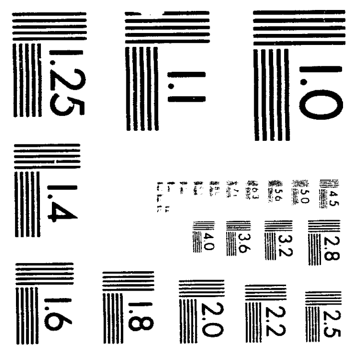
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Strategic Petroleum Reserve (SPR)
Additional Geologic Site Characterization Studies
Bayou Choctaw Salt Dome, Louisiana

James T. Neal
Sandia National Laboratories
Albuquerque, New Mexico

Thomas R. Magorian
Amherst, New York

Kathleen O. Byrne and Steven Denzler
Acres International Corporation
Amherst, New York

Prepared by Sandia National Laboratories
Albuquerque, NM 87185 and Livermore, CA 94550
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ABSTRACT

This report revises and updates the geologic site characterization report that was published in 1980. Some of the topics covered in the earlier report were provisional and it is now possible to reexamine them some 13 years later, using the data obtained from SPR cavern operations and several new caverns, and the experience of the Union Texas Petroleum Company, the operator of nine caverns adjacent to the DOE property.

Revised structure maps and sections show interpretative differences in the dome shape and caprock structural contours, especiallly a major east-west trending shear zone, not mapped in the 1980 report. Excessive gas influx in Caverns 18 and 20 may be associated with this shear zone.

Subsidence values at Bayou Choctaw are among the lowest in the SPR system, averaging only about 10 mm/yr (0.4 in/yr), but measurement and interpretation issues persist, as observed values often approximate measurement accuracy. Periodic, temporary flooding is a continuing concern because of the low site elevation (less than 10 ft), and this may intensify as future subsidence lowers the surface even further.

Cavern 4 was re-sonared in 1992 and the profiles suggest that significant change has not occurred since 1980, thereby reducing the uncertainty of possible overburden collapse -- as occurred at Cavern 7 in 1954. Caprock integrity may be affected by structural features, such as the east-west trending fault system that essentially divides the dome into northern and southern lobes. Other potential integrity issues persist, such as the proximity of Cavern 20 to the dome edge, and the narrow web separating Caverns 15 and 17. The Cavern 20 web is now believed to be some 90 ft thicker, as a result of well deviation that had not been considered earlier.

Injection wells have been used for the disposal of brine but have been only marginally effective thus far; recompletions into more permeable lower Pleistocene gravels may be a practical way of increasing injection capacity and brinefield efficiency. Cavern storage space is limited on this already crowded dome, but 15 MMBBL could be gained by enlarging Cavern 19 and by constructing a new cavern beneath and slightly north of abandoned Cavern 13. Environmental issues center on the low site elevation: the backswamp environment combined with the potential for periodic flooding create conditions that will require continuing surveillance.

TABLE OF CONTENTS

Strategic Petroleum Reserve (SPR)
Additional Geologic Site Characterization Studies
Bayou Choctaw Salt Dome, Louisiana

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This update of the 1980 geological site characterization of the Bayou Choctaw SPR facility is largely a refinement of the earlier report. However, it also substantiates many previous conclusions significant to safe cavern storage, and adds new insight on several important features that affect cavern operations.

The regional geological setting of th, Bayou Choctaw dome is quite well known as a result of widespread petroleum extraction. The structure contours of the salt stock are simplified to a degree, eliminating several smaller faults that have minimal bearing on cavern storage operations. The contour maps of the caprock and salt surfaces are modified and show a major shear zone transecting the dome. This anomalous feature probably has caused the preferential leaching and elongation of several caverns, and may also be associated with excess gas accumulation in Caverns 18 and 20.

Cavern 4 stability has been the object of continuing concern because of its geologic similarity to collapsed Cavern 7 (now Cavern Lake). 1992 sonar results show minimal change since 1980, suggesting that significant caprock dissolution has not occurred and that overburden collapse is unlikely. However, continuing surveillance is prudent.

Caverns 15 and 17 should continue to be operated at essentially equal pressure as the ~100 ft web thickness between them is pressure sensitive. Drawdown of these caverns will reduce the web thickness, leading to eventual coalescence and development of a single cavern.

Cavern 20 is 225±50 ft from the edge of the salt stock, 90 ft farther than originally thought. Previous determinations had not considered the cavern well deviation. The location near the edge of the salt limits oil drawdown to one or two cycles, but limited volumes may be extracted from the upper cavern segments above ~4000 ft without extending the current maximum radius.

Co-use of this dome with Union Texas Petroleum has proceeded with good cooperation and communication, even involving exchange of storage space to satisfy individual needs, and the transfer of brine for petrochemical processing. Total cavern space of the two operators is some 160 MMB, in 15 active and 10 abandoned caverns. This volume is sufficient to produce a small amount of subsidence (averaging ~0.05 ft per year) as a result of the continuing process of salt creep closure.

Periodic, temporary flooding is a fact of life around the dome, because of the low elevation under 10 ft and the ever-present cyclonic storms carrying high moisture. This pattern will not change and the continuing subsidence may require future road enhancement.

Seismicity is not a threat, but minor earthquakes can be expected to recur. The 1983 temblor (Richter Magnitude 3.8) with epicenter 17 miles from West Hackberry exemplifies the type of small seismic events that occur along Gulf Coast growth faults, usually with local, minor effects.

Expansion space on the already crowded and small Bayou Choctaw dome is extremely limited and 25 MMB of new space may be the upper limit for both operators. New caverns near salt stock edges are much more risky than interior locations, the latter being essentially fully occupied.

Injection wells are the principal means of brine disposal and have been less successful than originally planned. Current practices offer new hope for improved performance, and recompletion of existing wells at more shallow depths is possible. The older practice of using screened completions is largely obsolete, and careful attention to preventing flowback of brine is necessary to prevent sand influx in the wells.

1 INTRODUCTION AND PURPOSE

The initial geological characterization of the Bayou Choctaw salt dome was conducted in 1979-80 [Hogan et al., 1980]. Although the basic elements are essentially unchanged, refinements to the original report are now possible because of new information gained since then, and because of some 13 years operating history by SPR, and more than 50 years by Union Texas Petroleum (UTP) and its predecessors.

Caprock conditions have been a continuing concern because of its thinness and leach-through potential. Such conditions led to the overburden collapse over Cavern 7 in 1954 and the consequent formation of Cavern Lake. A similar situation exists with abandoned Cavern 4, which has the potential for a similar sinkhole collapse; thus periodic appraisals of Cavern 4 caprock conditions are desirable.

