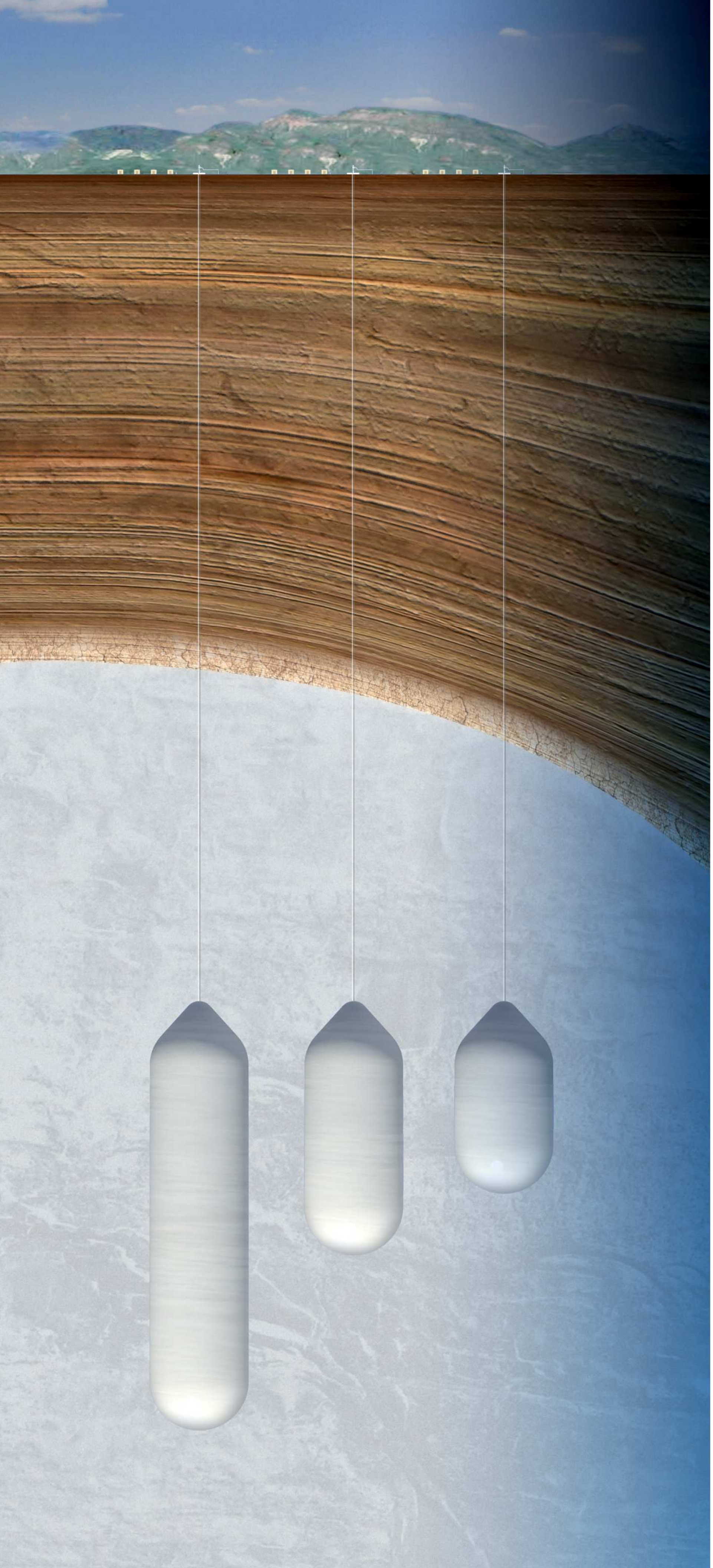
Attachment D

Construction and Cavern Development Plan



Cavern Construction and Development Plan

Underground Injection Control
Permit UTU 27-AP-9232389

CAVERN CONSTRUCTION
AND DEVELOPMENT PLAN
UNDERGROUND INJECTION CONTROLPERMIT UTU 27-AP-9232389

SAWTOOTH NGL CAVERNS, LLC
DELTA, UTAH

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Section 1
Introduction

1.1 Purpose of the Plan

This Plan has been developed to outline clear processes and procedures for storage cavern construction (drilling and cavern well installation) and development (solution mining) at the Sawtooth NGLs storage facility. The construction (drilling) of storage caverns at the facility is under the jurisdiction of both the Utah Department of Environmental Quality (DEQ), the Division of Water Quality (DWQ), and the Utah Department of Natural Resources (DNR), the Division of Oil, Gas and Mining (DOGM). The development of storage caverns is under the sole jurisdiction of the DWQ. In addition to the UIC Permit, Sawtooth has also obtained the appropriate permits and authorizations from the necessary federal, state and local agencies.

Sawtooth has created this Plan, to meet the requirements for the solution mining of salt caverns under DWQ Underground Injection Control (UIC) Permit UTU-27-AP-9232389. This Plan has been reviewed and approved by the DWQ. Any future modifications to this plan requested by Sawtooth are subject to approval by DWQ. DWQ may also modify the Plan after it receives new, previously unavailable information or after a review of the Plan. A copy of the Plan will be kept at the facility.

1.2 Facility Location

The Sawtooth NGLs storage facility is located approximately eight miles north of Delta in Millard County and on lands leased from the Utah School and Institutional Trust Lands Administration (SITLA). The facility address is 9650 North 540 East Delta, Utah 84624. As shown on Figure 1, the facility is situated west of Highway 6 near the intersection of Jones Road and Brush Wellman Road/SR-174.

1.3 Facility Description

The Sawtooth NGLs storage facility is located on a salt dome that is approximately one mile thick, two miles in diameter and 3,000 feet below the ground surface. Sawtooth will be solution mining storage caverns within the salt dome for the purpose of storing NGLs such as butane and propane. Figure 2 is a map depicting the storage facility layout as currently constructed and proposed. As shown, the facility consists of three main components that are connected by utilities contained within a central utility corridor. The main components are a Storage Cavern Field, a 152-acre brine evaporation pond, and a truck and rail loading and transfer facility. The utilities between the main components include brine, water, power, and product transfer lines. As currently designed, the facility will be capable of storing 16 million barrels (MMbbls) of NGLs in eight caverns with an individual capacity of 2 MMbbls each. The timing of cavern construction is dependent upon market demand.

