	38.4	35.5	33.6	37.0	28.0	43.4
	Morning SPL:	59.9	61.5	46.5	36.6	35.5	32.8	34.2	38.0	28.1	43.2
	3:47 PM	58.0	65.8	47.3	35.7	31.4	32.9	31.2	26.8	20.9	42.2
	Afternoon SPL:	58.0	65.8	47.3	35.7	31.4	32.9	31.2	26.8	20.9	42.2
	Average SPL:	**59.5**	**63.0**	**46.7**	**36.4**	**34.8**	**32.8**	**33.6**	**36.9**	**27.1**	**42.9**
Pos. 2 House (Ambrose Rd.) 2320' ESE of Proposed Compressor Site	11:31 AM	55.9	52.6	41.8	30.7	26.1	23.9	26.3	33.3	27.6	37.1
	11:33 AM	54.8	52.3	39.0	28.5	26.0	27.6	29.6	27.2	22.8	35.4
	11:37 AM	56.1	52.1	40.1	29.3	25.4	24.6	29.2	33.6	30.3	37.8
	Average SPL:	**55.6**	**52.3**	**40.5**	**29.6**	**25.8**	**25.7**	**28.6**	**32.2**	**27.9**	**36.9**
Pos. 3 Un-Occupied Trailer SE of Proposed Compressor Site	11:45 AM	52.2	46.2	35.0	30.1	28.5	28.3	30.6	30.3	41.9	42.2
	11:48 AM	51.1	43.5	35.1	28.7	25.8	23.9	32.4	35.4	42.7	43.4
	11:51 AM	50.5	43.3	34.1	29.6	27.0	27.5	33.2	29.6	40.4	41.3
	Average SPL:	**51.3**	**44.5**	**34.8**	**29.5**	**27.2**	**26.9**	**32.2**	**32.6**	**41.8**	**42.4**
Pos. 4 Near Site of Proposed Compressor Building	12:02 PM	59.2	59.6	38.0	27.4	26.1	23.5	29.1	30.7	21.2	37.5
	Average SPL:	**59.2**	**59.6**	**38.0**	**27.4**	**26.1**	**23.5**	**29.1**	**30.7**	**21.2**	**37.5**
Pos. 5 Near Site of Proposed Raw Water & Brine	12:18 PM	45.4	46.4	32.0	27.2	27.9	23.5	26.1	28.5	20.6	33.5
	Average SPL:	**45.4**	**46.4**	**32.0**	**27.2**	**27.9**	**23.5**	**26.1**	**28.5**	**20.6**	**33.5**

Table C: **Pine Prairie Energy Facility (LA): Meas'd Ambient Daytime Unweighted Octave-Band SPLs on 15 June 2004 around the Proposed Gas Storage Facility.**

Source No. & Dist (Ft)	Source PWL & Estimated Sound Level Contributions at Specified Distance	PWL / SPL in dB Per Octave-Band Center Frequency (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	A-Wt. Level	Calc'd Ldn
1)	PWL of Motor-Driven Raw Water Pumps	107	107	110	109	105	103	100	97	95	108	
	Atten. of Building (includes vent noise)	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding)	-2	-3	-4	-6	-7	-8	-10	-10	-10		
2700	Hemispherical Radiation	-66	-66	-66	-66	-66	-66	-66	-66	-66		
2700	Atm. Absorption (70% R.H., 60 deg F)	0	0	-1	-1	-2	-4	-8	-21	-37		
2700	Source Sound Level Contribution	38	37	39	36	30	25	16	0	0	32	
2)	PWL of Motor-Driven Brine Injection Pumps	105	105	108	107	103	101	98	95	93	106	
	Atten. of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding)	-2	-3	-4	-6	-7	-8	-10	-10	-10		
2700	Hemispherical Radiation	-66	-66	-66	-66	-66	-66	-66	-66	-66		
2700	Atm. Absorption (70% R.H., 60 deg F)	0	0	-1	-1	-2	-4	-8	-21	-37		
2700	Source Sound Level Contribution	36	35	37	34	28	23	14	0	0	30	
3)	PWL of Typical Oil Field Rig	125	129	121	115	111	112	109	103	97	116	
	NR of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding)	0	0	0	0	0	0	0	0	0		
3400	Hemispherical Radiation	-68	-68	-68	-68	-68	-68	-68	-68	-68		
3400	Atm. Absorption (70% R.H., 60 deg F)	0	0	-1	-1	-2	-5	-10	-26	-47		
3400	Source Sound Level Contribution	56	60	52	45	40	39	30	9	0	44	
Est'd Total Sound Level Contribution of Facility:	**2300 Ft.**	**57**	**60**	**52**	**46**	**41**	**39**	**31**	**10**	**5**	**44.4**	**50.8**
Meas'd Ambient Sound Level at NSA#1: Note (1)		**60**	**63**	**47**	**36**	**35**	**33**	**34**	**37**	**27**	**42.9**	**49.3**
Est'd Contribution of Facility plus Ambient Noise at NSA#1		**61**	**65**	**53**	**46**	**42**	**40**	**35**	**37**	**27**	**46.7**	**53.1**
		Potential increase of ambient sound level (dB):									**3.8**	