Salt contours need to be modified somewhat, as several new wells suggest complexities may occur in the overhang geometry. The resulting structural interpretation is modified from that in the 1980 report; the refinements reveal nuances that had not been recognized previously. The earlier report was prepared using manual graphics; modern methods rely on computer software which yields improved contour smoothing and interpretation. New understanding of salt tectonics in the Gulf of Mexico basin has altered traditional concepts, but this probably has little effect relative to Bayou Choctaw.

A number of caverns have been enlarged and some new ones leached. Oil has been filled in the SPR caverns, and the wells of older, unusable caverns have been plugged and abandoned. UTP has modified its operation somewhat, and plans call for the conversion of two caverns for storage of natural gas; one conversion was completed in 1992. The implications of these changes are synthesized, and appropriate revisions documented.

The generally low elevation (under~10 ft) makes periodic flooding a continuing concern, and subsidence resulting from cavern creep closure an ongoing issue. Some ten years of survey data are evaluated, with a view toward forecasting future trends.

Finally, several environmental conditions are considered. Co-use of this site by two operators requires continuing close coordination.

<u>New or Revised Information</u>

Since the 1980 report was published, SPR Caverns 18, 19, & 20 have been enlarged substantially; UTP Caverns 6 and 26 have been constructed, and Caverns 101 and 102 were leached by DOE. Cavern 102 subsequently was traded to UTP in a swap for Cavern 17, now used for SPR oil storage. In 1992 UTP converted its brine Cavern 24 to natural gas storage and by year's end had a billion cubic feet in storage. UTP had plans in 1993 for a new cavern south of Cavern 26 along the northeast dome edge.

New data from the nearby oil and gas wells is sparse as the Choctaw field was already a mature producer prior to the advent of SPR oil storage. However, some refinements are possible, based on new wells or new logs; consequently our revised understanding is presented. Of some particular interest to cavern stability considerations is the revised fault map that shows a lateral shear transecting the entire dome in an east-west direction, marking an anomalous zone.

Injection wells have been the primary method of brine disposal at Bayou Choctaw (along with limited transfers for petrochemical use), and there is now ample history to discuss methodology in hindsight. Changes in procedures and well recompletions at shallower depths are suggested, based on experience here and on data from other wellfields.

Subsidence data on the DOE property has been acquired nearly annually since 1982, and show some indications of subsidence trends, verifying the very low values that were obtained from earlier UTP data.

Flooding potential was re-examined and modified, based on revised flood insurance rate maps [FEMA] and Corps of Engineers experience.

Cavern 4, potentially unstable and geologically similar to collapsed (1954) Cavern 7, was re-sonared in August 1992. The results showed a profile similar to that obtained in 1980, indicating that the caprock probably has not eroded much further, although some uncertainty still exists. Consequently, a repeat of the Cavern 7 collapse seems an unlikely probability at this time.

2 GEOLOGIC ASPECTS

The regional geology that was presented in the 1980 report is essentially unchanged; consequently few remarks are necessary. A summary of the regional geologic history is included at Appendix A.

However, significant refinements have been made to the detailed geology of the Bayou Choctaw dome, and new structural contour maps were constructed for top of caprock, salt, the *Heterostegina* reef, and the *Marginulina texana* sand. Some 300 wells were available to use in constructing the contour maps and cross sections; these are shown on Figure 1 (well location), and listed in Appendix B, along with stratigraphic marker horizons, also listed here in Table 1, p.20.

The intricate pattern of small faults in sediments described and mapped in the original 1980 characterization report cannot be found within the salt or caprock, nor in the sediments more than a few hundred feet away from the salt stock. They rarely cut more than a few sands even in contact with the salt stock. In the interest of clarity, they have been omitted from the maps and sections in this report, as there is virtually no effect on cavern storage integrity. As a result, only three faults cutting the caprock and salt are included on the revised maps and discussed here. The major east-west fault is probably active, as suggested in the present subsidence data, although its topographic expression is subtle. It probably separates two spines within the salt and can be considered an anomalous zone, or shear zone [Neal et al., 1993]. The two additional and less certain faults form a shear pattern over the western crest and overhang.

Gravity Data

Residual gravity contours are plotted on Figure 2 for the area immediately adjacent to the dome; the gravimeter readings were taken at approximate quarter-mile spacing, or occasionally less along roads. The gravity data show a 22 milligal negative anomaly over the salt stock, typical of a dome of this size. St. Gabriel, the next dome to the east is only a 10 milligal negative feature, typical of a cone of salt at 11,000 ft. At Bayou Choctaw the thin caprock is reflected in the minimal 7 milligal positive anomaly over the site, resulting in a net -15 milligals. Its nose extends westward over Cavern 20, along the main fault, possibly related to a salt ridge toward Bayou Blue, the next dome to the west, and also reflected in the high temperature found in Texaco #1 well at the west edge of the map. More gravimeter stations were used to detail this feature [PGA and Associates, 1978]. The similar extension northeastward over UTP Cavern 26 supports the existence of more salt at the edge of the dome than was predicted by one consultant. The anomalous zone that transects the dome is clearly defined as a sharp step on the top of the salt and caprock, as mapped in this report. The Mississippi River levee east of the site is a broad positive anomaly of 6 milligals, showing that gravity data can be related to hydrology and shallow stratigraphy, including subsidence as well as growth-fault structure.

Deeper Structure

The contour map of top of the *Marginulina texana* sands (Figure 3) shows general similarity to previous maps, but with much less detail, so as to simplify the interpretation.

The contour map of the top of the *Heterostegina* reef (Figure 4) is far less complex than was presented in the 1980 report, showing the principal structure in the E-W fault that transects the dome. The previously identified faults are not shown, as they are very localized and presumably have no effect on cavern storage.

Hydrology

Few, if any, changes requiring modification have occurred since the original characterization. The base of fresh water (as defined by the U. S. Geological Survey 20-ohm criteria) is at 500 ft over the dome. The base of the same Gonzales Aquifer lies directly on the caprock, below which all aquifers are saline, as previously described. Water that will actually meet drinking water standards is found only above a depth of 400 ft.