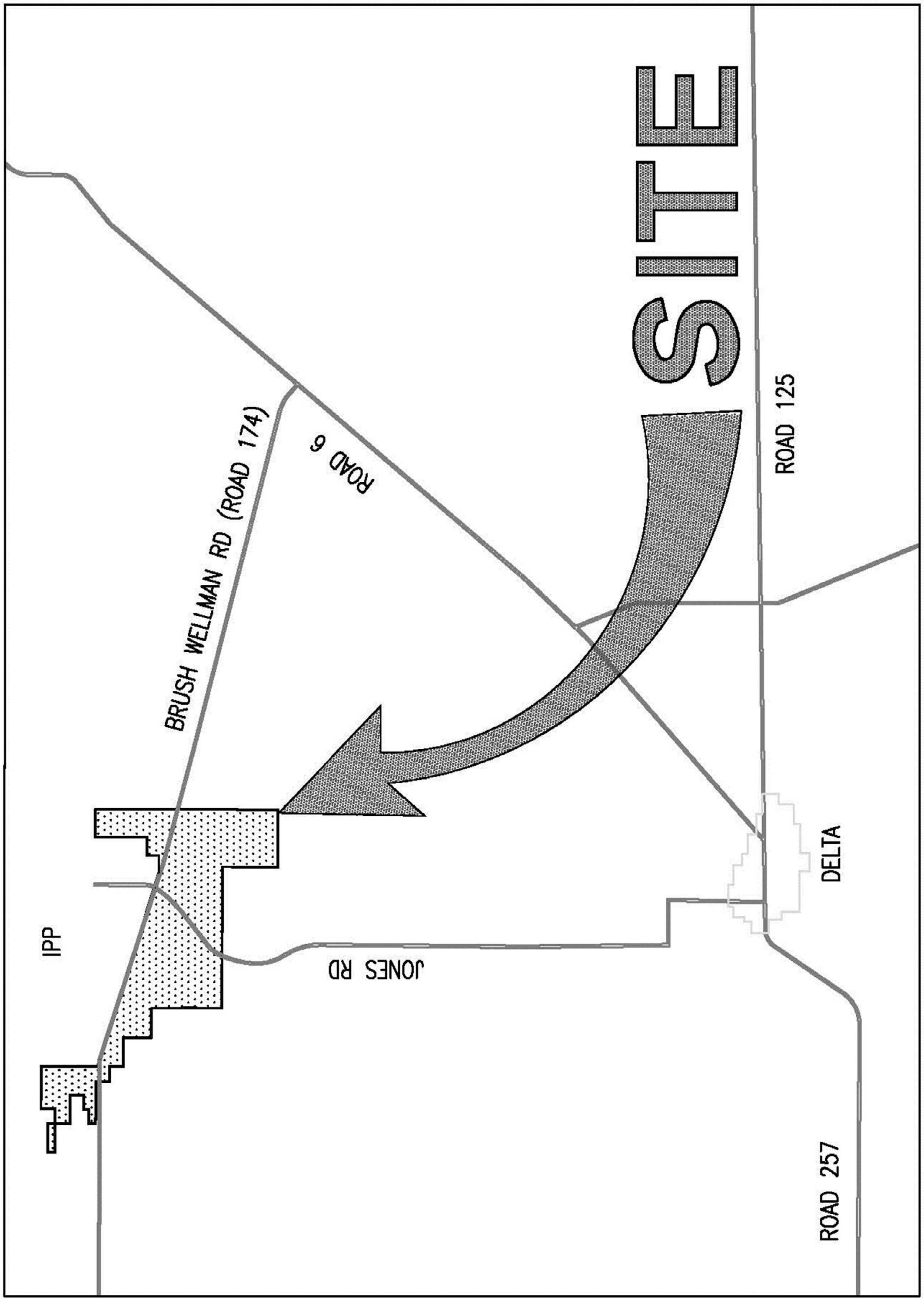

Figure 1: Vicinity Map

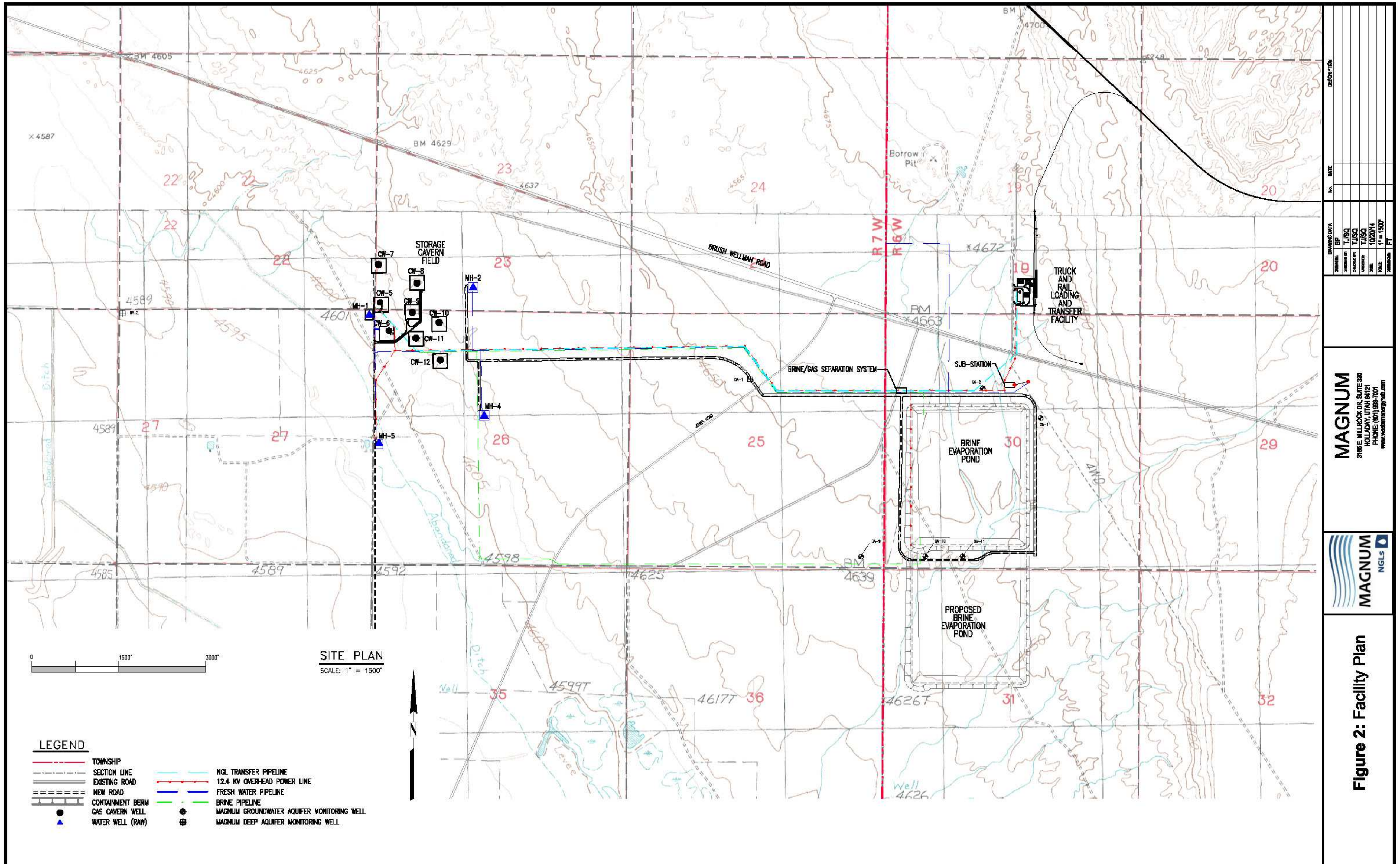

Figure 2: Facility Plan

1.4 Storage Cavern Field Description

This Plan specifically addresses the construction and development of cavern well and storage caverns within the Storage Cavern Field. Figure 2 depicts the location of the Storage Cavern Field within the broader facility, the specific locations and numbers of the first eight storage caverns and cavern wells, and the location of the gas detection system near the northwest corner of the brine evaporation pond. The Storage Cavern Field currently includes plans for eight storage cavern and cavern well locations: Cavern Well 5 (CW-5), Cavern Well 6 (CW-6), Cavern Well 7 (CW-7), Cavern Well 8 (CW-8), Cavern Well 9 (CW-9), Cavern Well 10 (CW-10) Cavern Well 11 (CW-11), and Cavern Well 12 (CW-12). The storage caverns within the Field are being constructed using conventional solution mining technology. Depending upon the cavern size, solution mining will take between six and 12 months to complete. Both DWQ and DOGM have approved the engineering design and plans for cavern well spacing, wellhead design, casing design, drilling plan, cementing plan, solution mining plan, and cavern operations.

The UIC Permit has cavern spacing and depth requirements in order to maintain both cavern wall and roof integrity of the individual caverns and of the overall salt web. The requirement for the solid salt pillars between any 2 caverns and offset from the edge of the salt dome is two times the individual storage cavern diameter. This translates to a 600 foot surface spacing of the cavern wells to accommodate storage caverns that are 2 MMbbls in size (approximately 200 feet in diameter and approximately 1,250 feet in height). Given the nature of NGLs storage, however, Sawtooth has spaced caverns within the Storage Cavern Field between 600 and 700 feet apart to ensure that each cavern maintains the required pillar spacing through time. While cavern depths within the salt dome are dependent upon the individual cavern locations relative to the below ground elevation of the top of salt, the tops of caverns will likely range in depth between 3,500 and 4,100 feet bgs and the base of caverns will range in depth between 4,500 to 5,500 feet bgs. With that said, the final cemented casing will be set a depth of no less than 200 feet below the top of the salt structure, and the roof of the cavern will be established at a depth no less than 100 feet below the setting depth of the last cemented casing.

Section 2
General Well Construction/Drilling Plan

2.1 Cavern Well Design Methodology

Prior to the construction of individual caverns in the Storage Cavern Field the specific cavern well design and cavern well construction plan is reviewed and approved by DOGM as part of the Permit to Drill process. The general cavern well design outlined in this section is a typical cavern well design developed specifically for the Sawtooth NGLs storage caverns and meets the state rules for drilling (R649-3-6) and casing testing (R649-3-13 and R649-3-7.4). The design has been previously reviewed and approved by both the DWQ and DOGM.

The typical Sawtooth NGLs cavern well design includes a well head, five cemented casings, and two hanging casing strings (Figure 3). The cavern well is designed to provide a strong foundation for mechanical integrity of the cavern well and storage cavern as well as protect against the potential for groundwater contamination. The cavern well casing design includes: one surface casing; two water protection casing strings, one cemented in the freshwater zone and the other to the top of the salt; two casing strings cemented into the upper section salt; and, two hanging strings.

The two guiding principles of the cavern well design are: the need to support injection and production from the completed storage cavern at 1,500 gpm with a velocity about 16 feet per second; and, sizing the casing to allow for the use of hanging casing strings for solution mining at rates of about 2,500 gpm. Consequently, the goal of the Sawtooth NGLs cavern well design is to specify casing sizes and grades that allow a safety factor of about 1.05 for collapse, 1.2 for burst and 1.6 for tensile forces based on published strength data. The various casing strings included in the typical design are therefore sized to withstand foreseeable collapse, burst and tensile forces that might act upon the casing.

In normal operations collapse forces generally are greatest during cementing of the casing string when the inside of the casing is filled with drilling mud and the annulus is filled with heavier cement slurry. In normal operations the collapse forces resulting from the weight difference between cement and drilling mud are low. At 4,000 feet this can amount to about 1,000 psi. However, in keeping with generally accepted practices (such as ERCB Directive 10) the collapse pressures are calculated with the assumption that the annulus is filled with cement and the inside of the casing is air-filled.

In the case of the outer hanging casing string, the collapse pressures also result from the use of nitrogen as a blanket material. The nitrogen blanket pressure will be greatest at the start of mining when the nitrogen blanket is at its deepest location. At the worst case (for collapse calculations) the largest pressures occur during reverse mining when the cavern is shut-in. In this instance, water is in the outer tubing string, and the brine in the cavern is unsaturated and continues to dissolve salt. The continued dissolution increases space in the cavern so that the wellhead fluid pressures fall to a vacuum. If at the same time the borehole has closed around the hanging tubing, the nitrogen pressure will be locked in at its normal operating pressure. The full nitrogen pressure of about 2,000 psi will be acting against the 13-3/8-inch tubing with a vacuum on the inside. The tubing has been sized to withstand this event, however it is unlikely.

Burst forces again are generally greatest during cementing operations but are normally very low during normal operations. The worst case occurs if the casing has been run in the well, the float shoe/collar gets stuck shut and a gas blowout occurs at the bottom of the hole. In this event the full hydrostatic pressure of the drilling mud in the casing would be acting against a low-pressure gas-filled annulus. The pressure of the annulus was conservatively assumed to be "0" psi.

In the case of the final cemented casing, significant burst forces occur during mining operations due to the use of nitrogen as the blanket material. After mining is completed, lesser pressures will act inside the final cemented casing as a result of normal liquid storage operations.

The purpose of the heavier wall casing at the bottom of the 8-5/8" string is to have a compatible set of hanging casing strings (13-3/8" and 8-5/8") that sonar caliper tools may be able to survey through. An intermediate sonar survey will be completed to determine if the hanging casing strings area compatible. In the event that the hanging casings strings are incompatible, then a workover to pull the strings will be required in order to obtain a cavern survey that meets the requirements of the UIC Permit.

Table 1: Summary of Casings for Sawtooth Gas Storage Well

Casing String	Size – inches	Weight – pounds/foot	Grade	Depth – feet
Conductor	36	282.35	X-52	0 – 150
Surface	30"	234.29	X-56	0 - 750
Intermediate	24"	156.17	X-52	0 – 950
Intermediate	24"	245.64	X-52	950 – 3,100
Intermediate **Final cemented depth 3,300 feet**	24"	303.7	X-52	3,100 – 3,300
First Salt	20"	129.33	X-52	0 – 1,500
First Salt **Final cemented depth 3,500 feet**	20"	202.92	X-52	1,500 – 3,500
Production (2nd Salt)	16"	97	N-80	0 – 2,400
Production (2nd Salt) **Final cemented depth 3,600 feet**	16"	109	P-110	2,400 – 3,600
Outer Mining String	13-3/8"	72	N-80	0 – 4,300
Inner Mining String	8-5/8"	32	K-55	0 – 3,950
Inner Mining String	8-5/8"	44	N-80	3,950 – 4,950

The typical casing design for the Sawtooth NGLs cavern wells is summarized in Table 1 and shown in Figure 3. In the event that these casing and pipe sizes are not available, the next higher grade or increased wall thickness should be chosen. The safety factors for the various loading scenarios are summarized in Table 2.

