LPG AND REFINED PRODUCTS STORAGE IN SOLUTION-MINED CAVERNS IN BEDDED AND DOMAL SALT DEPOSITS IN TEXAS AND MISSISSIPPI

Jun K. Yee
LDH Energy

Joe L. Ratigan
PB Energy Storage Services, Inc.

Nicolas Cocavessis
LDH Energy

ABSTRACT

Louis Dreyfus Highbridge Energy LLC (LDH Energy) began adding solution-mined storage caverns to its transportation and distribution infrastructure in 2004 and now has a total of 36 wells at two locations in Texas and one location in Mississippi. The Mont Belvieu, Texas, facility has approximately 47,000,000 barrels of storage in 24 active caverns. The Baden, Texas, facility has about 240,000 barrels of storage capacity in four active bedded salt caverns. The Hattiesburg, Mississippi, facility has approximately 6,000,000 barrels of storage in three active caverns. LDH Energy has been storing liquefied petroleum gases (LPG) but has recently converted some of that capacity to store refined motor fuels, including ultra-low sulphur diesel and gasoline. This paper describes the features and some of the challenges at the three storage facilities.

Keywords: Solution-Mined Caverns, Salt Domes, LPG, Bedded Salt

INTRODUCTION

Louis Dreyfus Highbridge Energy LLC (LDH Energy), through its operating subsidiaries, is a major North American energy merchant active in the processing, trading, marketing, and transporting of a wide range of energy products. LDH Energy currently markets more than 500,000 barrels per day (bpd) of natural gas liquids, primarily at major hub locations. The company's natural gas liquids (NGL) business includes ownership and operation of an approximately 1,100-mile-long NGL pipeline system that transports NGLs from west Texas to east Texas. The NGL business infrastructure includes significant underground storage capacity in solution-mined storage caverns in both bedded and domal salt deposits.

In this paper, the solution-mined storage cavern facilities at Mont Belvieu, Texas; Baden, Texas; and Hattiesburg, Mississippi,

are described. Some of the unique aspects of each facility are briefly described.

MONT BELVIEU COMPLEX

Historical Development

The LDH Energy storage complex at Mont Belvieu includes a "North Terminal" and a "South Terminal." The North Terminal includes storage assets acquired from Conoco. Well NT-1, drilled in 1953, was the first well in the current LDH Energy asset base to have been drilled at Mont Belvieu. Texas Butadiene Company started operations at the Barbers Hill salt dome area in the early 1950s. In early 1961, three storage wells (NT-1, NT-2, and NT-3), on 57 acres that included a liquefied petroleum gases (LPG) delivery truck and rail racks, were purchased by LDH Energy's predecessor, Texas Eastern Transmission Corporation (TET), and three wells (Wells 11, 12, and 13), on 5 acres, were purchased by Tenneco Oil Corp., another LDH Energy predecessor.

In 2003, Mont Belvieu Storage Partners, L.P., a newly formed joint venture of LDH Energy and TE Products Pipeline Company, Limited Partnership (TEPPCO) (the successor to TET), became owner of the Mont Belvieu storage assets. In 2007, LDH Energy bought TEPPCO's interest in the joint venture, making it a 100-percent LDH Energy subsidiary, and LDH Energy assumed operations in March 2007.

In addition to the 57-acre tract (which later was termed the "North Terminal"), TET purchased additional raw lands which were developed as the South Terminal. The South Terminal facility initially included five new wells developed as higher throughput storage caverns in the 1960s. TET developed these wells for storing LPGs (propane, normal butane, and iso-butane). These products were supplied from storage to TET's pipeline operations from southeast Texas to the Midwest and Northeast regions through the TET distribution system. The LPG products stored in these wells were from the refineries and natural gas liquids fractionators in the south and southeast Houston area.

In the 1970s, six wells were developed at the South Terminal for storing propane (only) to deliver a higher throughput to meet the increasing demands for propane deliveries to the midwestern corn crop dryer market and the winter heating market in the northeast. These wells are currently being converted to storage of refined motor fuels, such as gasoline and low sulphur diesel, with connectivity being added for additional major liquid pipeline systems, to allow movement of the products from the Gulf Coast to the East Coast. The first such connection, to the Colonial Pipeline System, was completed and became operational in May 2009.