A special study of the hydrocarbon accumulations in the shallow sands over the caprock was done in 1984-85, when a private company's assignees were offered the opportunity to develop these resources which they were claiming. Although ethane which had escaped from Cavern 4 was found in coreholes, only a small amount of natural gas was ever detected away from the older shallow and leaky caverns. Their claims for possible oil were based on the resistivity of

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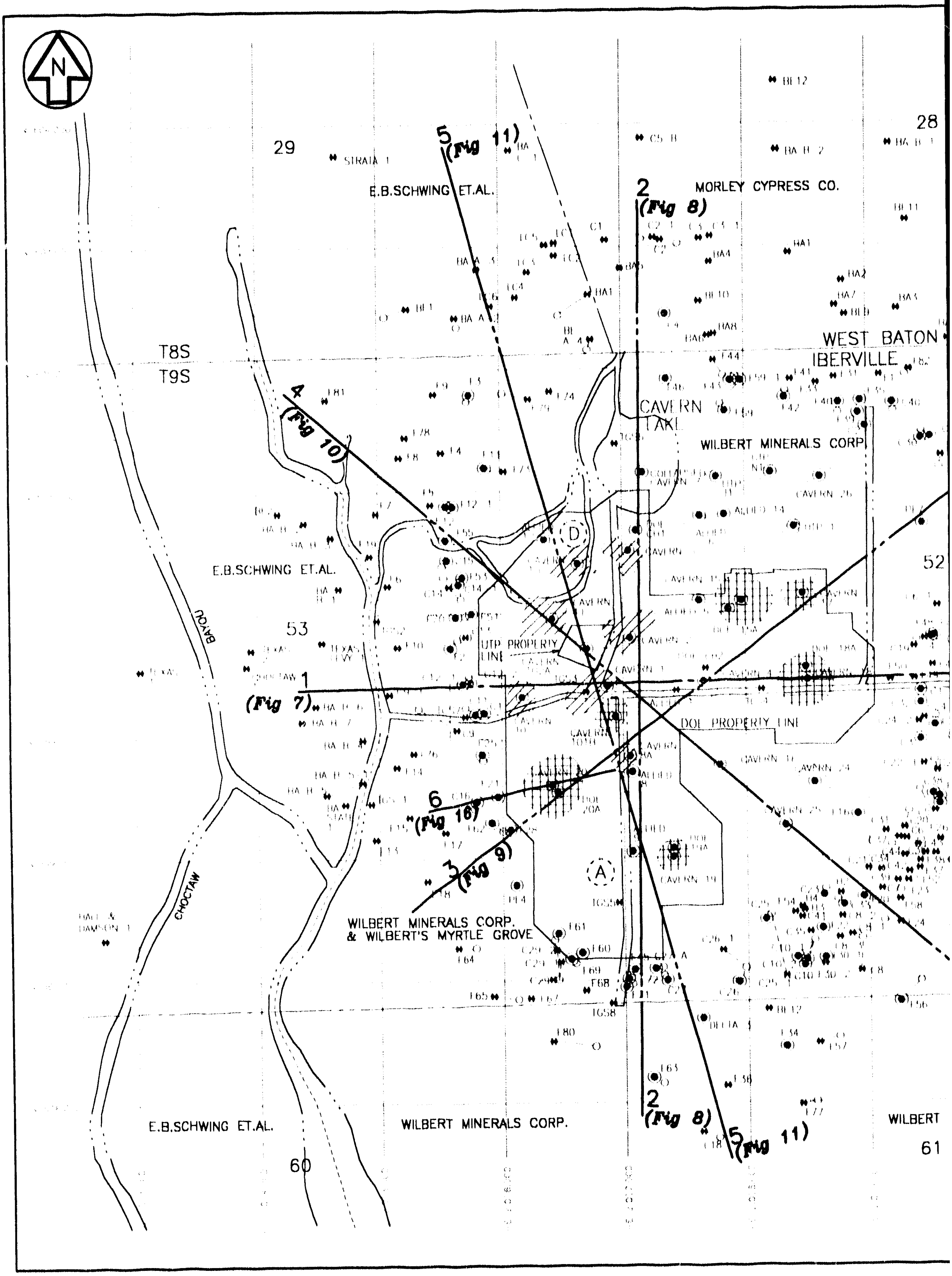