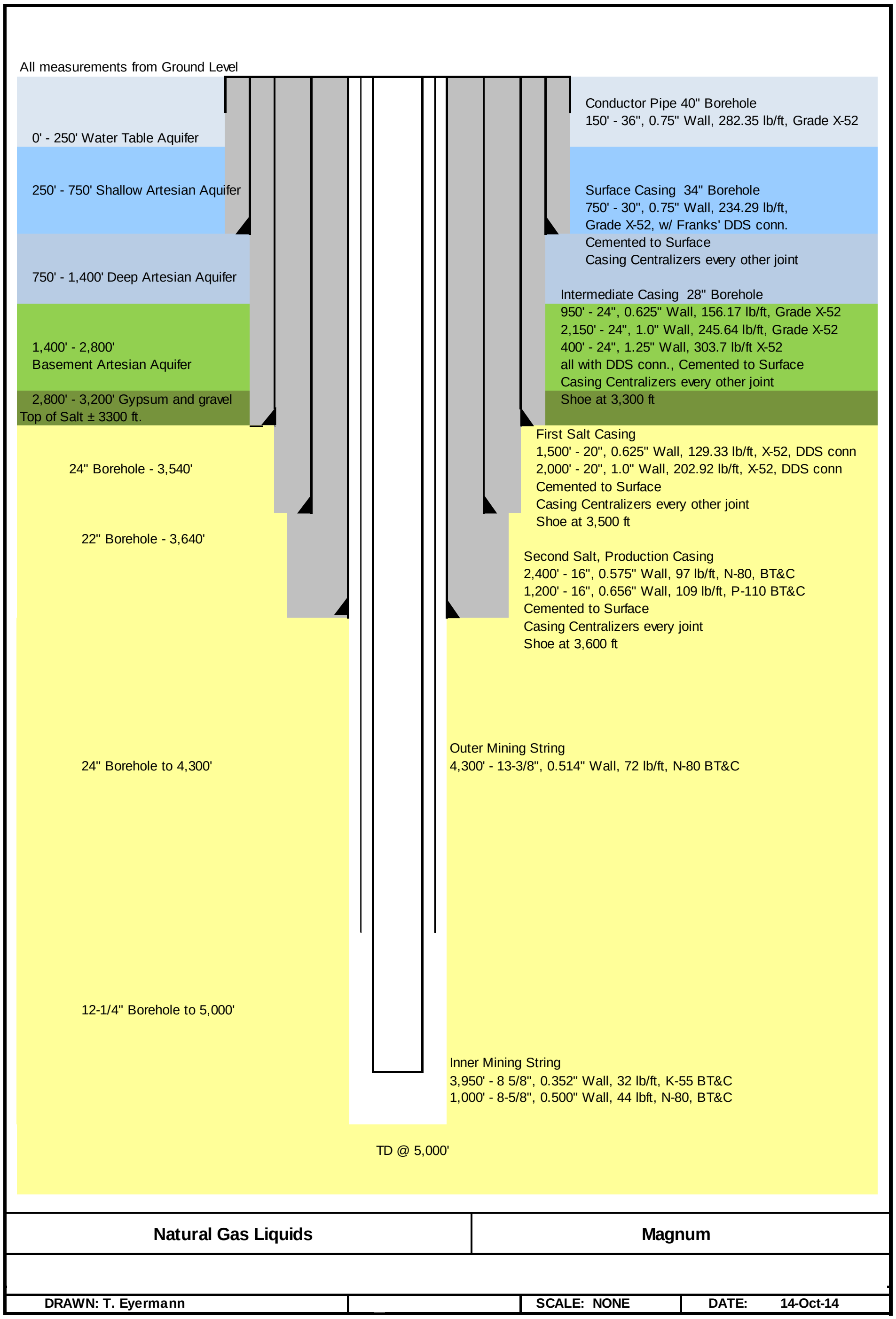

Figure 3: General Cavern Well Schematic

Table 2: Summary of Calculated Factors of Safety			
Casing String	**Safety Factor**		
	Collapse – 1.1	**Burst – 1.2**	**Tensile – 1.6**
36-inch Conductor	N/A	N/A	N/A
30-inch Surface	5.03	3.91	18.20
24-inch Intermediate	1.13	5.06	2.52
24-inch Intermediate	1.10	2.31	6.38
24-inch Intermediate	1.20	1.82	N/A
20-inch First Salt String	1.14	4.91	3.30
20-inch First Salt String	1.53	1.98	N/A
16-inch Production (2nd Salt String)	1.12	3.88	4.02
16-inch Production (2nd Salt String)	1.14	4.04	N/A
13-3/8-inch Outer Mining String	1.19	1.84	5.46
8-5/8-inch Inner Mining String	1.23	1.91	4.05
8-5/8-inch Inner Mining String	3.24	3.14	N/A

2.2 Casing Design Calculations

2.2.1 Conductor Pipe

36-inch, wall thickness 1-inch, grade X-52, plain end, welded pipe from 0 feet to approximately 150 feet. Pipe is to be cemented in an open hole.

2.2.2 Surface Casing

30-Inch, 234.29 lb/ft, wall thickness 0.75-inch, grade X-56 pipe, with Frank's DDS connections from 0 feet to 750 feet.

2.2.2.1 *Collapse Calculations*

Assume that the bottom hole depth of the 30-inch surface casing is at ±750 feet from surface, with a welded float shoe located at the bottom of the casing string. The worst-case scenario for collapse pressure would be a full column of cement in the casing/hole annulus, and a column of gas inside the 30-inch surface casing.

1. (750 feet) (0.052 psi/ft) (15.6 lb/gal cement) = 608 psi hydrostatic pressure exerted on the exterior of the 30-inch casing, at 750 feet.
2. 0 psi hydrostatic pressure is exerted on the interior of the 30-inch casing, at 750 feet.
3. Differential pressure, (collapse pressure) annulus pressure verses pressure inside the 30-inch casing equals: 608 psi – 0 psi = 608 psi.

The 30-inch surface casing has a collapse rating of 898 psi. According to the above differential calculations, the proposed 30-inch surface casing to be used has a collapse rating of 1,631 psi, greater than any outside pressure that will be exerted against the exterior of the casing.

2.2.2.2 *Burst Calculations*

Assume that the bottom hole depth of the 30-inch surface casing is at ±750 feet from surface, with a welded float shoe located at the bottom of the casing string. The 30-inch surface casing will be loaded with 9.5 lb per gallon drilling mud. The worst case for burst is if the float shoe becomes stuck closed and a gas blowout occurs at the shoe. In this case there would be a column of gas outside of the casing and a full column of drilling mud inside the casing.

1. (750 feet) (0.052 psi/ft/lb/gal) (9.5 lb/gal drilling mud) = 371 psi hydrostatic pressure exerted on the interior of the 30-inch casing, at 750 feet.
2. Differential pressure, (burst pressure) inside pressure verses annulus pressure on the outside of the 30-inch casing equals: 371 psi – 0 psi = 371 psi.

According to API Bulletin 5L the 30-inch surface casing has a minimum test pressure of 2,100 psi. According to the above differential calculations, the proposed 30-inch surface casing to be used has a minimum test pressure greater than any inside pressure that will be exerted against the interior of the casing.

2.2.2.3 *Tensile Calculations*

The proposed 30-inch surface casing weighs 234.29 lb/ft and will be set at approximately 750 feet, for a total string weight of 175,717.5 lbs.

The 30-inch, welded surface casing proposed has a tensile rating of 3,584,000 lbs, which is greater than tensile weight exerted by the weight of the casing.

2.2.3 Intermediate String Casing

24-inch, 156.17 lb/ft, Wall Thickness 0.625-inch, X-52 Grade, Plain end fitted with threaded connections from 0 feet to 950 feet

24-inch, 245.64 lb/ft, Wall Thickness 1.0-inch, X-52 Grade, Plain end fitted with threaded connections from 950 feet to 3,100 feet

24-inch, 303.70 lb/ft, Wall Thickness 1.25-inch, X-52 Grade, Plain end fitted with threaded connections from 3,100 feet to 3,300 feet

2.2.3.1 *Collapse Calculations*

Assume that the bottom hole depth of the 24-inch 303.7lb/ft casing (pipe) at ±3,300 feet from surface, with a welded float shoe located at the bottom of the casing string. The worst-case scenario for collapse pressure would be a full column of cement in the casing/hole annulus, and an empty column inside the 24-inch surface casing.

1. (950 feet) (0.052 psi/ft/lb/gal) (15.6 lb/gal cement) = 771 psi hydrostatic pressure exerted on the exterior of the 24-inch casing, at 950 feet.

1a. (3,100 feet) (0.052 psi/ft/lb/gal) (15.6 lb/gal cement) = 2,515 psi hydrostatic pressure exerted on the exterior of the 24-inch casing, at 3,100 feet.

1b (3,300 feet) (0.052 psi/ft/lb/gal) (15.6 lb/gal cement) = 2,677 psi hydrostatic pressure exerted on the exterior of the 24-inch casing, at 3,300 feet.

2. Differential pressure, (collapse pressure) annulus pressure verses pressure inside the 24-inch casing at 1,600 feet equals: 771 psi – 0 psi = 771 psi.

2a. Differential pressure, (collapse pressure) annulus pressure verses pressure inside the 24-inch casing at 3,100 feet equals: 2,515 psi – 0 psi = 2,515 psi.

2b. Differential pressure, (collapse pressure) annulus pressure verses pressure inside the 24-inch casing at 3,300 feet equals: 2,677 psi – 0 psi = 2,677 psi.

According to Frank's 2008, the 24-inch outer string casing at 950 feet has a collapse rating of 874 psi, at 3,100 feet the collapse rating is 2,761 psi and at 3,300 feet a collapse rating of 3,213 psi. According to the above differential Calculations, the proposed 24-inch outer string casing to be used has a collapse rating greater than any outside pressure that will be exerted against the exterior of the casing.

2.2.3.2 *Burst Calculations*

Assume that the bottom hole depth of the 24-inch surface casing is at ±3,300 feet from surface, with a welded float shoe located at the bottom of the casing string. The 24-inch surface casing will be loaded with 10.2 lb per gallon drilling mud. The actual cement process will be down drill pipe, which will be stung into the float shoe at 3,300 feet so that the casing is not filled with cement. The worst case for burst is if the float shoe becomes stuck closed and a gas blowout occurs at the shoe. In this case there would be a column of gas outside the outside of the casing and a full column of drilling mud inside the casing.

1. (950 feet) (0.052 psi/ft/lb/gal) (10.2 lb/gal drilling mud) = 504 psi hydrostatic pressure exerted on the interior of the 24-inch casing, at 950 feet.

1a. (3,100 feet) (0.052 psi/ft/lb/gal) (10.2 lb/gal drilling mud) = 1,644 psi hydrostatic pressure exerted on the interior of the 24-inch casing, at 3,100 feet.

1b (3,300 feet) (0.052 psi/ft/lb/gal) (10.2 lb/gal drilling mud) = 1,750 psi hydrostatic pressure exerted on the interior of the 24-inch casing, at 3,300 feet.

2. Differential pressure, (burst pressure) inside pressure verses annulus pressure on the outside of the 24-inch casing at 950 feet equals: 504 psi – 0 psi = 504 psi

2a. Differential pressure, (burst pressure) inside pressure verses annulus pressure on the outside of the 24-inch casing at 3,100 feet equals: 1,644 psi – 0 psi = 1,644 psi

2b. Differential pressure, (burst pressure) inside pressure verses annulus pressure on the outside of the 24-inch casing at 3,300 feet equals: 1,750 psi – 0 psi = 1,750 psi

According to Frank's, the 24-inch outer sting casing has a minimum burst pressure of 3,281 psi above 950 feet, 4,375 psi between 950 feet and 3,100 feet and 3,190 psi for the deeper segment of the string. According to the above differential calculations, the proposed 24-inch surface casing to be used has a minimum test pressure greater than any inside pressure that will be exerted against the interior of the casing.

2.2.3.3 *Tensile Calculations*

The proposed 24-inch outer string casing weighs 156.17 lb/ft, 245.64 lb/ft and 303.70 lb/ft and will be set at approximately 3,300 feet, for a total string weight of 737,228 lbs.

The proposed 24-inch, welded intermediate casing has a tensile rating of 1,856,000 lbs, which is greater than tensile weight exerted by the casing.

2.2.4 First Salt String Casing

20-Inch, 129.33 lb/ft, wall thickness 0.625-inch, grade X-52pipe, DDS connection, Casing from 0 to 1,500 feet.

20-Inch, 202.92 lb/ft, wall thickness 1.0-inch, grade X-56 pipe, DDS connection from 1,500 to 3,500 feet.

2.2.4.1 *Collapse Calculations*

Assume that the bottom hole depth of the 20-inch first salt string of casing is at ±3500 feet from surface, with a float shoe located at the bottom of the casing string. The casing string will be made up of two weights of casing.