Table D: **Pine Prairie Gas Storage Facility: Est'd Sound Contribution at the Closest NSA (i.e., NSA #1, 2300 Ft ENE of the Compressor Bldg.) during the Drilling Phase of Operation at Nearest Drill Site.**

Note (1): Measured ambient octave-band SPLs and A-wt. sound level (Leq) at NSA#1 during a recent site sound survey on 06/15/04, and the results of the sound survey are reported in Table C of the report.

Source No. & Dist (Ft)	Source PWL & Estimated Sound Level Contributions at Specified Distance	PWL / SPL in dB Per Octave-Band Center Frequency (Hz)									A-Wt. Level
		31.5	63	125	250	500	1000	2000	4000	8000	
1)	PWL of Engine-Compr. Noise thru Bldg. (6 Units)	128	127	128	127	126	126	127	128	126	134
	Atten. of Compr Building (includes vent noise)	-10	-12	-18	-26	-35	-38	-40	-42	-42	
	Misc. Atten.	0	0	0	0	0	0	0	0	0	
2300	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65	
2300	Atm. Absorption (70% R.H., 60 deg F)	0	0	0	-1	-2	-3	-7	-17	-32	
2300	Source Sound Level Contribution	53	50	45	35	24	20	15	4	0	32
2)	PWL of Gas Piping (between Bldg. & Coolers)	116	116	113	110	106	100	98	96	93	108
	Atten. of Noise Control	0	0	0	0	0	0	0	0	0	
	Misc. Atten. (Shielding)	-3	-5	-7	-8	-10	-10	-12	-12	-12	
2300	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65	
2300	Atm. Absorption (70% R.H., 60 deg F)	0	0	0	-1	-2	-3	-7	-17	-32	
2300	Source Sound Level Contribution	48	46	41	36	29	22	14	2	0	32
3)	PWL of Gas Piping (Pipeway & Separators)	116	116	113	110	106	100	98	96	93	108
	NR of Noise Control	0	0	0	0	0	0	0	0	0	
	Misc. Atten. (Shielding)	-3	-5	-7	-8	-10	-10	-12	-12	-12	
2400	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65	
2400	Atm. Absorption (70% R.H., 60 deg F)	0	0	0	-1	-2	-4	-7	-18	-33	
2400	Source Sound Level Contribution	48	45	40	36	29	21	13	0	0	31
4)	PWL of Unsilenced Exhaust (1 Engine)	135	141	143	133	131	135	131	119	108	138
	PWL of Unsilenced Exhaust: 6 Engines (+8dB)	143	149	151	141	139	143	139	127	116	146
	Atten. of Noise Control (Exhaust Muffler)	-18	-28	-38	-40	-40	-36	-34	-30	-25	
	Misc. Atten.	0	0	0	0	0	0	0	0	0	
2300	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65	
2300	Atm. Absorption (70% R.H., 60 deg F)	0	0	0	-2	-2	-3	-7	-17	-32	
2300	Source Sound Level Contribution	60	56	48	34	32	39	33	15	0	41
5)	PWL of Exhaust Piping & Muffler Body (1 Engine)	108	105	102	100	98	98	96	95	95	104
	PWL of Piping & Muff Body: 6 Engines (+8dB)	116	113	110	108	106	106	104	103	103	112
	Atten. of Noise Control (In-Line Muffler)	-2	-4	-6	-8	-12	-15	-18	-18	-15	
	Misc. Atten.	0	0	0	0	0	0	0	0	0	
2300	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65	
2300	Atm. Absorption (70% R.H., 60 deg F)	0	0	0	-1	-2	-3	-7	-17	-32	
2300	Source Sound Level Contribution	49	44	39	34	27	23	14	3	0	30
6)	PWL of Unit Air Intake w/Hvy. Dty. Filter (1 Engine)	85	80	78	78	79	81	83	100	83	101
	PWL of Air Intake w/Filter: 6 Engines (+8dB)	93	88	86	86	87	89	91	108	91	109
	NR of Noise Control	0	0	0	0	0	0	0	0	0	
	Misc. Atten.	0	0	0	0	0	0	0	0	0	
2300	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65	
2300	Atm. Absorption (70% R.H., 60 deg F)	0	0	0	-1	-2	-3	-7	-17	-32	
2300	Source Sound Level Contribution	28	23	21	20	20	21	19	26	0	29
7)	PWL of One (1) 3-Fan Gas Cooler	110	108	105	98	95	94	92	90	88	100
	PWL of Twelve (12) 3-Fan Gas Coolers (+11dB)	121	119	116	109	106	105	103	101	99	111
	NR of Noise Control	0	0	0	0	0	0	0	0	0	
	Misc. Atten. (Shielding)	-3	-5	-7	-8	-10	-10	-12	-12	-12	
2450	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65	
2450	Atm. Absorption (70% R.H., 60 deg F)	0	0	0	-1	-2	-4	-7	-19	-34	
2450	Source Sound Level Contribution	41	37	32	24	18	15	7	0	0	22
8)	PWL of One (1) 2-Fan Jacket-Water Cooler	106	106	104	98	94	92	90	88	85	98
	PWL of Six (6) 2-Fan JW Coolers (+8dB)	114	114	112	106	102	100	98	96	93	106
	NR of Noise Control	0	0	0	0	0	0	0	0	0	
	Misc. Atten. (Shielding)	0	0	0	0	0	0	0	0	0	
2300	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65	
2300	Atm. Absorption (70% R.H., 60 deg F)	0	0	0	-1	-2	-3	-7	-17	-32	
2300	Source Sound Level Contribution	41	41	39	32	27	24	18	6	0	30