A parcel of 90 acres located south of the TET North Terminal was independently developed by Conoco beginning in 1978. These wells are now part of the LDH Energy North Terminal. Conoco originally drilled three wells to store propane and E/P mix to support its facilities at the Chocolate Bayou southeast of Houston, Texas, and Lake Charles in Louisiana. Two of these wells are currently used for storing ethylene, and the other well is used for storing ethane.

Geology

The LDH Energy Mont Belvieu storage caverns are located in the Barbers Hill salt dome, a typical United States Gulf Coast piercement salt dome. The salt plug of the dome is located at a depth of about 1,400 feet and has a caprock with a thickness of up to 1,000 feet. This dome, as with other Gulf Coast salt domes, originated from a much deeper bedded salt deposit called the Louann salt. The uplift of the piercement dome caused the adjacent sediments to be lifted at the flanks of the dome. These uplifted areas can be oil and gas traps. More than 100 million barrels of oil were produced from the Barbers Hill Field up through about 1965.

Facilities and Operations

The LDH Energy storage caverns at the North Terminal are illustrated in Figure 1. Of the 13 wells at the North Terminal, 11 are active storage wells. The storage volume in the active caverns is nearly 18 million petroleum

barrels (MMbbls). The North Terminal wells are permitted for expansion up to about 27 MMbbls. Minimal problems have been encountered in the North Terminal wells. A side wall salt fall occurred in Well NT-9 in the late 1990s. This cavern is currently in active storage service.

The North Terminal has four on-site and off-site brine ponds with a total capacity of more than 7 MMbbls of storage. This brine is used to displace the LPG from the solution-mined storage caverns. The North Terminal has a brine pond volume-to-cavern storage volume ratio of about 40 percent.

Figure 1 also illustrates the location of two plugged and abandoned caprock brine disposal wells (labeled COD1 and COD2). These wells were abandoned in the early 1990s.

The 13 storage wells at the South Terminal are illustrated in Figure 2. All of these wells are active storage wells. The storage volume in the active caverns is about 30 MMbbls. The South Terminal wells are permitted for expansion up to 48 MMbbls. The South Terminal operations included a caprock brine disposal well (labeled TED1) that was abandoned in the 1990s after discovering a large void at the base of the injection well production casing. The large void was subsequently filled with sand and gravel.

The South Terminal currently has five brine ponds and expects to have a sixth in service by the end of 2009. This will bring the total brine pond storage capacity to about 21 MMbbls.

Figure 1. LDH Energy North Terminal Storage Caverns.