Above 1,500 feet the casing will be 129.33 lb/ft X-52 casing. From 1,500 feet to 3,500 feet the casing will be 202.92 lb/ft X-52 casing. This string will have proprietary connections on the entire string. The worst-case scenario for collapse pressure would be a full column of cement in the casing/hole annulus, and an empty inside the 20-inch surface casing.

1. (1,500 feet) (0.052 psi/ft/lb/gal) (16.3 lb/gal cement) = 1,271 psi hydrostatic pressure exerted on the exterior of the 20-inch casing, at 1,500 feet.

1a. (3,500 feet) (0.052 psi/ft/lb/gal) (16.3 lb/gal cement) = 2,967 psi hydrostatic pressure exerted on the exterior of the 20-inch casing, at 3,500 feet.

2. At 1,500 feet, the differential pressure equals: 1,271 psi – 0 psi = 1,271 psi. According to API, the 20-inch 129.33-lb/ft casing has a collapse rating of 1,445 psi. According to the above differential calculations, the proposed 20-inch first salt string casing to be used has a collapse rating greater than any outside pressure that will be exerted against the exterior of the casing.

2a. At 3,500 feet, the differential pressure equals: 2,967 psi – 0 psi = 2,967 psi. The 20-inch 202.92 lb/ft pipe has a collapse rating of 4,550 psi according to Frank's. According to the above differential calculations, the proposed 20-inch first salt string casing to be used has a collapse rating greater than any outside pressure that will be exerted against the exterior of the casing.

2.2.4.2 *Burst Calculations*

Assume that the bottom hole depth of the 20-inch surface casing is at ±3,500 feet from surface, with a welded float shoe located at the bottom of the casing string. The 20-inch surface casing will be loaded with 10.2 lb per gallon drilling mud. The actual cement process will be down drill pipe, which will be stung into the float shoe at 3,500 feet so the casing will not be filled with cement. The worst case for burst considerations would be if there was a gas blowout in the salt after the casing was set but before it was cemented. This could potentially leave a column of gas along the outside of the casing and a full column of drilling mud inside the casing.

1. (1,500 feet) (0.052 psi/ft/lb/gal) (10.2 lb/gal drilling mud) = 796 psi hydrostatic pressure exerted on the interior of the 20-inch casing, at 1,500 feet.

1a. (3,500 feet) (0.052 psi/ft/lb/gal) (10.2 lb/gal drilling mud) = 1,856 psi hydrostatic pressure exerted on the interior of the 20-inch casing, at 3,500 feet.

2. Differential pressure (burst pressure), inside pressure verses annulus pressure on the outside of the 20-inch casing equals: 796 psi – 0 psi = 796 psi.

2. Differential pressure (burst pressure), inside pressure verses annulus pressure on the outside of the 20-inch casing equals: 1,856 psi – 0 psi = 1,856 psi.

The 20-inch pipe has a minimum burst pressure of 3,904 psi above 1,500 feet and 3,675 psi for the deeper segment of the string. According to the above differential calculations, the proposed

20-inch surface casing to be used has a minimum test pressure greater than any inside pressure that will be exerted against the interior of the casing.

2.2.4.3 *Tensile Calculations*

The 20-inch surface casing proposed weighs 129.33 lb/ft set at 1,500 feet and 202.92 lb/ft set at approximately 3,500 feet, for a total string weight of 599,835 lbs.

Franks provides a tensile strength for the DSS connection on the casing at the top of the string of 1,978,000 pounds; which exceeds the above-calculated weight of the 20-inch casing.

2.2.5 Production String Casing

16-inch, 97 lb/ft, grade N-80 pipe, wall thickness 0.575-inch, buttress connection, casing from 0 to 2,400 feet.

16-inch, 109 lb/ft, grade P-110 pipe, wall thickness 0.656-inch, buttress connection, casing from 2,400 to 3,600 feet.

2.2.5.1 *Collapse Calculations*

Assume that the bottom hole depth of the 16-inch production string of casing is at ±3,600 feet from surface, with a welded float shoe located at the bottom of the casing string. This string will have buttress connections. The worst-case scenario for collapse pressure would be a full column of cement in the casing/hole annulus, and gas (from a blowout) inside the 16-inch surface casing.

1. (2,400 feet) (0.052 psi/ft/lb/gal) (16.3 lb/gal cement) = 2,034 psi hydrostatic pressure exerted on the exterior of the 16-inch casing, at 2,400 feet.

1a. (3,600 feet) (0.052 psi/ft/lb/gal) (16.3 lb/gal cement) = 3,051 psi hydrostatic pressure exerted on the exterior of the 16-inch casing, at 3,600 feet.

2. Differential pressure, collapse pressure, annulus pressure verses pressure inside the 16-inch casing equals: 2,034 psi – 0 psi = 2,034 psi.

2a. Differential pressure, collapse pressure, annulus pressure verses pressure inside the 16-inch casing equals: 3,051 psi – 0 psi = 3,051 psi.

According to API, the 16-inch N-80 97 lb/ft casing has a collapse rating of 2,270 psi and the 16-inch P-110, 109-lb/ft casing has a collapse rating of 3,470 psi. According to the above differential calculations, the proposed 16-inch casing to be used has a collapse rating greater than any outside pressure that will be exerted against the exterior of the casing.

2.2.5.2 *Burst Calculations*

Assume that the bottom hole depth of the 16-inch surface casing is at ±3,600 feet from surface, with a welded float shoe located at the bottom of the casing string. The 16-inch surface casing will be loaded with 10.2 lb per gallon drilling mud. The actual cement process will be down drill pipe, which will be stung into the float shoe at 3,600 feet so the inside of the casing will not be filled with cement. The worst case for burst considerations would be if there was a gas blowout in the salt after the casing was set but before it was cemented. This could potentially leave a column of gas along the outside of the casing.

1. (2,400 feet) (0.052 psi/ft/lb/gal) (10.4 lb/gal drilling mud) = 1,298 psi hydrostatic pressure exerted on the interior of the 16-inch casing, at 2,400 feet.

1a. (3,600 feet) (0.052 psi/ft/lb/gal) (10.4 lb/gal drilling mud) = 1,947 psi hydrostatic pressure exerted on the interior of the 16-inch casing, at 3,600 feet.

2. Differential pressure (burst pressure), inside pressure verses annulus pressure on the outside of the 16-inch casing equals: 1,298 psi – 0 psi = 1,298 psi. The 16-inch casing above 2,400 feet has a minimum test pressure of 5,030 psi. According to the above differential calculations, the proposed 16-inch surface casing to be used has a minimum test pressure greater than any inside pressure that will be exerted against the interior of the casing.

2a. Differential pressure (burst pressure), inside pressure verses annulus pressure on the outside of the 16-inch casing equals: 1,947 psi – 0 psi = 1,947 psi. According to API, the 16-inch casing has a minimum test pressure of 7,870 psi. According to the above differential calculations, the proposed 16-inch surface casing to be used has a minimum test pressure greater than any inside pressure that will be exerted against the interior of the casing.

3. During mining operations, the 16" casing annulus will be filled with nitrogen used as a blanket during mining operations. At the surface, the maximum gas pressure will be about 1,872 psi / (e ^ (0.00003347 * 0.58 * depth) = 1,770 psi. The wellhead gas pressure is below the rated burst pressure of 5,030 psi of the 16" casing at the surface.

2.2.5.3 *Tensile Calculations*

The 16-inch surface casing proposed weighs 97 lb/ft at 2,400 ft. and 109 lb/ft at approximately 3,600 feet, for a total string weight of 472,600 lbs.

The tensile strength for buttress end casing is about 2,229,000 pounds; which exceeds the above-calculated weight of the 16-inch casing.

2.2.6 Outer Mining String

13-3/8-inch, 72 lb/ft, wall thickness 0.514-inch, grade N-80 pipe, buttress connection, casing from 0 to 4,300 feet.

2.2.6.1 *Collapse Calculations*

Assume that the nitrogen roof blanket will be at a depth of ±3,600 feet from surface, the maximum differential pressure exerted against the 13-3/8-inch casing will be at the surface.

The worst-case scenario for collapse pressure would be a column of fluid in the casing (during the first steps of mining) that goes on a vacuum when the well is shut-in and the brine in the cavern continues to dissolve salt; and nitrogen is in the annulus.

1. (3,600 feet) (0.052 psi/ft/lb/gal) (10.0 lb/gal brine) = 1,872 psi hydrostatic pressure exerted on the exterior of the 13-3/8-inch casing, at 3,600 feet. The nitrogen pressure on the outside of the string and the brine pressure in the cavern are balanced at this point.

1a. Pressure outside the 13-3/8-inch at the surface is (nitrogen blanket pressure) / (1.000316 ^ blanket level depth) = 1,872 / (1.0000316 ^ 3600) = 1,770 psi

2. (3,600 feet) (0.052 psi/ft/lb/gal) (10.0 lb/gal brine) = 1,872 psi hydrostatic pressure exerted on the interior of the 13-3/8-inch casing, at 3,600 feet.

2a. Differential pressure, collapse pressure, annulus pressure verses pressure inside the 13-3/8- casing at the surface equals: 1,770 psi – (-100 psi) (vacuum) = 1,870 psi. According to API Bulletin 5C2, the 13-3/8-inch string casing has a collapse rating of 2,670 psi. According to the above differential calculations, the proposed 13-3/8-inch casing to be used has a collapse rating greater than the pressure that will be exerted against the exterior of the casing.

2.2.6.2 *Burst Calculations*

Assume that the bottom hole depth of the 13-3/8-inch surface casing is at ±4,300 feet from surface, with an open end of the hanging casing string. The 13-3/8-inch surface casing will be loaded with water during reverse mining steps. The worst case for burst considerations would be if the nitrogen blanket bled off and the bottom of the 13-3/8-inch tubing was salted into the 16-inch production casing during normal operations with a salt plug at or near the bottom of the 13-3/8” x 8-5/8” annulus. This could potentially leave a column of gas along the outside of the tubing and high-pressure fluid on the inside of the tubing string.

1. 0 psi hydrostatic pressure is exerted on the exterior of the 13-3/8-inch casing, at the 16-inch casing shoe.
2. Pump pressure (Value unknown but assumed) 780 psi exerted on the 13-3/8-inch casing.
3. Fluid pressure at 3,600 feet of (3,600 feet) (0.052 psi/ft/lb/gal) (8.34 lb/gal water) = 1,561 psi exerted on the interior of the 13-3/8-inch casing at 3,600 feet.
4. Differential pressure (burst pressure), inside pressure verses annulus pressure on the outside of the 13-3/8-inch casing equals: 1,561 psi + 780 psi (assumed pump pressure) – 0 psi = 2,341 psi.

According to API Bulletin 5C2, the 13-3/8-inch casing has a minimum test pressure of 5,380 psi. According to the above differential Calculations, the proposed 13-3/8-inch surface casing to be used has a minimum test pressure greater than any inside pressure that will be exerted against the interior of the casing.

2.2.6.3 *Tensile Strength*

The outer hanging casing string 72 lb/ft casing set at 4,300 feet. Based on these depths, the maximum hanging casing string weight will be 309,600 lbs. This is well below the maximum tensile strength at the surface of 1,693,000 lbs.