Table E: Pine Prairie Gas Storage Facility: Est'd Sound Contribution at the Closest NSA (i.e., NSA #1, 2300 Ft ENE of Compressor Bldg.) with Six (6) Engine-Driven Compressor Units Operating along with the Operation of the Raw Water and Brine Disposal Facility (cont'd. next page).

Source No. & Dist (Ft)	Source PWL & Estimated Sound Level Contributions at Specified Distance	PWL / SPL in dB Per Octave-Band Center Frequency (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	A-Wt. Level	Calc'd Ldn
9)	PWL of Motor-Driven Raw Water Injection Pumps	107	107	110	109	105	103	100	97	95	108	
	Atten. Of Pump Building (includes vent noise)	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding)	-2	-3	-4	-6	-7	-8	-10	-10	-10		
2700	Hemispherical Radiation	-66	-66	-66	-66	-66	-66	-66	-66	-66		
2700	Atm. Absorption (70% R.H., 60 deg F)	0	0	-1	-1	-2	-4	-8	-21	-37		
2700	Source Sound Level Contribution	38	37	39	36	30	25	16	0	0	32	
10)	PWL of Motor-Driven Brine Disposal Pumps	105	105	108	107	103	101	98	95	93	106	
	NR of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding)	-2	-3	-4	-6	-7	-8	-10	-10	-10		
2700	Hemispherical Radiation	-66	-66	-66	-66	-66	-66	-66	-66	-66		
2700	Atm. Absorption (70% R.H., 60 deg F)	0	0	-1	-1	-2	-4	-8	-21	-37		
2700	Source Sound Level Contribution	36	35	37	34	28	23	14	0	0	30	
11)	PWL of Substation Equipment	90	90	98	88	82	80	78	72	70	87	
	Atten. of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding)	-2	-3	-4	-5	-6	-7	-7	-8	-8		
2650	Hemispherical Radiation	-66	-66	-66	-66	-66	-66	-66	-66	-66		
2650	Atm. Absorption (70% R.H., 60 deg F)	0	0	-1	-1	-2	-4	-8	-20	-36		
2650	Source Sound Level Contribution	22	21	27	16	8	3	0	0	0	14	
12)	PWL of Outdoor Gas Heaters	110	110	107	105	100	97	95	90	87	103	
	Atten. of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding)	0	-1	-2	-3	-4	-6	-8	8	-8		
2800	Hemispherical Radiation	-67	-67	-67	-67	-67	-67	-67	-67	-67		
2800	Atm. Absorption (70% R.H., 60 deg F)	0	0	-1	-1	-2	-4	-8	-21	-38		
2800	Source Sound Level Contribution	43	42	38	34	27	20	12	10	0	30	
13)	PWL of Misc. Pumps & Other Misc. Equipment	95	95	94	92	90	90	88	88	85	96	
	Atten. of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten.	0	-1	-2	-3	-4	-6	-8	-8	-8		
2650	Hemispherical Radiation	-66	-66	-66	-66	-66	-66	-66	-66	-66		
2650	Atm. Absorption (70% R.H., 60 deg F)	0	0	-1	-1	-2	-4	-8	-20	-36		
2650	Source Sound Level Contribution	29	28	25	22	18	14	6	0	0	20	
Est'd Total Sound Level Contribution of Facility:	**2300 Ft.**	**62**	**58**	**52**	**44**	**39**	**39**	**34**	**10**	**0**	**43.8**	**50.2**