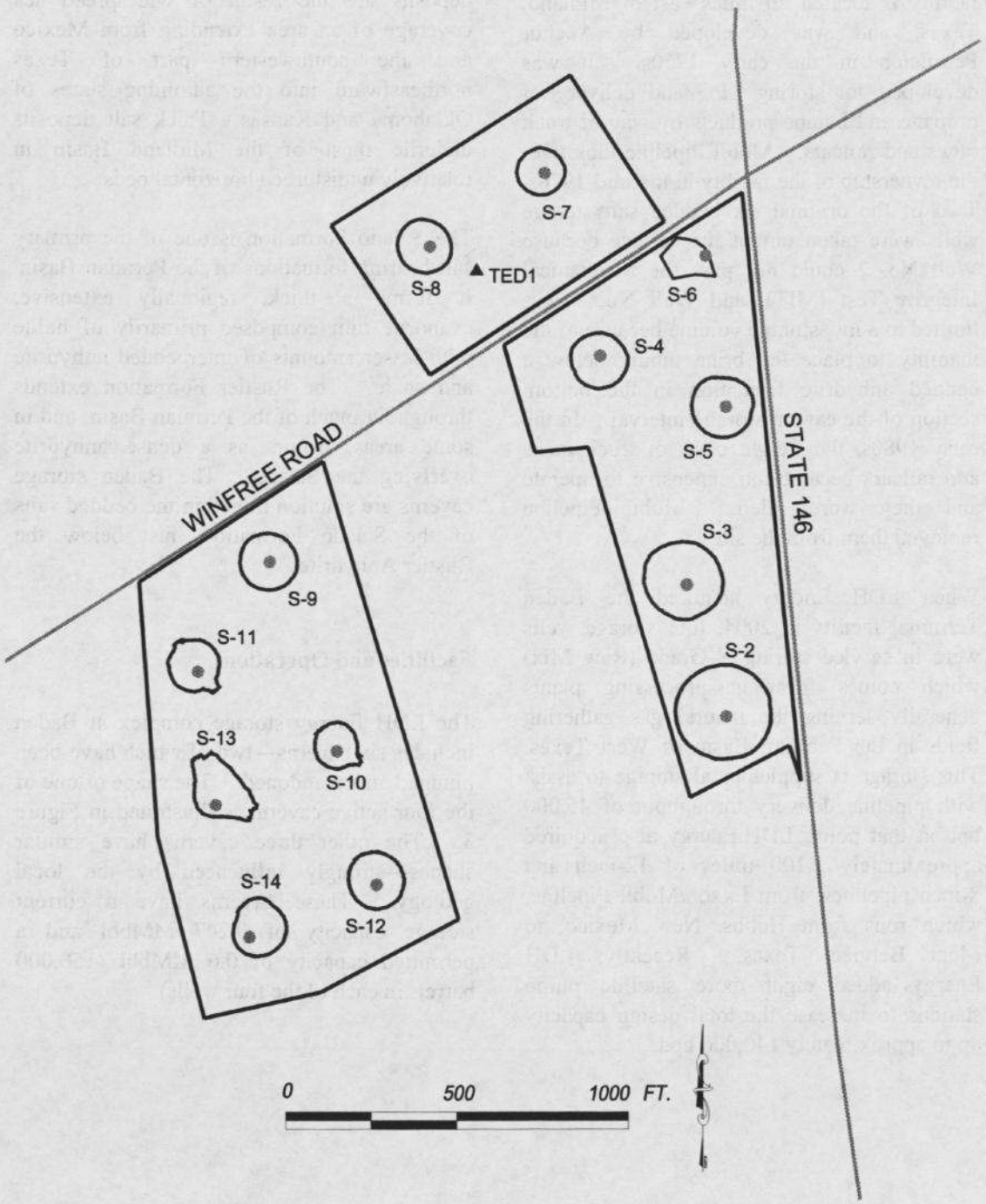

Figure 2. LDH Energy South Terminal Storage Caverns.

BADEN COMPLEX

Historical Development

The Baden Bedded Salt Storage Terminal facility is located 20 miles east of Midland, Texas, and was developed by Anchor Petroleum in the early 1950s. It was developed for storing LPG and delivery of propane and butane products by way of truck racks and railcars. Mobil Pipeline took over the ownership of the facility in the mid-1970s. Two of the original six bedded salt storage wells were taken out of the service because Well No. 2 could not pass the Mechanical Integrity Test (MIT), and Well No. 3 was limited to a low storage volume because of the inability to place the brine tubing below a bedded anhydrite formation in the bottom section of the cavern storage interval. In the early 1980s, the freight costs of truck racks and railcars became too expensive to operate and they were idled. Mobil Pipeline removed them from the site.

When LDH Energy acquired the Baden Terminal facility in 2004, four storage wells were in service storing Y-Grade (Raw Mix) which comes from gas-processing plants generally serving the natural gas gathering fields in the Permian Basin of West Texas. This storage is supplemental storage to assist with pipeline delivery throughput of 45,000 bpd at that point. LDH Energy also acquired approximately 1,100 miles of 12-inch and 8-inch pipelines, from Exxon/Mobil Pipeline, which runs from Hobbs, New Mexico, to Mont Belvieu, Texas. Recently, LDH Energy added eight more satellite pump stations to increase the total design capacity up to approximately 140,000 bpd.