2.2.7 Inner Mining String

8-5/8-inch, 32 lb/ft, Wall Thickness 0.352-inch, K-55 Grade, Buttress Connection, Casing from 0 to 3,950 feet

8-5/8-inch, 44 lb/ft, Wall Thickness 0.55-inch, N-80 Grade, Buttress Connection, Casing from 3,950 to 4,950 feet.

2.2.7.1 *Burst and Collapse Calculations*

The 8-5/8-inch inner wash hanging casing string has the similar circumstance as the 13-3/8-inch outer hanging casing string, in that the tubing will basically have equal weight of fluids (brine water) on the outside as well as the inside, internal and external pressures will be equal.

Therefore, since there will not be any differential pressures exerted externally or internally, burst and collapse calculations are not necessary. The 8-5/8-inch hanging casing string will not have nitrogen acting against it.

2.2.7.2 *Tensile Strength*

The deepest depth for the inner hanging casing string is estimated at approximately 4,950 feet. Based on this depth, the maximum sting weight will be 170,400 lbs. This is well below the maximum tensile 690,000 lbs.

2.2.8 Sources Used for Cavern Well Design

- American Petroleum Institute, Specification for Line Pipe, API Specification 5L.
- American Petroleum Institute, Bulletin on Performance Properties of Casing, Tubing and Drill Pipe, API Specification 5C2.
- American Petroleum Institute, Technical Report on Equations and Calculations for Casing, Tubing and Line Pipe Used as Casing or Tubing; and Performance Properties Tables for Casing and Tubing, API Technical Report 5C3.
- Energy Resource Conservation Board, 2008. Minimum Casing Design Requirements, Directive 010.
- Frank’s Casing, 2008, DDS Double Drive Shoulder Connector.

2.3 General Well Construction/Drilling Plan

Cavern wells are drilled from the surface to about eighteen hundred feet into the salt, generally between 3,500 and 4,100 feet bgs. The depths lists are approximate from ground level. Casing lengths, grades and wall thicknesses may change as determined by availability and drilling conditions. The cavern well design, to include the casing specifications and setting depths, conforms to the requirements set forth in the UIC Permit. The typical cavern well design depicted in Figure 3 corresponds to the general well construction /drilling plan presented in this section. The well construction process for the individual cavern wells will be completed per the steps outlined below:

1. Rig up drilling rig.
2. Drill 40” hole for or drive 36” 0.75” wall thickness, 282.35 lb/ft, Grade X-52 conductor pipe to approximately 150 feet.
3. During all drilling of pilot holes, the deviation should be measured at least every 200 feet. The deviation is not to exceed 1.5 °. If the deviation exceeds the tolerance, steps will be taken to correct it. Chip samples will be collected every five feet of drilling. The on-site geologist will log these chip samples but the samples will not be saved.
4. Drill a 17-1/2" hole to ±770 feet and log.
5. Open 17-1/2" hole up to 34" with hole openers as appropriate.

6. Run and cement 750 feet of 30" O.D., 0.75” wall thickness, API 5L Grade X-56 pipe. Centralizers to be placed every other casing section.
7. Allow the cement to set a minimum of 18 hours. Pressure test the casing in accordance with State rules.
8. After the cement sets, cut off the 30" casing and attach appropriate mud piping.
9. Drill a 17-1/2" hole to about 3,300 feet, slightly above top of salt structure estimated to be ± 3,250 feet. Lost circulation may occur over this interval; control as necessary by the use of lost circulation material, cement plugs or drill without returns.
10. Run gamma ray, neutron, density, SP induction and resistivity logs as specified.
11. Open the 17-1/2" hole to 28" with hole openers of increasing size.
12. Run X-Y caliper log.
13. Run and cement ±200 feet of 24: O.D. 1.25” wall thickness, API 5L X-52, 2,150 feet of 24" O.D., 1” wall thickness, API 5L X-52 and 950 feet of 24” O.D. 0.625” wall thickness API 5L X-52 or equivalent threaded and coupled pipe to top of salt structure. *Casing string weight is approximately 737,228 pounds in air*. Use the stab-in cementing method. Centralizers to be placed every other casing section.
14. After the cement sets for 48 hours, pressure test the casing in accordance with State rules.
15. Cut off the 24" casing and connect appropriate mud flow equipment.
16. Drill out cement and shoe with 22” bit.
17. Switch to salt saturated mud after drilling out cement.
18. Drill a 12-1/4” hole to ± 3,650 feet.
19. Run gamma ray, SP induction, neutron and bulk density logs as specified. An experienced salt geologist will review the logs to determine the top of salt.
20. Open the 12-1/4" hole to 24" to about 3,520 feet with hole openers and underreamers of increasing size.
21. Run X-Y caliper log.
22. Run and cement 2,000 feet of 20”, 1.0” wall thickness, X-52, threaded and coupled pipe and 1,500 feet of 20", 0.625" wall thickness, X-52 threaded and coupled pipe. *Casing string weight is approximately 600,000 pounds in air*. Use the stab-in cementing method. Centralizers to be placed on each of the first 10 joints and then every other casing section.
23. Allow the cement to set a minimum of 72 hours.
24. Cut off the 20" casing and weld on a 21-1/4" flange. Nipple up an annular BOP or blind flange for testing. Pressure test the casing in accordance with State rules.
25. Drill out cement, shoe and about 5 feet of formation. Pressure test casing seat in accordance with state regulations.
26. Open the 12-1/4" hole up to 22" to about 3,620 feet using hole openers and underreamers.
27. Run X-Y caliper log.
28. Run and cement 1,200 feet of 16” 0.656" wall thickness, P-110 BT&C API pipe and 2,400 feet of 16" 0.575” wall thickness N-80 casing. Use the stab-in cementing method. Centralizers to be placed every casing joint.
29. Allow the cement to set a minimum of 96 hours. Pressure test the casing in accordance with State rules (R649-3-13 and R649-3-7.4).

30. Install blowout preventer on 16” or 20” casing.
31. Drill out plug and ten feet of salt formation.
32. Pressure test casing shoe in accordance with the State rules and regulations.
33. Drill a 12-1/4” hole to ±5,000 feet.
34. Log cuttings and check for loss of drilling fluid indicating a porous formation is encountered. If so, perform a tightness test over this interval.
35. Run gamma ray, neutron and bulk density logs as specified.
36. If logs indicate a porous zone in the salt section, perform tightness test over the zone.
37. If no gas has been encountered, nipple down BOP.
38. Under ream the 12-1/4” hole to 24” down to a depth of about 4,350 feet.
39. Flush hole with clean brine, approximately 1,100 barrels.
40. Run X-Y caliper log.
41. Run casing inspection, cement evaluation logs in 16” casing from shoe to surface and inclinometer log from total depth to surface..
42. Run in approx. 4,300 feet of 13-3/8” 0.514” wall thickness, 72 lb/ft N-80, BT&C pipe.
43. Install and test the upper wellhead assembly.
44. Run in approx. 3,950 feet of 8-5/8” 0.352” wall thickness, 32 lb/ft, K-55, BT&C pipe and 1,000 feet of 8-5/8”, 0.55” wall thickness, 44 lb/ft, N-80, BT&C casing.
45. Install remainder of wellhead.
46. Rig down and move out rig from location.
47. Clean up location.

2.4 Welding Protocol

1. Lift ring welding and inspection to be performed in accordance with AWS (American Welding Society) D1.1 Structural Welding Code. Perform nondestructive testing (NDT) on the welds using ultrasonic shear wave equipment as specified in AWS D1.1 and interpreted by a NDT Level II or III Certified Technician who is qualified under ASNT CP-189, Standard for Qualification and Certification for Nondestructive Testing Personnel, 2006 Edition and CP-105, ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel, 2006 Edition..

2. Casing double joint welding shall be performed in accordance with API Standard 1104 Welding of Pipelines and Related Facilities. Pipe base material’s carbon equivalency will be computed from the material composition as written in the Material Test Report (MTR) that is provided when the pipe is purchased. The welding contractor will provide a Welding Procedure Specification (WPS) that matches the base material and Procedure Qualification Report (PQR) and welders who are qualified to the WPS with Welders Qualification Report (WQR). The welding contractor will provide the WQR for each potential welder prior to beginning production welding. The field supervisor will verify that the WQR and welder’s photo identification match. Perform nondestructive testing (NDT) on the butt welds using radiography as specified in API Standard 1104 and interpreted by a NDT Level II or III Certified Technician who is qualified under ASNT CP-189, Standard for Qualification and Certification for

Nondestructive Testing Personnel, 2006 Edition and CP-105, ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel, 2006 Edition. Each completed girth, butt weld shall be radiograph tested to API Standard 1104 qualifications. The radiograph methods and qualifications shall comply with API Standard 1104 –"Certification of Nondestructive Testing Personnel" and "Acceptance Methods for Nondestructive Testing Personnel".

3. Casing rig welding shall be performed in accordance with API Standard 1104 Welding of Pipelines and Related Facilities. Pipe base material's carbon equivalency will be computed from the material composition as written in the Material Test Report (MTR) that is provided when the pipe is purchased. The welding contractor will provide a Welding Procedure Specification (WPS) that matches the base material and Procedure Qualification Report (PQR) and welders who are qualified to the WPS with Welders Qualification Report (WQR). The welding contractor will provide the WQR for each potential welder prior to beginning production welding. The field supervisor will verify that the WQR and welder's photo identification match. Perform nondestructive testing (NDT) on the butt welds using radiography as specified in API Standard 1104 and interpreted by a NDT Level II or III Certified Technician who is qualified under ASNT CP-189, Standard for Qualification and Certification for Nondestructive Testing Personnel, 2006 Edition and CP-105, ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel, 2006 Edition. Each completed girth, butt weld shall be nondestructively tested to API Standard 1104 qualifications. The test methods and qualifications shall comply with API Standard 1104 "Certification of Nondestructive Testing Personnel" and "Acceptance Methods for Nondestructive Testing Personnel".

2.5 Well Conditioning

Before commencing drilling operations (spudding the well), Sawtooth will condition the well hole prior to cementing casing. The procedures for drilling mud conditioning will ensure that the drilling mud in the well has been displaced at least one time (circulated bottoms up) after completion of drilling to displace drill cuttings before tripping out the drill string. After running in the casing string to the desired depth, the mud volume will again be circulated bottoms up. This "pre-flush" procedure will ensure that the wellbore is properly conditioned for cementing operations in accordance with recommendations from the cementing contractor. The process will entail the circulation of drilling fluids to sweep cuttings out of the hole and obtain consistent fluid properties as well as adjust the fluid viscosity and density in an attempt to prevent cement channeling through the fluid.

2.6 Cementing Services and Materials Specifications

Sawtooth will cement the individual casings during the cavern well installation of the Sawtooth NGLs storage caverns per the UIC Permit requirements. The specification presented in this section covers the requirements to supply cement, equipment and services. A detailed overview of the typical cementing program for the installation of a Sawtooth NGLs cavern well is provided below. A land rig will be used to complete the process described.