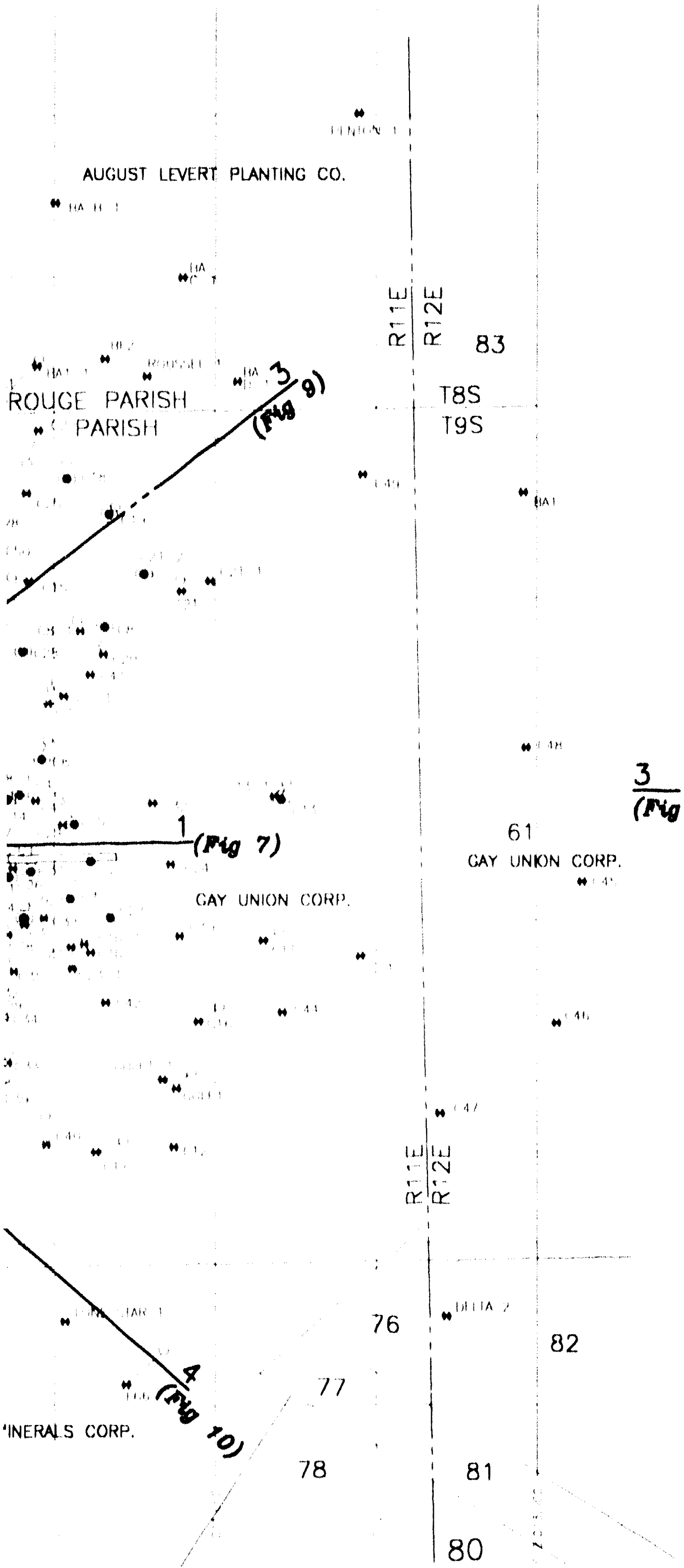

LEGEND

- CAVERN LOCATION SHOWING MAXIMUM CAVERN DIAMETER
- STRATEGIC PETROLEUM RESERVE (SPR) CAVERN
- ABANDONED CAVERN
- UNION TEXAS PETROLEUM (UTP) CAVERN
- POSSIBLE EXPANSION CAVERN
- SURFACE LOCATION OF WELL
- SURVEYED BOTTOM HOLE LOCATION OF WELL
- SURVEYED BOTTOM HOLE LOCATION OF SIDETRACK HOLE
- DRILLED AS VERTICAL HOLE. NO BOTTOM-HOLE SURVEY AVAILABLE.
- LOCATION OF WELL PENETRATING SALT
- PARISH BOUNDARY
- PROPERTY LINE
- 3 (Fig 9) CROSS SECTION

NOTES

1. SURFACE WELL LOCATIONS ARE ACCURATE TO WITHIN 25 FEET AS MAPPED.
2. UNSURVEYED HOLE MAY DEVIATE FROM VERTICAL BY UP TO 2 1/2°

0 1000 2000

FEET

FIGURE 1

WELL AND PROFILE LOCATION

BAYOU CHOCTAW SPR SITE

THOMAS R. MAGORIAN, 1993

ACRES

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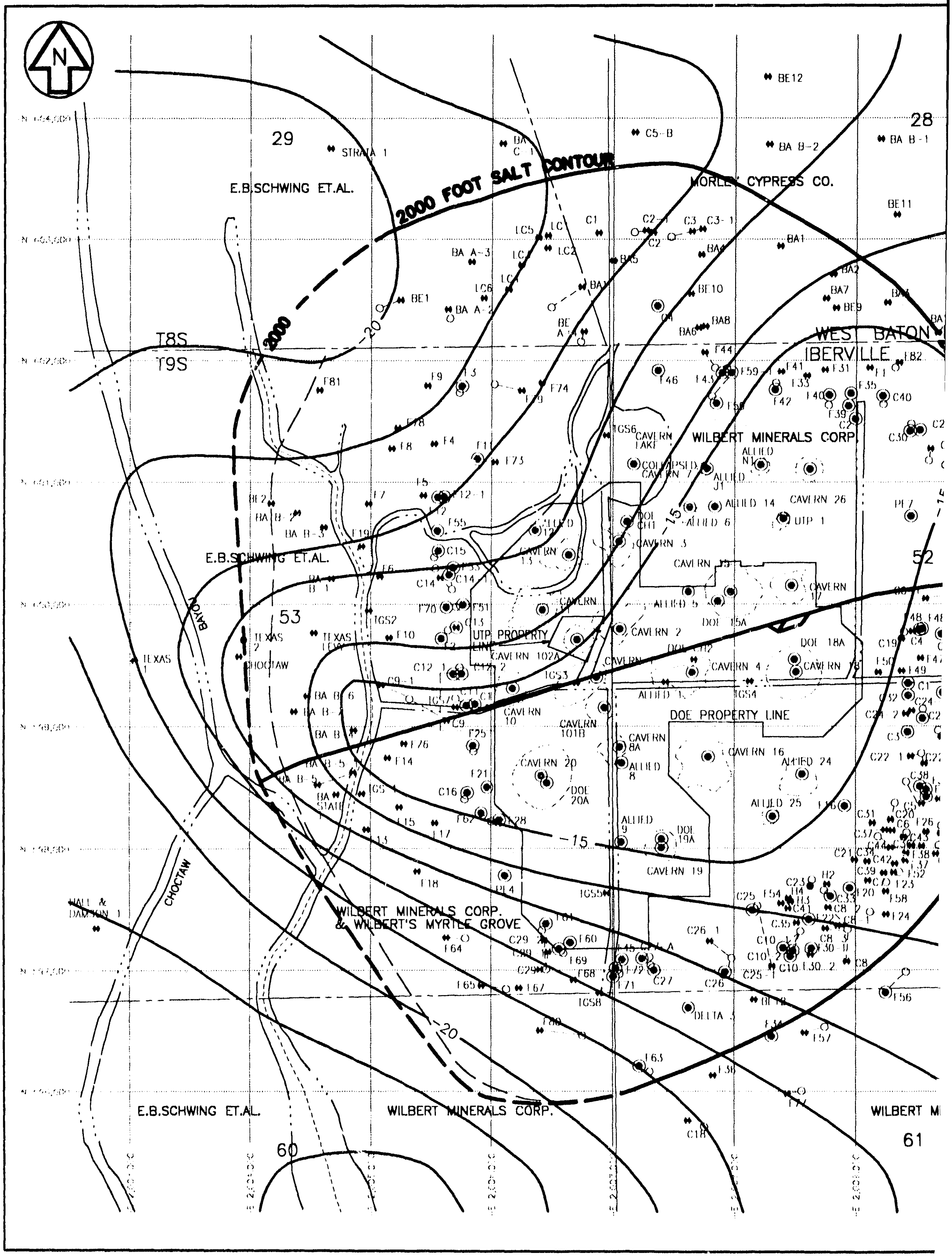