Geology

The Baden Storage Terminal is located within the Midland Basin, a subdivision of the much larger Permian Basin. Permian Basin deposits are the result of widespread sea coverage of an area extending from Mexico and the southwestern part of Texas northeastward into the adjoining states of Oklahoma and Kansas. Thick salt deposits underlie most of the Midland Basin in relatively undisturbed horizontal beds.

The Salado Formation is one of the primary salt-bearing formations of the Permian Basin. It forms a thick, regionally extensive, evaporite unit composed primarily of halite with lesser amounts of interbedded anhydrite and shale. The Rustler Formation extends throughout much of the Permian Basin, and in some areas, occurs as a dense anhydrite overlying the Salado. The Baden storage caverns are solution mined in the bedded salts of the Salado Formation, just below the Rustler Anhydrite.

Facilities and Operations

The LDH Energy storage complex at Baden includes six caverns—two of which have been plugged and abandoned. The shape of one of the four active caverns is illustrated in Figure 3. The other three caverns have similar shapes—strongly influenced by the local geology. These caverns have a current storage capacity of 0.247 MMbbl and a permitted capacity of 0.6 MMbbl (150,000 barrels in each of the four wells).

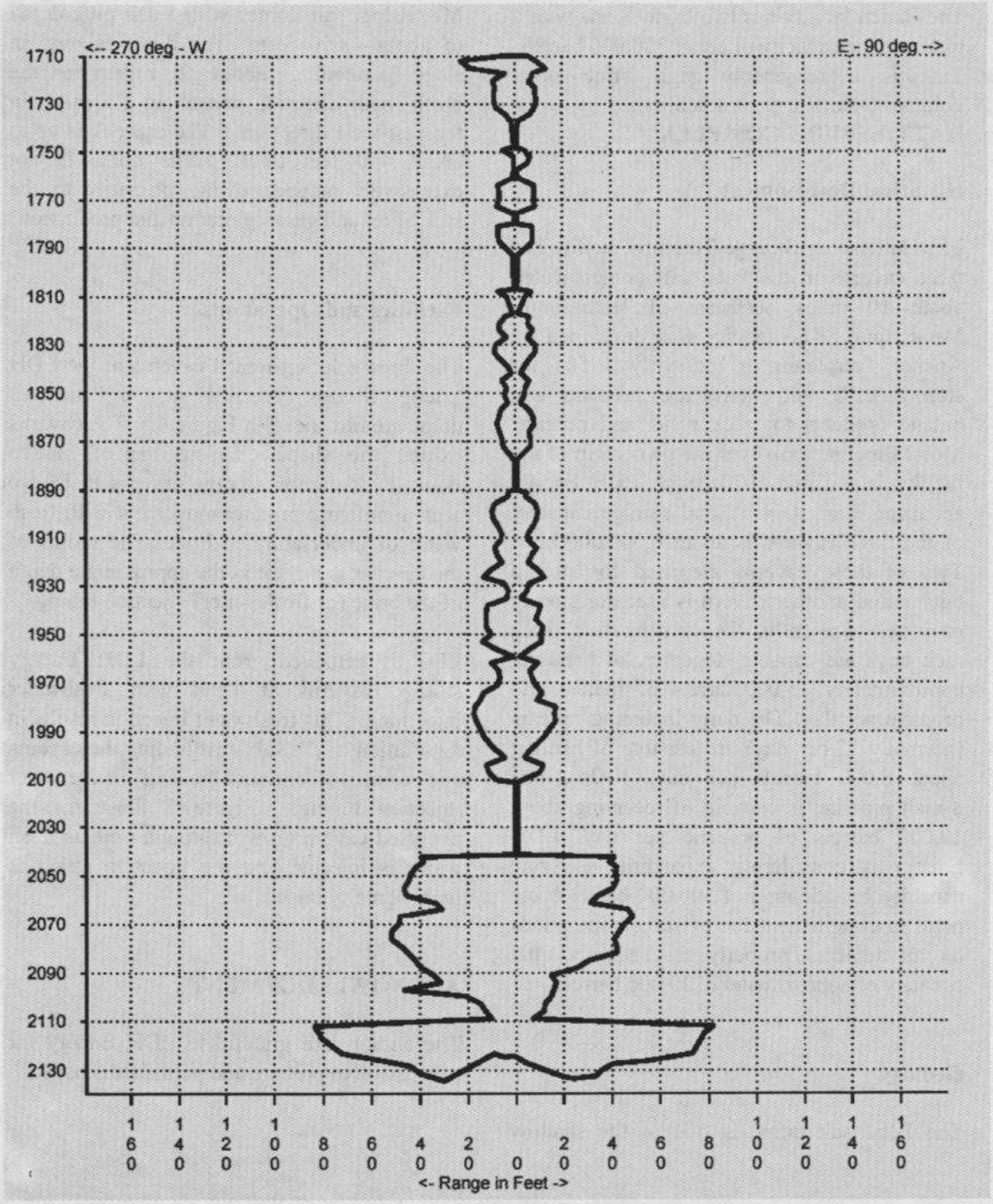

Figure 3. Cross Section Through the November 15, 2002, Sonar Survey of LDH Energy Baden Storage Well No. 1.

The Baden facility has two brine ponds with a total storage capacity of about 300,000 barrels. This is a reasonably high brine pond volume-to-storage cavern facility.

HATTIESBURG COMPLEX

Historical Development

The Hattiesburg Storage Terminal facility has three caverns in the Petal salt dome located about 10 miles northeast of Hattiesburg, Mississippi. The facility was developed by Anchor Petroleum in the early 1950s for storing LPG and delivering propane and butane products to truck racks and railcars. Mobil Pipeline