Typical wellbore configuration (Depths RKB):

36” Conductor Pipe: 0 - Approx. 150 feet (Driven or set in 40” hole)
30” Surface Casing: 0 - Approx. 750 feet (Approx. 34” Open Hole)
24” Intermediate Casing: 0 – 3,300 feet (Approx. 28” Open Hole)
20” Next to Last Casing: 0 – 3,500 feet (Approx. 24” Open Hole)
16” Last Cemented Casing: 0 – 3,600 feet (Approx. 22” Open Hole)
Top of Salt: Approx. 3,400 feet

1. Cement specifications for the 30" Surface casing. Cement job will be pumped through a stabbed-in 5-1/2” DP.
   Cement to surface: Class A (Standard) + Defoamer (if deemed necessary)
   Water Ratio 5.2 gals/sack
   Slurry Weight 15.6 lbs/gal.
   Slurry Volume 1.18 cu. ft./sack
   Excess 50% Open Hole Volume (Caliper Available)

2. Cement specifications for the 24" Intermediate. Cement job will be pumped through a stabbed-in 5-1/2” DP.
   Cement to surface: Class A (Standard) + Defoamer (if deemed necessary).
   Water Ratio 5.2 gals/sk
   Slurry Weight 15.6 lbs/gal.
   Slurry Volume 1.18 cu. ft./sack
   Excess 50% Open Hole Volume (Caliper Available)

3. Cement specifications for the 20" Next to Last Casing. Cement job will be pumped through a stabbed-in 5-1/2” DP.
   Cement to surface: Class G (Premium) + 37.2% Salt + Defoamer (as necessary).
   Water Ratio 5.0 gals/sk
   Slurry Weight 16.3 lbs/gal.
   Slurry Volume 1.24 cu. ft./sack
   Excess 30% Open Hole Volume (Caliper Available)

4. Cement specifications for the 16" Last Casing. Cement job will be pumped through a stabbed-in 5-1/2” DP.
   Cement to surface: Class G (Premium) + 37.2% Salt + Defoamer (as necessary).
   Water Ratio 5.0 gals/sk
   Slurry Weight 16.3 lbs/gal.
   Slurry Volume 1.24 cu. ft./sack
   Excess 30% Open Hole Volume (Caliper Available)

A summary of the typical cementing program for Sawtooth NGLs well is included in Table 3 below.

Table 3: Typical Cementing Program					
Hole Size	**Driven**	**34-inch**	**28-inch**	**24-inch**	**22-inch**
Casing Size	**36-inch**	**30-inch**	**24-inch**	**20-inch**	**16-inch**

Mud Weight Type	N/A	9.5 ppg Fresh Water	10.2 ppg Fresh Water	10.2 ppg Saturated Brine	10.2 ppg Saturated Brine
Slurry Weight	N/A	15.6 ppg Fresh Water	15.6 ppg Fresh Water	16.3 ppg Saturated Brine	16.3 ppg Saturated Brine
Cement Type	N/A	Class A Standard	Class A Standard	Class G Premium	Class G Premium
Cement Yield	N/A	1.18cu ft/sk	1.18 cu ft/sk	1.24 cu ft/sk	1.24 cu ft/sk

Cementing operations will be visually verified at the time of the cementing via the observance of cement rising within the outer well annulus to the surface. The casing cement jobs will also be documented by an affidavit from the cementing company showing the amount and type of cementing materials and the method of placement. Three samples of the cement slurry for each of the salt casings shall be collected in suitable sized and shaped containers so that the hardened cement can be tested for compressive strength. As noted in Section 2.1 above a cement evaluation log will also be completed for each cemented casing after a 72 hour curing period and attaining a compressive strength of 500 psi. The results of these tests will be included in the Well Completion Report.

Section 3

Cavern Development /Solution Mining Plan

3.1 Cavern Development Plan Methodology

The individual solution mining plans for the Sawtooth NGLs storage caverns are developed using a cavern simulation modeling program, SaltCav3D that simulates mining asymmetrically around the well. The program is based on SalGas, an industry-accepted cavern simulation program developed for the Solution Mining Research Institute. SalGas and SaltCav3D are well suited for modeling development of caverns in massive salt deposits, such as salt domes. The general assumptions used in the Sawtooth NGLs model are detailed below.

The desired final cavern capacity is 2,000,000 barrels. The final cemented 16” casing is set at about 3400 feet. The hanging strings for mining are 13-3/8” and 8-5/8”. The tubular sizes are not important to the mining plan after the first few days of mining. The blanket is initially set at about 3650 feet and is moved upward as mining progresses. The final roof level was placed at 3575 feet depth or about 175 feet below the final cemented casing.

An average insoluble content of 8% with a bulking factor of 1.3 was used in the modeling. The gamma log shows the salt to be somewhat dirty, and chemical analysis performed by Sandia National Laboratories on samples from the MH-1 well core confirmed that the insolubles content is variable, averaging about 9%. Mining of CW-5 indicted that the insoluble content was about 8%. This assumption is not significant as long as the overall insoluble content is less than 12%.

The basic input for the model consists of average radii of the well, the depth of the water injection and brine production strings, the depth of the product level, water injection rates, and duration of mining. If a cavern exhibits a region of abnormal or non-symmetric growth, SaltCav3D cannot fully predict continued growth in such a region until after an initial sonar survey in the anomalous region has been conducted. However, the simulated growth can closely approximate future growth in regions of concern once shape data from a sonar survey of the cavern has been obtained.

As with all numerical models, SaltCav3D does not fully represent the actual salt caverns. This is due to limitations in the equations for flow within the cavern. The limitations in the hydraulic equations result in over-estimation of development near the bottom of the injection tubing in both reverse and direct mining and a corresponding underestimation of mining in the upper portions of the cavern. This limitation becomes more evident at high water injection rates, which were utilized in this study.

For this model, the cavern interval from the chimney to 5,000 feet depth was divided into a series of twenty foot tall cells. The final cemented casing was 16 inches. The inner string was to be 8-

5/8” tubing and the outer string to be 13-3/8” tubing. The casing sizes do not impact the final solution mining plan, although they have some influence on the very early days of mining.

The production flow rate was modeled at 2,500 gpm. A normal dissolution factor of “1” was used for the salt with an assumed cavern brine temperature of 80° F.

3.2 Cavern Development Plan

3.2.1 Solution Mining Schedule

Development of a storage cavern with a 2,000,000-barrel capacity will require approximately 318 days to complete. The “total time” required to develop a cavern includes time for mining, workovers, unknown shutdown times, logging episodes, and mechanical integrity testing at the end. A summary of the total time to develop a Sawtooth NGLs storage cavern is detailed in Table 4.

Table 4: Summary of Estimated Time to Develop a Typical Sawtooth NGLs Cavern

Mining Plan	Solution Mining Time (days)	Workover Time (days)	15% Contingency (days)	Sonar, Logging and Blanket Movement Time (days)	Mechanical Integrity Test & Completion Workover Time (days)	Total Time (days)
2,000,000 bbl. Cavern	230	15	35	8	30	318

As described in Table 4, the actual “solution mining time” is only 230 days of the 318 total days required to complete a cavern. Solution mining time represents days when water is injected at 2,500 gpm without interruption for 24 hours. The additional activities included in Table 4 are activities that may or may not be required, such as a workover. A workover is not required at a specific time during the solution mining of a cavern, but it be necessary sometime during mining to repair damaged tubing or to allow a sonar survey to be conducted. In order to create a conservative schedule, time for a workover has been included as well as a number of days for contingency, blanket movements, sonar surveys, and mechanical integrity testing.

Figure 4 shows both the rate of cavern development and the change in brine specific gravity through the development process, to include the change in the flow regime from direct to reverse circulation.

It is anticipated that approximately 19,000,000 barrels of brine will be produced during the development of the 2,000,000 barrel cavern. During mining operations the brine will have a specific gravity of less than 1.18, or about 90% saturation. During filling operations, the displaced brine will be saturated.

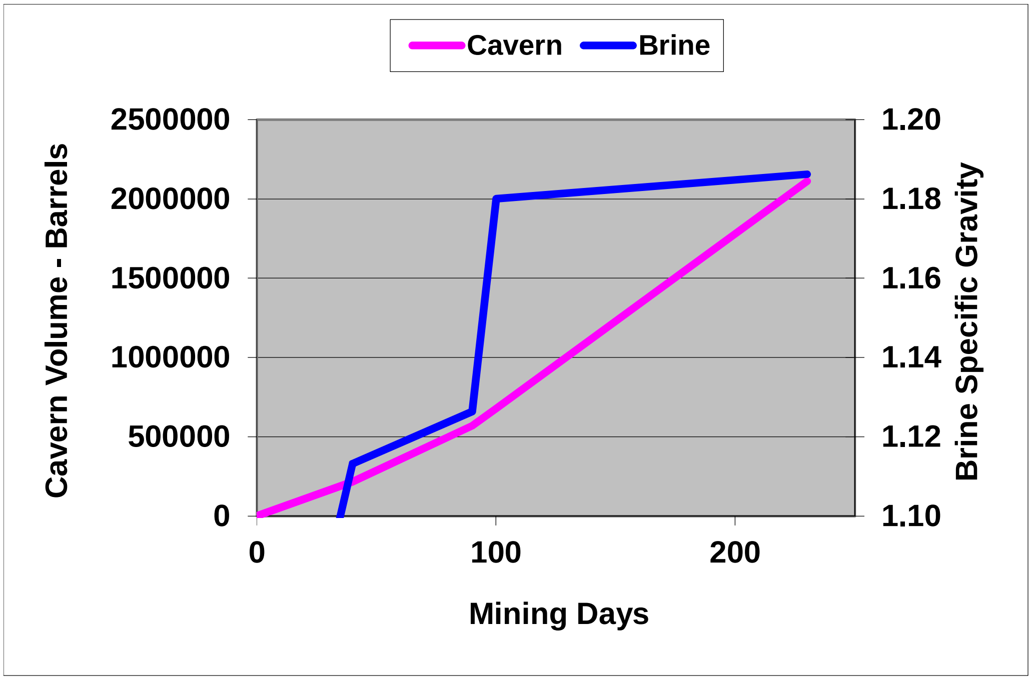

Figure 4: Rate of Cavern Development and Increase in Brine Specific Gravity for 2,000,000 Barrel Cavern

3.2.2 Typical Solution Mining Plan

Mining begins with the inner tubing string set close the bottom of the borehole. The outer string is set at 4,300 feet, about 700 feet above the inner string. The nitrogen blanket is set at about 3,650 feet or about 250 feet below the last cemented casing string. The setting depths for the tubing strings and blanket for a typical Sawtooth NGLs cavern are shown in Table 5 for all steps of the mining plan.

Mining commences with water injected in the deeper inner string and brine produced from the outer string – direct mining. Mining in this combined sump and chimney stage develops a large sump near the bottom of the cavern for accumulation of the insolubles that will be released from the salt during mining of the salt. This mining also begins development of the chimney where the main cavern will be located. This stage lasts about 50 days as shown in Table 6.

During the sump/chimney stage, the inner tubing may need to be cut one or more times to keep it above the accumulating insoluble pile. Direct mining can generally continue even with the inner string buried in the insoluble pile as long as water injection is maintained. In order to maintain the maximum height of the cavern, the inner tubing should be kept as near to the floor during this stage as is practical.

During the sump/chimney stage, the roof blanket should be monitored about every two weeks to ensure that it remains at the desired depth. Small quantities of nitrogen should be added on a weekly basis until a clear roof at a stable depth has been developed.