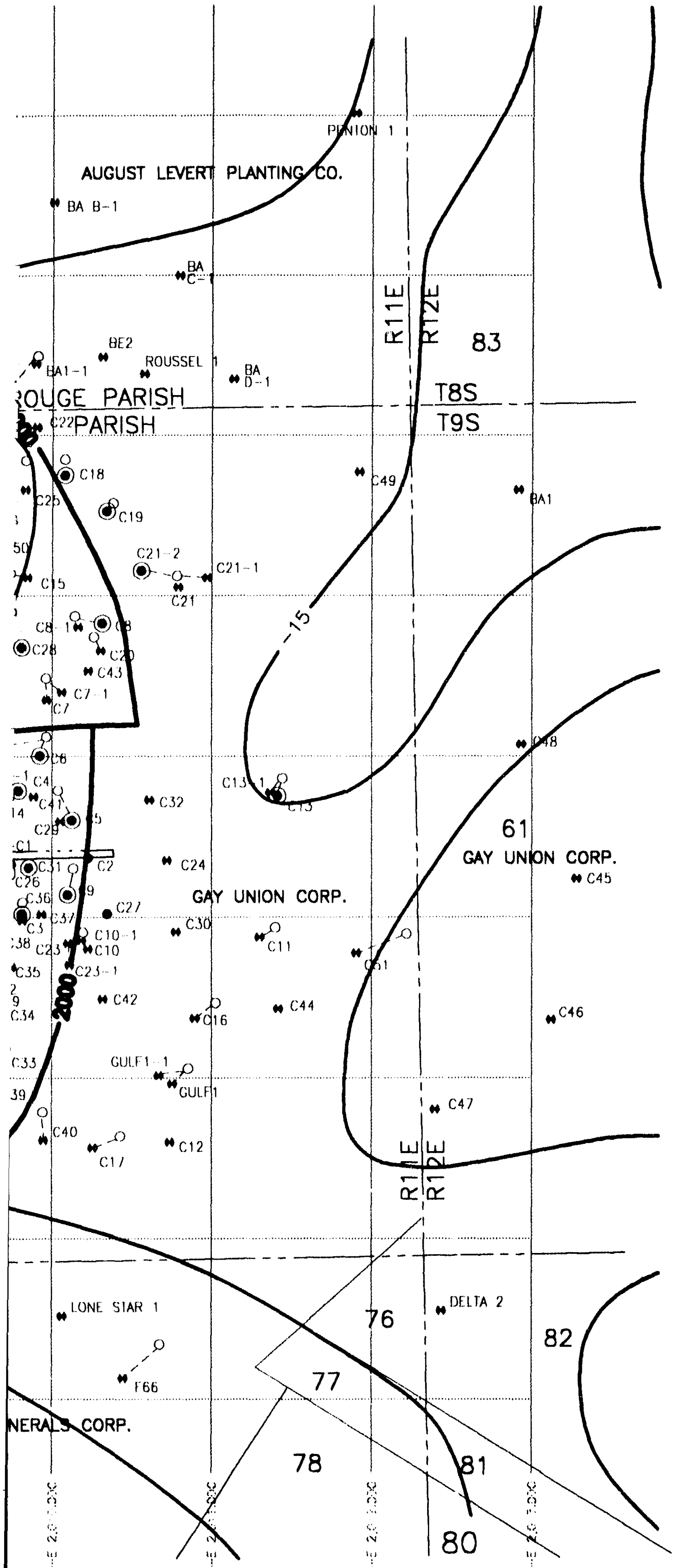

LEGEND

CAVERN LOCATION SHOWING MAXIMUM CAVERN DIAMETER

SURFACE LOCATION OF WELL

C15 SURVEYED BOTTOM HOLE LOCATION OF WELL

C15-1 SURVEYED BOTTOM HOLE LOCATION OF SIDETRACK HOLE

DRILLED AS VERTICAL HOLE. NO BOTTOM-HOLE SURVEY AVAILABLE

C15 LOCATION OF WELL PENETRATING SALT

-15- RESIDUAL GRAVITY (IN MILLIGALS)

FAULT

PARISH BOUNDARY

PROPERTY LINE

2000 FOOT SALT CONTOUR (DASHED ZONE REPRESENTS OVERHANG)

NOTES

1. SURFACE WELL LOCATIONS ARE ACCURATE TO WITHIN 25 FEET AS MAPPED.
2. UNSURVEYED HOLE MAY DEVIATE FROM VERTICAL BY UP TO 2 1/2°
3. GRAVITY SURVEY PERFORMED BY PGA & ASSOCIATES

0 1000 2000

FEET

FIGURE 2

RESIDUAL GRAVITY WITH 2000 FOOT SALT CONTOUR

BAYOU CHOCTAW SPR SITE

THOMAS R. MAGORIAN, 1993

the fresh-water sands, as shown on the logs in the original characterization report, and they were never able to raise the money to test them. This spurious sort of possible economic prospect has occurred on many salt domes and is easiest to dismiss simply by allowing closely-monitored test drilling only to the top of the salt.

Injection Wells

The Bayou Choctaw disposal wellfield was constructed in 1978 using concepts and completion techniques that are somewhat different than being practiced in 1993. The 12 wells have not performed as originally intended for a variety of reasons, some of which are because of inherent limitations in formation properties, and some of which are due to the completion techniques that were used. All 12 have been recompleted -- #s 6 and 12 in 1984, and the remainder in 1987, but repeating the same procedures higher in the geologic sections, and thus with similar and less than desired results. Eleven wells are currently capable of receiving about 100,000 BPD; No. 12 was removed from service because of downhole mechanical problems, presumably screen clogging, as its average yield was just 5400 BPD over 637 days of operation. The original completion was screened open hole below the casing shoe, but was later plugged and then recompleted in 1984 with perforations in two separate 30-foot zones near 6500 feet. An epoxy-coated sand was "squeezed" into the reservoir, ostensibly to prevent fallback into the well casing. Such practices, while popular 15 years ago, are seldom used today.

The remaining 11 wells are using several Miocene sands between 4000 and 5000 feet, particularly Sand 2 at 4500 feet. The wells have been screened twice now in several of the candidate Miocene sands and the screens have irreversibly clogged while operated without adequate filtration. Screen completions are much too dependent on the filtration system, including expensive cartridge polishing filters at each well, since the screens cannot be effectively cleaned once installed. The state-of-the-art technology now avoids screens and includes more cost-effective cyclone (centrifugal separator) filtration, along with alum treatment in the brine pond. Little disposal has been achieved below Sand 2 (Upper Miocene *Bigenerina B* zone because this sand and the #1 sand immediately above it will take all the brine available. Recompletions with open perforations are now preferred, based on accumulated industry-wide experience. As long a rathole as possible is kept open to reduce the frequency of sanding up the disposal face.

Because brine disposal through well injection will continue to be a major operating requirement in coming years, some attention can now be given to recompleting the wells at even shallower depths and using newer methods, with appropriate filtration and at much lower cost. While the current system has been baselined to dispose of 100,000 BPD, the formations are capable of accepting several times this amount, as has been demonstrated in other operations at other sites. The PB-KBB [1989] study of the brine disposal system showed that sufficient thick sands exist to handle the brine with negligible pressure buildup in the formation behind the screens, and that no faulting occurs in or near the brine field.