Meas'd Ambient Sound Level at NSA#1: Note (1)		**60**	**63**	**47**	**36**	**35**	**33**	**34**	**37**	**27**	**42.9**	**49.3**
Est'd Contribution of Facility plus Ambient Noise at NSA#1		**64**	**64**	**53**	**45**	**40**	**40**	**37**	**37**	**27**	**46.4**	**52.8**
	Potential increase of ambient sound level (dB):										**3.5**	

Table E: **Pine Prairie Gas Storage Facility: Est'd Sound Contribution at the Closest NSA (i.e., NSA #1, 2300 Ft ENE of the Compressor Bldg.) with Six (6) Engine-Driven Compressor Units Operating along with the Operation of the Raw Water and Brine Disposal Facility.**

Note (1): Measured ambient octave-band SPLs and A-wt. sound level (Leq) at NSA#1 during a recent site sound survey on 06/15/04, and the results of the sound survey are reported in Table C of the report.

Note: Muffler DIL & Equipment PWL values on this Table should not be used as the specified values.
Refer to "Noise Control Measures" section in report or other company specifications for actual specified values.

DESCRIPTION OF THE ANALYSIS METHODOLOGY AND THE SOURCE OF SOUND DATA FOR THE PROPOSED FACILITY

ANALYSIS METHODOLOGY

In general, the predicted sound level contributed by the facility was calculated as a function of frequency from estimated octave-band sound power levels (PWLs) for each significant sound source. The following summarizes the analysis procedure:

- Initially, unweighted octave-band PWLs for each noise source (without noise control) were determined from actual sound measurements performed by H&K on similar equipment and/or obtained from the equipment manufacturer.
- Then, expected noise reductions in dB per octave-band frequency due to any designated noise control measures for each source were subtracted from the estimated PWL.
- Next, octave-band SPLs for each source (with noise control) were determined by compensating for sound attenuation due to propagation (hemispherical radiation) and atmospheric sound absorption.
- Since sound shielding by buildings can influence the sound level contributed at the NSAs, we also included the sound shielding due to buildings, if appropriate. Effects of vegetation or land contour were typically not considered in this analysis.
- Finally, the estimated octave-band SPLs for each source (with noise control and other sound attenuation effects) were corrected for A-weighting, and the total SPLs of all sound sources were logarithmically summed and corrected for A-weighting to provide the estimated A-wt. sound level contributed at the specified distance(s) by the proposed facility.