Table 5: Setting Depths for Development of Well CW-7 Developed to 2 mmbbls Capacity

Mining Step	Injection Setting –	Production Setting	Blanket Setting -	Insoluble Depth at

	Feet	- Feet	Feet	End of Step– Feet
Sump/Chimney	5,000	4,300	3,650	4,809
Reverse flow, cut inner tubing, raise blanket, run sonar survey, add nitrogen				
Reverse 1	4,300	4,700	3,625	4,757
Cut inner tubing, raise blanket, possibly run sonar survey, add nitrogen				
Reverse 2	4,300	4,650	3,600	4,701
Cut inner tubing, raise blanket, add nitrogen				
Reverse 3	4,300	4,600	3,575	4,649

At the completion of the sump/chimney stage, a workover is not required to reposition the tubing strings, but the inner string will need to be cut above the insolubles as shown in Table 5. Cavern volume, not elapsed time, is the key indicator for changes in flow and blanket depth to form the cavern roof. Mining is then changed to reverse flow – water injected in the outer, shallower string and brine produced from the deeper, inner string. At the start of reverse mining, the roof blanket should be moved uphole about 100 feet to about 3,500 feet.

Table 6: Duration and Volumes for Development of Sawtooth NGLs Caverns					
Mining Step	**Step Time – Days**	**Total Mining Time – Days**	**Gross Volume Mined in Step - Barrels**	**Open Cavern Volume – Barrels**	**Cumulative Brine Produced – MMbbls**
Sump/Chimney	90	90	639,000	568,000	7,560,000
Reverse 1	45	135	535,000	1,042,000	11,340,000
Reverse 2	45	180	560,000	1,537,000	15,120,000
Reverse 3	50	230	650,000	2,112,000	19,320,000

Reverse mining continues until completion of the initial mining. The blanket will need to be moved uphole twice during the reverse mining as shown in Table 5. The inner tubing string will probably have to be cut one or two times during mining depending upon the rate of insoluble build-up on the floor of the cavern.

At completion of mining, a workover will be required to remove the mining string and run a sonar survey of the entire cavern including the roof. Sonar surveys of the cavern will include imaging of the cavern floor and cavern roof after each solution mining phase and before commencement and / or recommencement of product storage in accordance with Part III(D)(12) of the UIC Permit. A mechanical integrity test will also need to be conducted before injecting natural gas liquids for storage.

The various steps vary in cavern height and maximum cavern diameter. The cavern height is a function of the amount of mining completed in the sump/chimney stage as compared to the overall volume of the completed cavern and the amount of insolubles in the salt. The maximum diameter and open height of the cavern is listed in Table 7.

Table 7: Parameters for Sawtooth NGLs Storage Caverns at Completion			
Cavern Storage Capacity – Barrels	**Maximum Diameter – Feet**	**Open Height of Cavern – Feet**	**Open Cavern Volume – Barrels**
2,000,000	198	1,034	2,112,000

As shown in Table 7, not all of the open space in a salt cavern is useable for storage. Some portion at the bottom of the cavern will remain filled with brine because the dewatering string will be set above the floor. This is done to prevent material on the floor from being carried into the dewatering string where it might form a plug, stopping brine flow. Additional space is loss due to the need to keep the brine/product interface above the shoe of the dewatering string to prevent overfilling and resulting hazardous conditions at the surface. A permanent brine pool of about 135,000 barrels remains in the cavern during storage operations.

3.2.3 Allowable Operating Pressure Gradients

Minimum and maximum operating pressures for the cavern well and storage cavern will be maintained at all times during cavern well development. While the typical operating pressure is anticipated to be 0.55 pounds per square inch per foot of depth to the last cemented casing shoe, a minimum allowable operating pressure gradient (MinAOPG) and maximum allowable operating pressure gradient (MaxAOPG) have been established in the UIC Permit. These pressure gradients are based on geomechanical analyses provided to DWQ by Sawtooth. The pressure gradients that will be maintained at the last cemented casing seat are:

- A MinAOPG of 0.25 pounds per square inch per foot of depth;
- A MaxAOPG of 0.75 pounds per square inch per foot of depth; and,
- A maximum allowable test pressure of 0.85 pounds per square inch per foot of depth.

Based on the geomechanical analysis of the salt formation in which the Sawtooth NGLs caverns are designed and built, the upper limit of operating pressures is 0.92 pounds per square inch per foot of depth to the last cemented casing shoe. This is well above the MaxAOPG of 0.75 pounds per square inch per foot of depth to the last cemented casing shoe. While the individual maximum operating pressures will differ for each cavern well/storage cavern system due to the individual cavern designs, at no time will the cavern wells or storage caverns be subjected to pressures in excess of the MaxAOPG, including pressure pulsations and abnormal operating conditions.

3.2.4 Cavern Testing

Upon completion of drilling, the well will be tested by a nitrogen/brine interface test. The test pressures will utilize the maximum allowable test pressure of 0.85. The well will be tested again in a similar manner after completion of solution mining (or the initial stage of mining) and before storage of hydrocarbons begins. The detailed procedures for the testing will be provided to DWQ for review and approval before the testing starts.

Section 4

Cavern Capacity Expansion Plan

4.1 Cavern Capacity Expansion Schedule

The schedule for new cavern construction and the initial cavern size of new caverns is heavily dependent upon the demand for storage in the NGLs market. Consequently, caverns may be developed and placed into service with a capacity that is less than the total 2,000,000 barrel permitted capacity. As market demand increases for storage, Sawtooth plans to complete additional solution mining to increase the capacity of individual storage caverns to the maximum permitted size. After a cavern has been placed into operation, cavern expansion can only be completed during periods of product storage when the caverns are mostly empty. Some product will be left in the cavern to protect the cavern roof.

This section provides an overview of the two methods that are utilized in the salt cavern storage industry to enlarge the caverns. The overview does not provide detailed procedures, just the basic principles. In the event that Sawtooth would like to expand the capacity of a cavern, a cavern specific Cavern Expansion Plan will be developed that takes into account the size and shape of the cavern when the enlargement is planned to start. Sawtooth will submit this plan to DWQ for approval and inclusion in the well specific files prior to the initiation of any cavern expansion.

4.2 Cavern Capacity Expansion Options

There are two basic options for expanding capacity or enlarging the storage caverns:

- Using freshwater to displace the product, and
- Conducting “normal” solution mining.

The preferred method for any particular cavern will depend upon the:

- Shape of the existing cavern,
- Configuration of the well (hanging strings, roof, depth),
- Amount of stored product in the well during the enlargement operation, and
- Time frame in which the capacity expansion is to be completed.

<u>4.2.1 Freshwater Displacement</u>

Conceptually the simplest method to expand the capacity of existing storage caverns is through freshwater displacement. Freshwater, instead of brine, is used to displace product when it is removed from the cavern. The freshwater then dissolves more salt. There is no need to change the completion plans for the wells or perform any workover to ready the cavern for mining or to return it to storage configuration. However, the success of this method is dependent upon the:

- Shape of the cavern;

- Spacing to adjacent caverns;
- Time available to complete the enlargement; and,
- Operational mode of product movement.

The shape and size of the cavern to be enlarged and adjacent caverns must be such that a sufficiently strong web will remain between them after enlarging a cavern. The shape and spacing of the cavern must be consistent with the shape that will be developed using freshwater for product displacement.

The time available to enlarge the cavern may impact the feasibility of freshwater displacement for enlargement. The freshwater that can be used to enlarge the cavern is limited in volume to the volume of product displaced. Assuming that the freshwater dissolves sufficient salt to become saturated brine (an assumption that is dependent upon the time between emptying the cavern and then refilling it), the cavern will grow by about 15% of volume of water injected during each cycle.

The operational mode of product movements in the cavern is the principle unknown in developing a safe freshwater enlargement plan. In order to avoid preferential mining of portions of the cavern during the enlargement program, several operational limits need to be adhered to:

- A sufficient pool of brine must exist above the shoe of the hanging string when injecting water,
- An adequate amount of product must be left in the cavern to protect the roof until the cavern brine has become nearly saturated, and
- The product withdrawal time should not be interrupted by numerous or large episodes of product injection.

The brine pool between the end of the hanging string and the product/brine interface should be of a volume and height that allows the injected water to dilute within it and spread the new dissolution over the cavern wall to minimize growth of a wide disk at the injection level. If product has been stored within this safety zone, it should be moved by the injection of brine until the safety pool has been cleared of product.

The roof salt needs to be protected from being dissolved by undersaturated brine. During enlargement by freshwater displacement, freshwater injection needs to be stopped before the roof is exposed, leaving a minimum of 1,500 barrels of product in the well until the cavern p\brine is essentially saturated.

Once enlargement of the cavern has begun, the brine-filled portion of the cavern will be undersaturated. If the enlargement program is interrupted by product injections there is an increased risk of developing overly enlarged diameters as the brine is pushed downward and continues to mine portions of the cavern that have already been enlarged.

4.2.2 Conventional Solution Mining

Enlargement of a well by conventional mining techniques would require that a second hanging string be in the well. If two hanging strings are not in the well, a workover would need to be performed while the well is in storage mode to pull the existing brine string and to reinstall both the outer string and the brine string. A workover would require that all product be removed from the well prior to the workover.

Enlargement would then be accomplished by injecting freshwater in one string and producing brine from the second string. The direction of flow will be determined by the size and shape of the cavern being enlarged and the depth to the product/brine interface.

Plan for Cavern Enlargement

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June 24, 2016

1.0 Introduction

This correspondence presents a general solution mining plan for enlargement of underground hydrocarbon storage wells at the Sawtooth NGL facility in Delta, Utah. This document is presented as an addendum to the Cavern Development Plan, provided as Attachment D of the Utah Division of Water Quality Class III Area Permit (UTU-27-AP-9232389). A working, cavern well-specific enlargement plan will be developed and approved before each solution-mining event.

Initial development of the onsite caverns has been and will be completed utilizing conventional solution mining, consisting of water injected in one string, brine produced from a second and the roof of the cavern protected by a nitrogen blanket. Details for this method of solution mining have been provided in the Cavern Development Plan noted above.

This correspondence details the solution mining procedures to accomplish cavern enlargement following initial development and placement of product into the cavern. The plan includes detail for product displacement with freshwater and conventional mining. While freshwater displacement may be utilized on multiple occasions, when product is displaced from the well, it is anticipated that the bulk of the cavern enlargement will be through conventional solution mining at a time when there is little or no inventory in the cavern.

Parameters and conditions that will be taken into account in developing the individual plans include, but are not limited to:

- Well configuration, including depth of concentric leaching strings
- Review of the latest logs and sonar survey analysis to verify the location of the cavern roof and casing seat.
- Type of product in the cavern, and type of product to be re-introduced
- Likelihood of non-symmetric growth in the cavern
- Depth of product level, water injection rates, and duration of mining
- Estimated growth of the cavern during the mining phase, and estimated final volume
- Distance and spacing from adjacent caverns and property lines

2.0 Procedures and Methodology

This Section of the plan will define and describe procedures utilized to complete freshwater displacement (utilized to achieve limited cavern growth during periods of product changeout) and conventional mining.

2.1 Definition of a Cavern Solution Mining Phase

The UIC Class III Permit, Part III, Section D, Item 12 requires activities to be completed after each solution mining phase and before commencement/recommencement of product storage.