Since the Illinoian and Wisconsinan sands (Gonzales Aquifer) lie above the caprock, they are relatively fresh. The shallowest beds of interest for brine injection are the basal Pleistocene

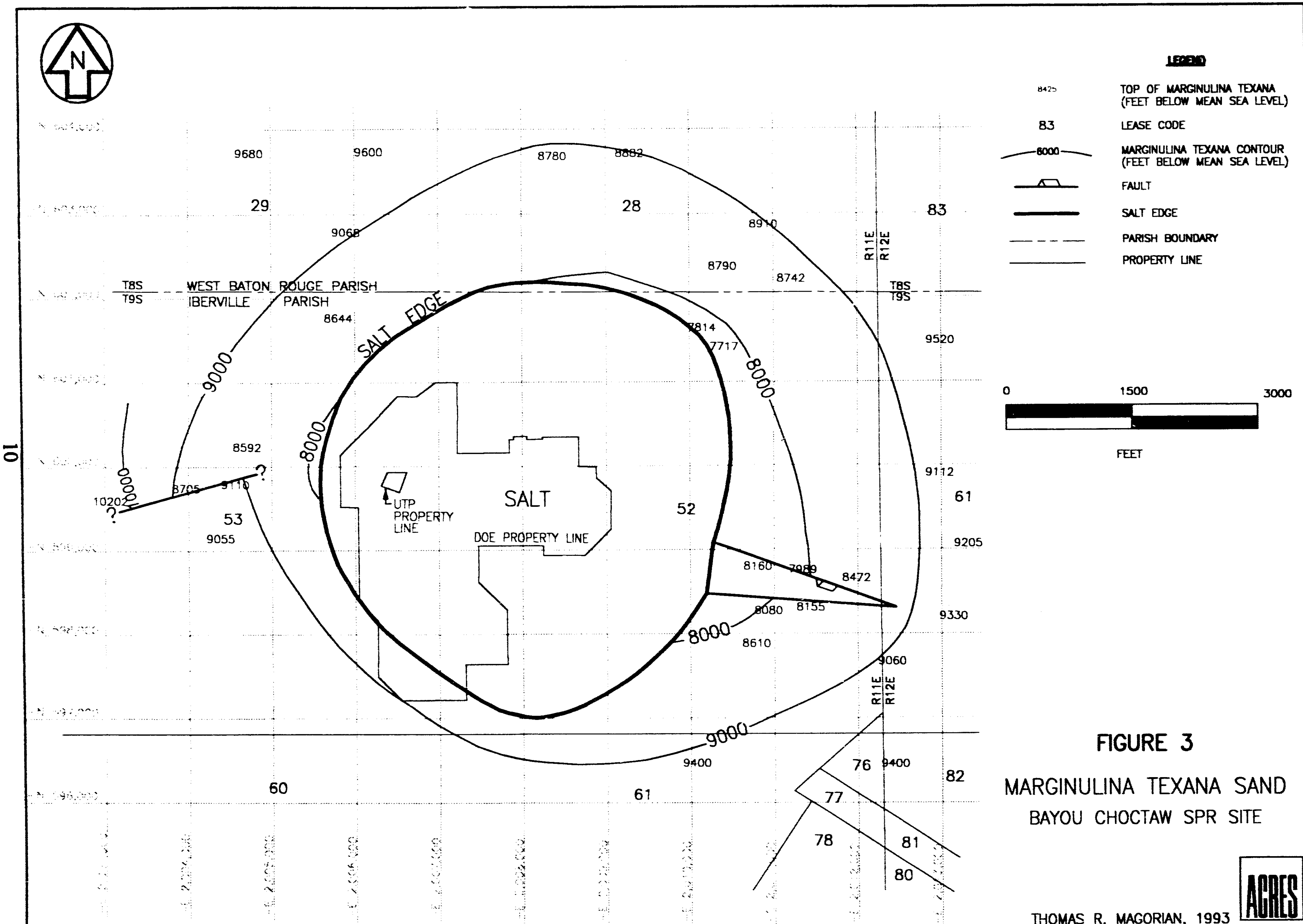

FIGURE 3
MARGINULINA TEXANA SAND
BAYOU CHOCTAW SPR SITE

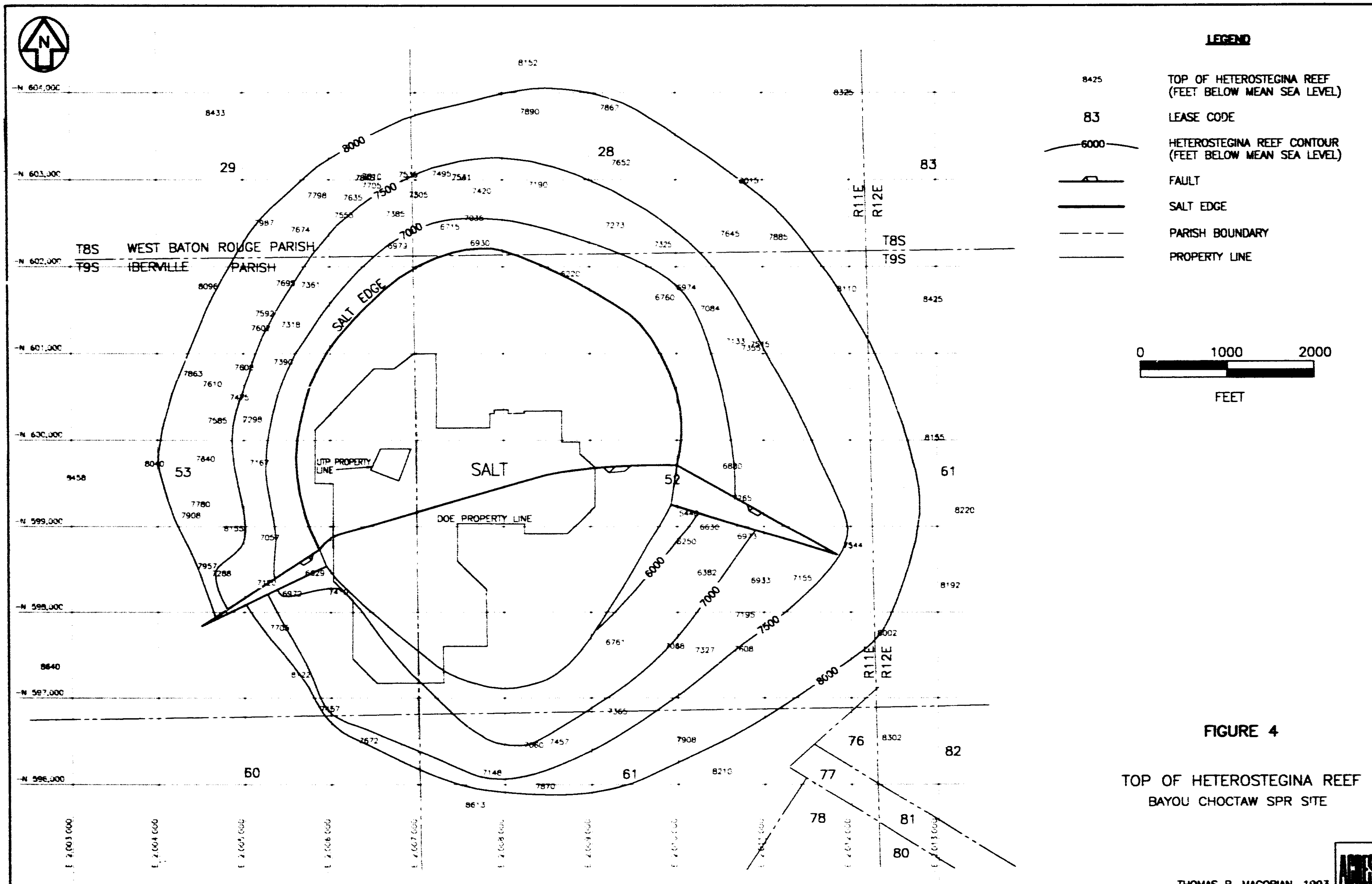

FIGURE 4

TOP OF HETEROSTEGINA REEF
BAYOU CHOCTAW SPR SITE

"Lafayette" (Citronelle Fm.) gravels occurring below 900 feet on the flanks of the dome and 1250 feet in the brine injection area. The 100 feet of gravel is separated from the Gonzales by two clays each over 100 feet thick, the lower of which is more than 200 feet thick in the brine injection field. The intervening Kansan sand is 30 feet thick near the dome, and 100 feet thick and fully saturated with brine in the disposal area.

Several 100 to 200-foot sands are found between the "Lafayette" gravel and the (#1) sand presently used for brine injection at a depth of 4000 feet, particularly the Goliad at the base of the Pliocene and the A sand. These might be used in addition to the Lafayette gravels.

Caprock

The revised caprock map (Fig. 5) shows much more detail in the topography atop the caprock, especially where shallower than 600 ft, which was the limit shown in the earlier report. The "high" shown in the southwest corner suggests the presence of a dominant lobe or salt spine, emergent in that vicinity. Improved well control along the eastern flanks allows the revised map to extend the contours another 1000 ft eastward, to a depth of 5000 ft. A major fault, dipping to the southeast, exhibits minor displacement on the caprock surface. This fault is active and marks the boundary anomalous zone in the dome. Other faulting that is shown on the cross-sections (Figs. 7-11) comes through the caprock to the surface and is uncertain and probably minimal, in the sense that caprock is inevitably extensively faulted because of the continued movement of the underlying salt.