SOURCE OF SOUND DATA

The following describes the source of sound data for estimating the source sound levels and source PWLs used in the noise impact analysis. Note that equipment noise levels and acoustical performance of mufflers/silencers utilized in the acoustical analysis (i.e., spreadsheet analysis) are generally higher than the sound level requirement for the new equipment and new mufflers to insure that the design incorporates an acoustical "margin of safety."

(1) Engine exhaust PWL were calculated from sound data recently measured in the field by H&K on a engine-compressor unit using a similar engine anticipated for the gas storage plant. The DIL values for the exhaust muffler system utilized in the acoustical analysis

are generally lower than the recommended values in order that the noise design analysis incorporates an acoustical "margin of safety."

(2) The estimated PWL of equipment inside the building (i.e., engine-driven compressors and equipment inside the building) was calculated from sound data measured by H&K on a similar compressor installation used for gas storage.

(3) The estimated PWL of the outdoor aboveground gas piping of the gas storage facility were determined from sound measurements by H&K on gas piping similar to that of the proposed gas storage compressor installation.

(4) The estimated PWL for JW and gas coolers were designated to meet the design noise goal. Note that the estimated PWL for the cooler utilized in the acoustical analysis includes noise associated with jacket-water piping.

The noise level for the coolers used in the acoustical analysis is generally higher than the sound level requirement in order that the noise design analysis incorporates an acoustical "margin of safety." In addition, there can be other noise associated with the coolers that is not directly related to the operation of the cooler fans (e.g., noise of jacket-water piping and/or compressor noise radiated from the tubes of the gas coolers).

(5) The estimated PWL for the engine air intakes were calculated from measured sound data in the field tests by H&K on similar engines.

(6) The estimated PWL and sound level for other miscellaneous equipment for the Gas Surface/Storage Facility was calculated from measured sound data in the field tests by H&K on similar equipment.

(7) The estimated octave-band sound power levels (PWLs) of the motor-driven pumps, substation equipment and any other site equipment associated with the Raw Water and Brine Disposal Facility were estimated from field sound measurements by H&K on a similar equipment and/or from sound data provided by the equipment manufacturer.

Summary of Typical Metrics for Regulating Environment Noise & Definitions

(1) Decibel (dB)

A unit for expressing the relative power level difference between acoustical or electrical signals. It is ten times the common logarithm of the ratio of two related quantities that are proportional to power. When adding dB or dBA values, the values must be added logarithmically. For example, the logarithmic addition of **35 dB** plus **35 dB** is **38 dB**.

(2) Human Perception of Change in Sound Level

- A **3 dB** change of sound level is barely perceivable by the human ear
- A **5 or 6 dB** change of sound level is clearly noticeable
- If sound level increases by **10 dB**, it appears as if the sound intensity has doubled.

(3) A-Weighted Sound Level (dBA)

The A-wt. sound level is a single-figure sound rating, expressed in decibels, which correlates to the human perception of the loudness of sound. The dBA level is commonly used to measure industrial and environmental noise since it is easy to measure and provides a reasonable indication of the human annoyance value of the noise. The dBA measurement is not a good descriptor of a noise consisting of strong low-frequency components or for a noise with tonal components.

(4) Background or Ambient Noise

The total noise produced by all other sources associated with a given environment in the vicinity of a specific sound source of interest, and includes any Residual Noise.

(5) Sound Pressure Level (L_p or SPL)

Ten times the common logarithm to the base 10 of the ratio of the mean square sound pressure to the square of a reference pressure. Therefore, the sound pressure level is equal to 20 times the common logarithm of the ratio of the sound pressure to a reference pressure (20 micropascals or 0.0002 microbar).

(6) Octave band Sound Pressure Levels (SPLs)

Sound is typically measured in spectra, or frequency ranges (e.g., high-pitched sound, low-pitched sound, etc.) that provides more meaningful sound data regarding the sound character of the noise. When measuring two noise sources for comparison, it is better to measure the spectrum of each noise, such as in octave band SPL frequency ranges. Then, the relative loudness of two sounds can be compared frequency range by frequency range. As an illustration, two noise sources can have the same dBA rating and yet sound completely different. For example, a high-pitched sound concentrated at a frequency of 2000 Hz could have the same dBA rating as a much louder low-frequency sound concentrated at 50 Hz.