took over the ownership of the facility in the mid-1970s, with LDH Energy acquiring it in 2004. Total storage capacity of the three caverns is about 6,000,000 bbls. Two of these caverns are used for storing butane and another cavern is used for storing propane. Presently, the existing five truck rack bays are capable, together, of handling approximately 15,000 barrels of butane and propane per day. The daily incoming railcars (normally 12 per day) are capable of hauling about 8,000 barrels per day. Also, one 8-inch pipeline is capable of receiving about 17,000 barrels of propane per day. LDH Energy is considering expanding its brine capacity by adding a 1,500,000-barrel brine pond to complement the existing brine ponds on an adjacent property that have a total capacity of approximately 120,000 barrels.

Geology

The Petal salt dome is one of the shallow Mississippi salt domes with a salt plug depth of about 1,650 feet. The dome is oval in shape extending about 2 miles in the north-south direction and about 1.5 miles in the east-west direction. The caprock is up to about 450 feet thick. The dome is not extensively mapped owing primarily to the lack of oil and gas exploration and production.

Facilities and Operations

The three solution-mined caverns at the LDH Energy Storage Terminal at the Petal salt dome are illustrated in Figure 4. The caverns exhibit the shape characteristic of mature liquid hydrocarbon storage caverns that have seen significant product movement with fresh water or undersaturated brine. The radius of the caverns is largest at the approximate depth of the brine (or fresh water) injection tubing.

LPG is removed from the LDH Energy storage caverns at Petal with freshwater injection. This freshwater injection results in dissolution of the salt surrounding the caverns and requires a continual "raising" of the water injection tubing. Figure 5 illustrates the expected cavern growth through time as fresh water is injected and the injection string is incrementally raised.