The major fault transecting the dome, oriented N75°E, appears to have affected the shape of some of the now-abandoned caverns, particularly Cavern 4. This azimuth may also reflect the direction of secondary faulting and jointing in the caprock.

The 1980 characterization report indicated some disagreement between authors on the amount of anhydrite and carbonate in the caprock. X-ray diffraction analyses in 1978 of selected samples reported only gypsum in the sulfate components, and this may be important from a solubility and structural integrity viewpoint as gypsum is somewhat less soluble than anhydrite at temperatures less than 50°C. Conceivably this could lead to less solutioning in the already-eroded caprock over Cavern 4. Corehole 2 over Cavern 4 provided some of those samples for x-ray determination that showed only gypsum. There has not been any new information that would resolve this disagreement and the 1992 sonar survey of Cavern 4 showed little change from the previous 1980 survey, although a 6% volume increase may be equivocable, owing to inherent accuracy limitations in sonar surveys. This suggests that the caprock over the cavern is only questionably stable at this time, but at least that *major* changes did not occur. The absence of carbonate caprock has prevented development of the lost-circulation zones or karst which has plagued cavern development in many other domes.

Slezak (1988) indicated that previous brine injection into caprock had induced caprock shifting and that this practice was possibly associated with casing failure, but that cessation of injection stopped the problem. This practice has been discontinued and all brine is now disposed of on the flanks of the dome.

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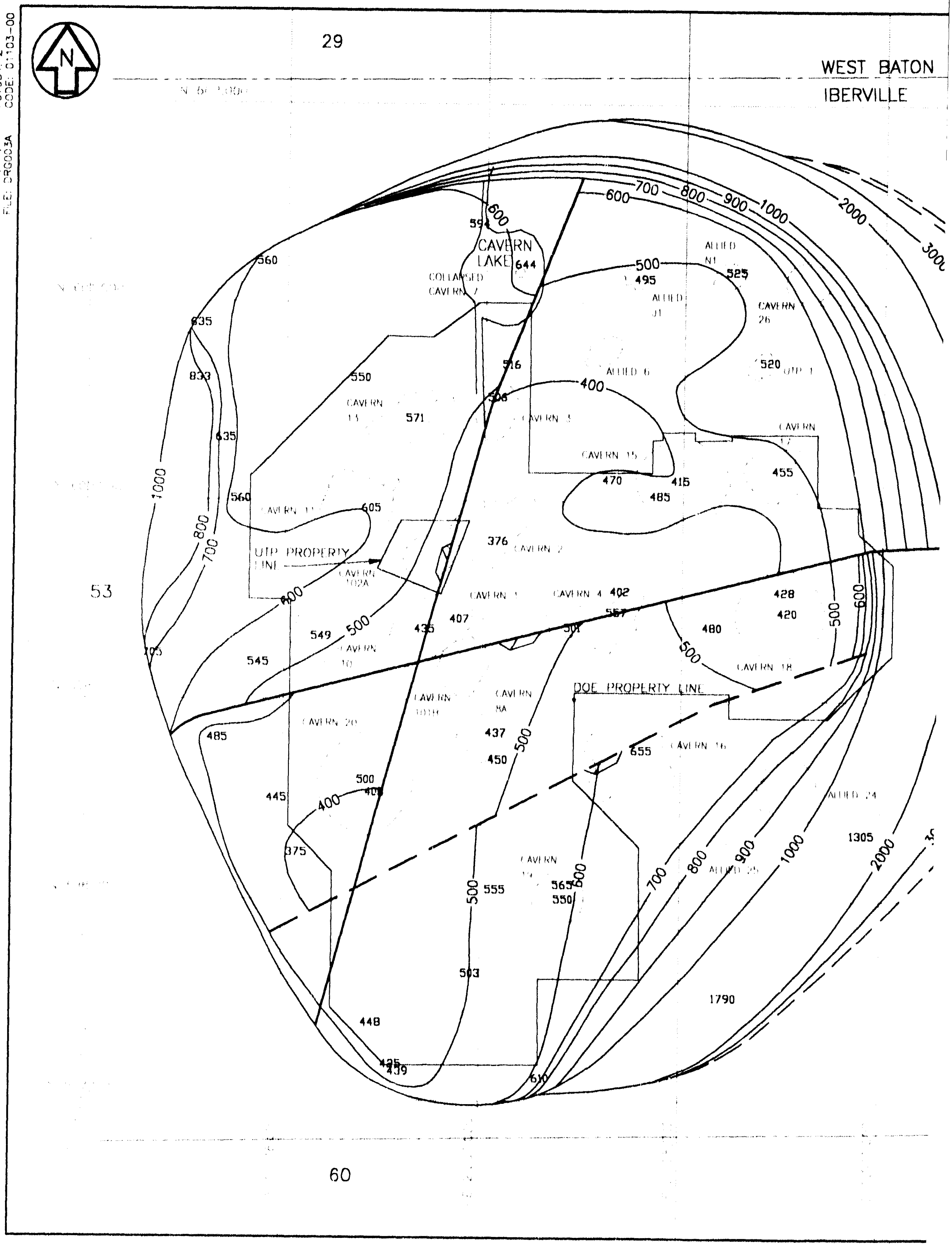