For purposes of this document and the procedures described in the Cavern Construction and Development Plan, completion of a freshwater solution mining phase is defined as:

- Application of freshwater displacement that results in a cumulative increase in cavern capacity of 20% measured from the most recent sonar survey.
- All elements of the UIC Class III Permit, Part III, Section D, Item 12, Parts b) through g) will be completed following conclusion of each 20% growth cycle.
- This will not require all elements of the UIC Class III Permit, Part III, Section D, Item 12 to be completed before recommencement of product storage following freshwater displacement, unless resulting in overall growth of cavern capacity by 20%.
- Once the permitted cavern capacity is achieved, the schedule for cavern testing and monitoring will proceed as provided in the UIC Class III Permit.

To determine when 20% cavern growth has occurred, cavern capacity will be monitored as required by the UIC Class III Permit, Section E, item 6 utilizing the existing continuous electronic monitoring system in place at the well. This will include monitoring changes in well capacity, utilizing brine and product injection/withdrawal. In addition, appropriate geophysical logging techniques and cavern modelling simulations will be utilized to insure that the capacity of the cavern can be accurately measured.

For purposes of this document and the procedures described in the Cavern Construction and Development Plan, completion of a conventional solution mining phase is defined as:

- Application and completion of conventional mining techniques as defined in Section 3.2.2 of the Cavern Construction and Development Plan.
- All elements of the UIC Class III Permit, Part III, Section D, Item 12, Parts b) through g) will be completed following conclusion of the conventional mining phase.
- Once the permitted cavern capacity is achieved, the schedule for cavern testing and monitoring will proceed as provided in the UIC Class III Permit.

2.2 Mining Utilizing Freshwater Displacement

Freshwater displacement mining is performed by injecting water through the deeper inner string and withdrawing product from the cemented outer string. This initial step displaces the existing product from the well. As required by Section 4 of the Cavern Construction and Development Plan, freshwater injection will be stopped at an elevation not less than 5 feet below the exposed cavern roof, leaving a minimum of 5,000 barrels of product in the well until the cavern brine is essentially saturated. To achieve this, the final 30,000 barrels of propane will be removed by injecting brine from the brine pond to displace it. The saturation level of the brine pond is monitored continuously, which allows verification of the brine saturation prior to injecting the material into the cavern. This brine injection will minimize contact with the roof section of the cavern. Sawtooth NGL's will maintain the product roof blanket until the cavern brine is essentially saturated.

To verify that the roof is protected during product displacement and to protect the cavern roof from solution mining during product displacement and product changeover, the following procedure will be utilized:

- Volume calculations from the most recent sonar survey will be utilized to estimate the vertical footage from the cavern roof needed to place the minimum volume of product in the well, and
- The location of the product blanket will verified by completion of appropriate geophysical logging at the well

This will provide a margin of safety and insure a minimum of 5 feet and at least 5,000 bbls of product blanket.

Saturation level of the brine and volume of product in the well will be monitored utilizing the electronic metering system in place at the wellhead. Establishment of the product blanket will be based on metered volume of brine evacuated, as measured by the electronic monitoring system. In addition to the geophysical logging described above, the blanket level will be monitored by utilizing the metered level of the product evacuated.

Following completion of the freshwater displacement, a summary report will be generated for submittal to DWQ and approval obtained as detailed in the UIC Class III Permit, Part III, Section D, Item 12, Parts e) through g) before the cavern is re-filled with product.

Cavern modelling techniques have indicated that mining in this method (water displacement of product) expands the cavern approximately equally in radial growth with most of the growth occurring in the lower part of the cavern, near the injection string depth. Simulation indicates that essentially no growth will occur in the upper part of the cavern.

Additional freshwater displacement that may occur will be completed as described above. In the event that a cumulative growth of 20% in cavern capacity is achieved utilizing freshwater displacement (or multiple displacements) as measured from the last sonar survey, the solution mining phase is complete and all required activities as described in Section 2.1 will be performed.

2.3 Conventional Mining With a Roof Blanket

As discussed in the Cavern Construction and Development Plan, individual wells may also be enlarged utilizing conventional mining techniques with a nitrogen roof blanket. A detailed plan, specific to each well and event, will be provided to DWQ for approval prior to initiating field activities. The plan will follow requirements as outlined in the UIC Class III Permit, Part III, Section E, item 6. The produced brine will not be saturated and will be disposed of into the existing pond.

As required by Part III (E)(6) of the UIC Class III permit, the location of the blanket/brine interface will be maintained, utilizing periodic wireline surveys to confirm the location of the blanket brine interface. If the interface cannot be confirmed by wireline surveys, solution mining will stop until the interface can be re-established and confirmed.

In addition, daily monitoring of flow rate of injected water, saturation level of injected water, pressure of injected water, temperature of injected water, flow rate of produced brine, saturation level of produced brine, pressure of produced brine, temperature of produced brine, pressure of blanket, volume of blanket, and temperature of blanket shall be completed. This will be completed utilizing the electronic monitoring system in place at the wellhead.

Following completion of the conventional mining phase, the well will be worked over as required by Part III, Section D, Item 12(b) through (g) of the UIC operating permit. The workover will include removal of the hanging strings, which will allow a sonar caliper survey of the entire cavern, to include a complete survey of the roof. After the sonar survey, the well will be reassembled. A complete MIT will then be conducted to insure the integrity of the cavern and roof. As required by Part III (D)(12) of the UIC Class III permit, a summary workover report will be submitted to the DWQ following completion of the solution mining phase and before re-commencement of product storage, and written approval from DWQ will be received prior to commencement of product storage.

Summary

As noted in Section 4.1 of the Cavern Construction and Development Plan, Sawtooth NGLs plans to complete additional solution mining, as market demand increases for storage, to increase the capacity of individual storage caverns to the maximum permitted size.

This plan has been developed to allow for safe cavern expansion utilizing displacement of product with freshwater and/or the use of conventional solution mining. The plan defines completion of a freshwater solution mining phase as being complete when the cavern capacity has increased by 20% through application of one or more freshwater displacement(s). Upon completion of a solution mining phase, all elements of the UIC Class III Permit Part III, Section D, Item 12, Parts (b) through (g) will be completed.

Upon completion of freshwater displacement that does not result in 20% cumulative cavern growth, a summary report will be generated for submittal to DWQ and approval obtained as detailed in the UIC Class III Permit, Part III, Section D, Item 12, Parts (e) through (g) before the cavern is filled with product.

In the event that conventional mining techniques are employed at the well following freshwater displacement, all applicable elements of UIC Class III Permit, Part III, Section D, Item 12 as defined in Section 2.3 above will be completed.

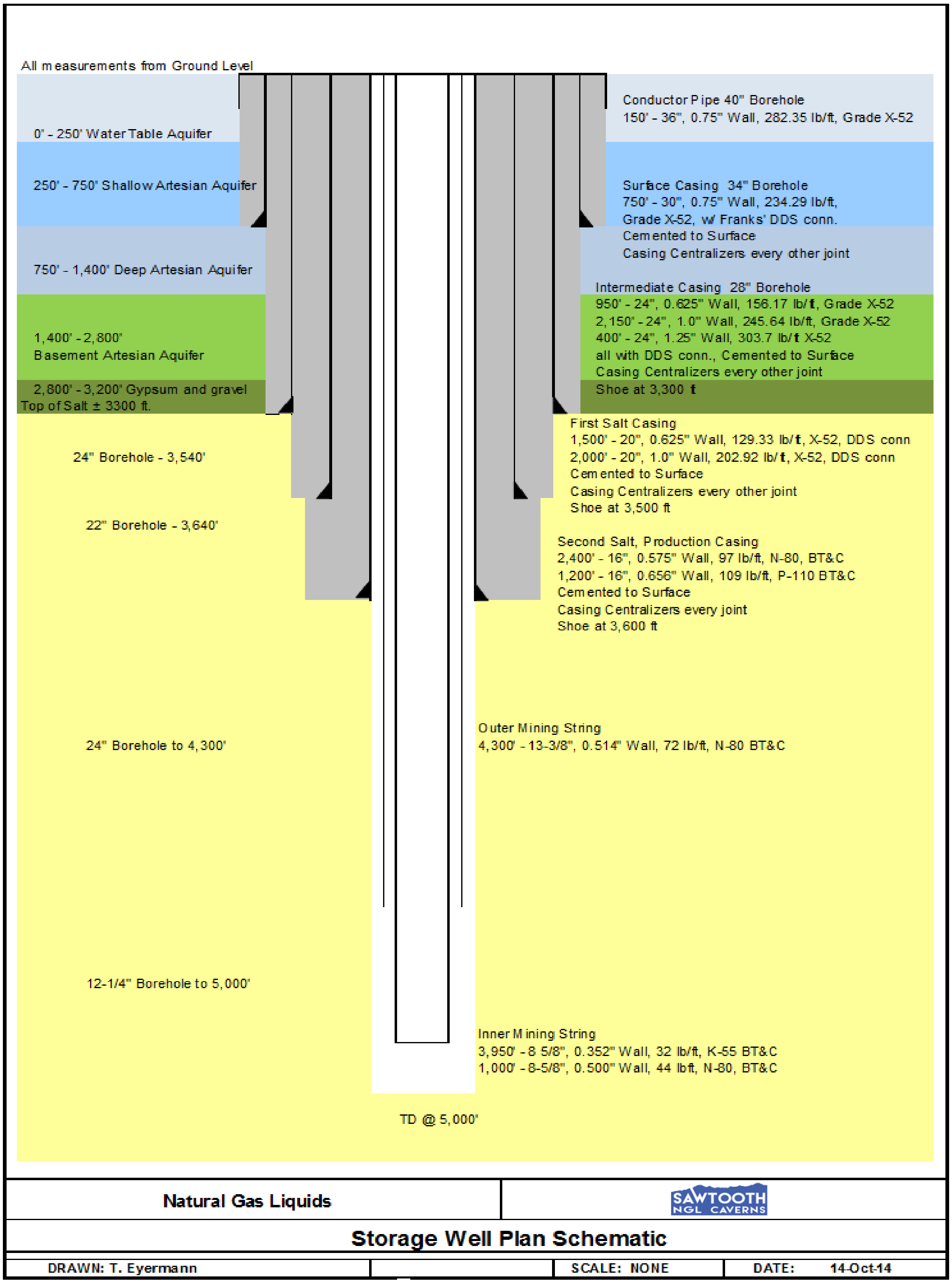
Once the approved cavern capacity has been achieved, the schedule for cavern testing and monitoring will proceed as provided in the UIC Class III Permit.

Displacement utilizing fresh water can be safely accomplished due to the following:

1. Fresh water displacement will occur through the inner tubing, which is at or near the bottom of the cavern and below the level of the product. This will allow for preferential cavern growth at the base of the cavern, and mitigate freshwater contact with the cavern roof.
2. During the fresh water displacement cycles, the cavern will contain product, which will also promote cavern growth primarily in the lower cavern, while protecting the roof from contact with fresh water or unsaturated brine.
3. Appropriate geophysical logging will be completed, along with electronic monitoring of product and brine volumes, and brine saturation levels to insure that adequate product remains in the cavern to insure the integrity of the cavern roof.

As described above, all applicable elements of Part III (D)(12) and Part III (E)(6) of the UIC Class III permit, along with Section 4 of the approved Cavern Construction and Development Plan will be followed during completion of the field activities and follow-up report.

Figure 1 – Typical Well Diagram



Section 5

Revision History

Type of Review	Reviewed By	Date
Plan Finalized & Released		12/22/14
Review of Document to Reflect Ownership Change		July 2017