(7) Daytime Sound Level (L_d) & Nighttime Sound Level (L_n)

L_d is the equivalent A-weighted sound level, in decibels, for a 15 hour time period, between 07:00 to 22:00 hours (7:00 a.m. to 10:00 p.m.). L_n is the equivalent A-weighted sound level, in decibels, for a 9 hour time period, between 22:00 to 07:00 hours (10:00 p.m. to 7:00 a.m.).

(8) Equivalent Sound Level (L_{eq})

The equivalent sound level (L_{eq}) can be considered an average sound level measured during a period of time, including any fluctuating sound levels during that period. In this report the L_{eq} is equal to the level of a steady (in time) A-weighted sound level that would be equivalent to the sampled A-weighted sound level on an energy basis for a specified measurement interval. The concept of the measuring L_{eq} has been used broadly to relate individual and community reaction to aircraft and other environmental noises.

(9) Day-Night Sound Level (L_{dn})

The L_{dn} is an energy average of the measured daytime L_{eq} (L_d) and the measured nighttime L_{eq} (L_n) plus **10 dB**. The **10-dB** adjustment to the L_n is intended to compensate for nighttime sensitivity. As such, the L_{dn} is not a true measure of the sound level but represents a skewed average that correlates generally with past sound surveys which attempted to relate environmental sound levels with physiological reaction and physiological effects. For a steady sound source that operates continuously over a 24-hour period and controls the environmental sound level, an L_{dn} is approx. **6.4 dB** above the measured L_{eq}.

(10) Sound Level Meter (SLM)

An instrument used to measure sound pressure level, sound level, octave-band SPL, or peak sound pressure level, separately or in any combinations thereof. The measured weighted SPL (i.e., A-Wt. Sound Level or dBA) is obtained by the use of a SLM having a standard frequency-filter for attenuating part of the sound spectrum.

SOUND LEVELS FOR TYPICAL ACTIVITIES **REFERENCE AND COMMUNITY RESPONSES**

Subjective Human Response and Conversation	Home and Industrial (Indoor Noise)	dBA Scale (Level)	Community and Traffic (Outdoor Noise)	Reference Loudness	Community Reaction To Outdoor Noise
		-- 140 --	Aircraft Carrier		
Threshold of Pain			Military Jet Aircraft		
		-- 130 --			
			Large Siren at 100 Ft.		
			Jet Takeoff at 200 Ft.	16 Times	
	Rock Band (Max.)	-- 120 --		as Loud	
Threshold of			Thunderstorm Activity		
Discomfort	Discotheque (Max.)			8 Times	
		-- 110 --	Elevated Train	as Loud	
	Symphonic Music (Max.)				
Maximum Vocal Effort			Auto Horn at 5 Ft.	4 Times	
	Industrial Plant	-- 100 --		as Loud	
Very Loud			Compacting Trash Truck		
	Newspaper Printing Rm.			2 Times	
Shouting in Ear		-- 90 --	Heavy Truck at 25 Ft.	as Loud	Vigorous Action
	Food Blender				and Law Suits
	Symphonic Music (Typ.)		Motorcycle at 25 Ft.	Reference	
Shouting		-- 80 --		Loudness	Threats of
	Garbage Disposal		Small Truck at 25 Ft.		Legal Action
Very Annoying	Alarm Clock		Heavy Traffic at 50 Ft.		Appeals to Officials
		-- 70 --		1/2 as Loud	Widespread
Moderately Loud	Vacuum Cleaner		Avg. Traffic at 100 Ft.		Complaints
	Electric Typewriter				
Normal Conversation		-- 60 --		1/4 as Loud	Sporadic Complaints
	Air Conditioner at 20 Ft.				
			Light Traffic at 100 Ft.		No Reaction,
	Typical Office	-- 50 --		1/8 as Loud	Although Noise
Quiet					is Noticeable
	Living Room		Typical Suburban Area		
	Bedroom	-- 40 --			
			Birdsong		
Very Quiet	Library				
		-- 30 --			
Soft Whisper	Broadcasting Studio		Rural Area		
				Just Audible	
		-- 20 --			
				Threshold	
		-- 10 --		of Hearing	
Hoover & Keith Inc. (Consultants in Acoustics) 11391 Meadowglen, Suite D Houston, Texas 77082		-- 0 --			