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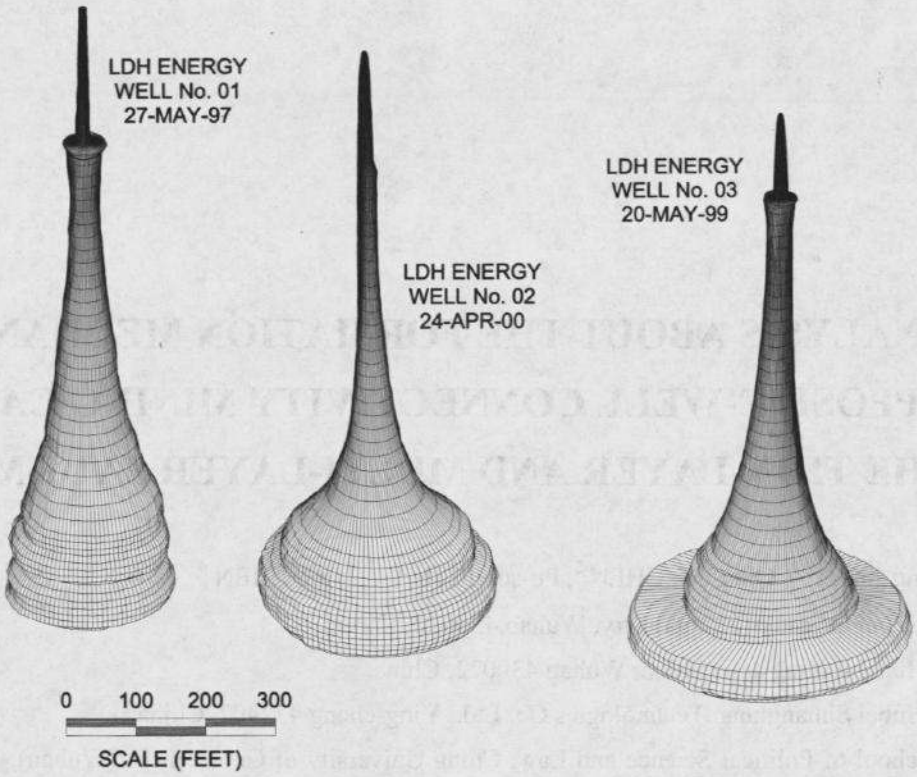

Figure 4. LDH Energy Solution-Mined Storage Caverns at the Petal Salt Dome.

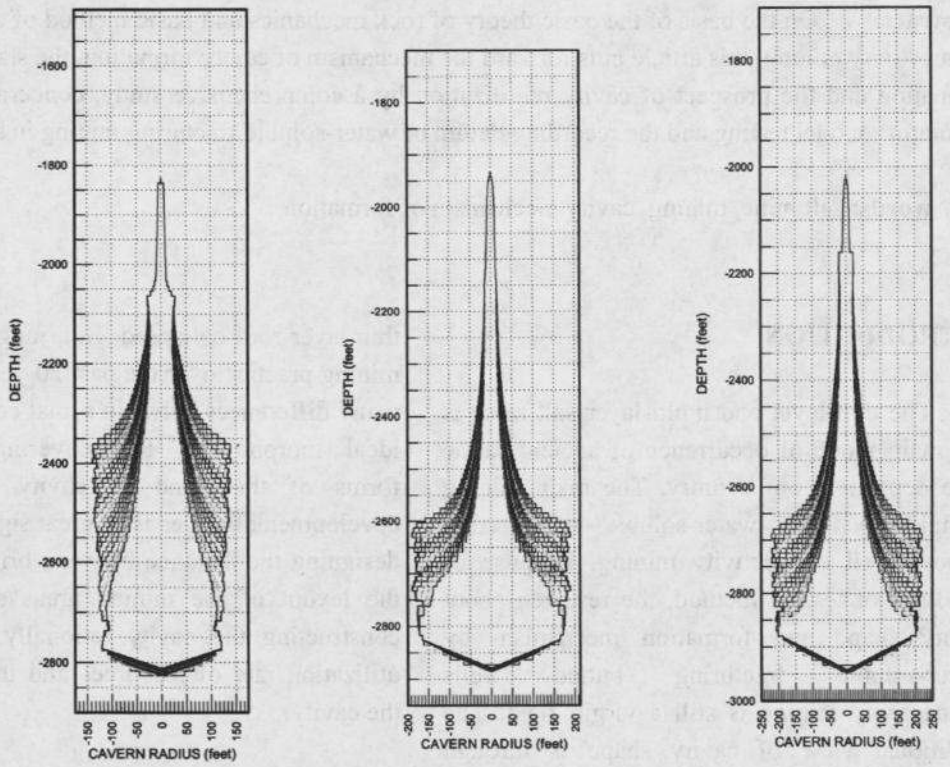

Figure 5. Illustration of Expected Cavern Growth in the LDH Energy Storage Wells Using Fresh Water for Product Displacement.