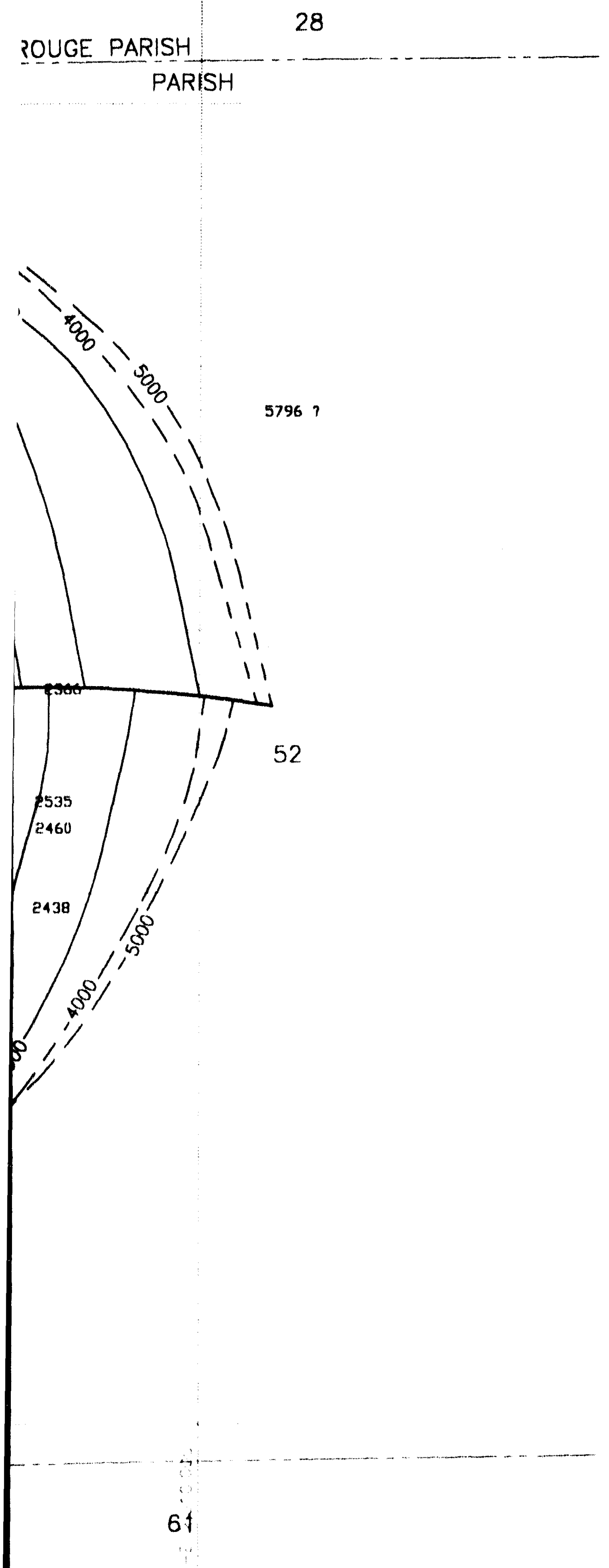

LEGEND

5796 — TOP OF CAPROCK (FEET BELOW MEAN SEA LEVEL)

28 — LEASE CODES

5000 — CAPROCK CONTOUR (FEET BELOW MEAN SEA LEVEL) (DASHED LINE REPRESENTS PROBABLE CONTOUR)

FAULT

PROBABLE FAULT

PARISH BOUNDARY

PROPERTY LINE

CAVERN

0 600 1200

FEET

FIGURE 5

CAPROCK

BAYOU CHOCTAW SPR SITE

THOMAS R. MAGORIAN, 1993

Salt

As noted above, the improved mapping of the caprock surface showed a major fault transecting the entire dome (Fig. 5). This revised interpretation led to a similar mapping of the top-of-salt (Figs. 6a, 6b) along with associated faulting. Thus, a faulted top-of-salt surface is now evident and this in turn likely marks a boundary between separate salt spines; we believe it would satisfy Kupfer's (1992) nomenclature of anomalous zones. As similar features exist at other domes having cavern storage, this anomalous zone would not necessarily have a significant impact on the deeper SPR caverns.

The shape of the salt has been modified only slightly based on new data (Fig. 6b). The critical west-side overhang that limits DOE storage has been extended south and minor anomalies removed by new well control since the New Orleans geological Society Map of 1961, and subsequent updates such as the 1980 DOE characterization and PB-KBB's mapping for Union Texas Petroleum.

As with the caprock map, the southwest corner is a structural high, suggesting that this part of the dome is rising faster than other parts. The reentrant of the 900 ft contour in the northwest corner may also be structurally controlled. Similar troughs have been noted at other domes, e. g., Weeks Island, LA, and Big Hill, TX, SPR sites.

In drilling the well to leach Cavern 26, Union Texas encountered black shaly material somewhere between 3690 and 3819 ft. This was interpreted as an overhang, but our interpretation of a vertical seismic profile conducted for them, and with the gravity data, does not confirm that geometry. The refraction data from the VSP clearly shows the east face of the salt stock leaning to the west (dipping eastward, as shown in all the surrounding wells which tagged salt), while reflections could not be tied to the black shale, suggesting it is an inclusion of material from the outside. The first sonar profile of Cavern 26 was normal, but further leaching could indicate an anomaly on this flank.

The salt cored for Cavern 101 is clear with 1-2 cm crystals and 1-2 mm gray anhydrite bands down to 2390 ft depth. The core taken at 4741-4745 ft, was black, ~5%-anhydritic salt with 0.5 cm crystals and wavy vertical bands up to 1 cm wide. Both of these types of salt are common in Gulf Coast domes, the clear coarse-crystalline salt typical of the centers of spines being more common at shallow depths, apparently because of recrystallization with release of pressure uplift; while the black salt is typical of the edges closer to the anomalous zones. The inclusions measured in Fig 6.24 of the 1980 characterization report are another function of the same increase in insolubles with depth.

Structural Interpretations

Five new cross-sections have been prepared, showing domal geometry and structure (Figures 7 - 11) along principal azimuths. These sections show the relations of the storage caverns to the main fault cutting the caprock and shallow salt; this fault is believed to mark the anomalous zone separating the principal spines in the salt stock. In addition, the sections show

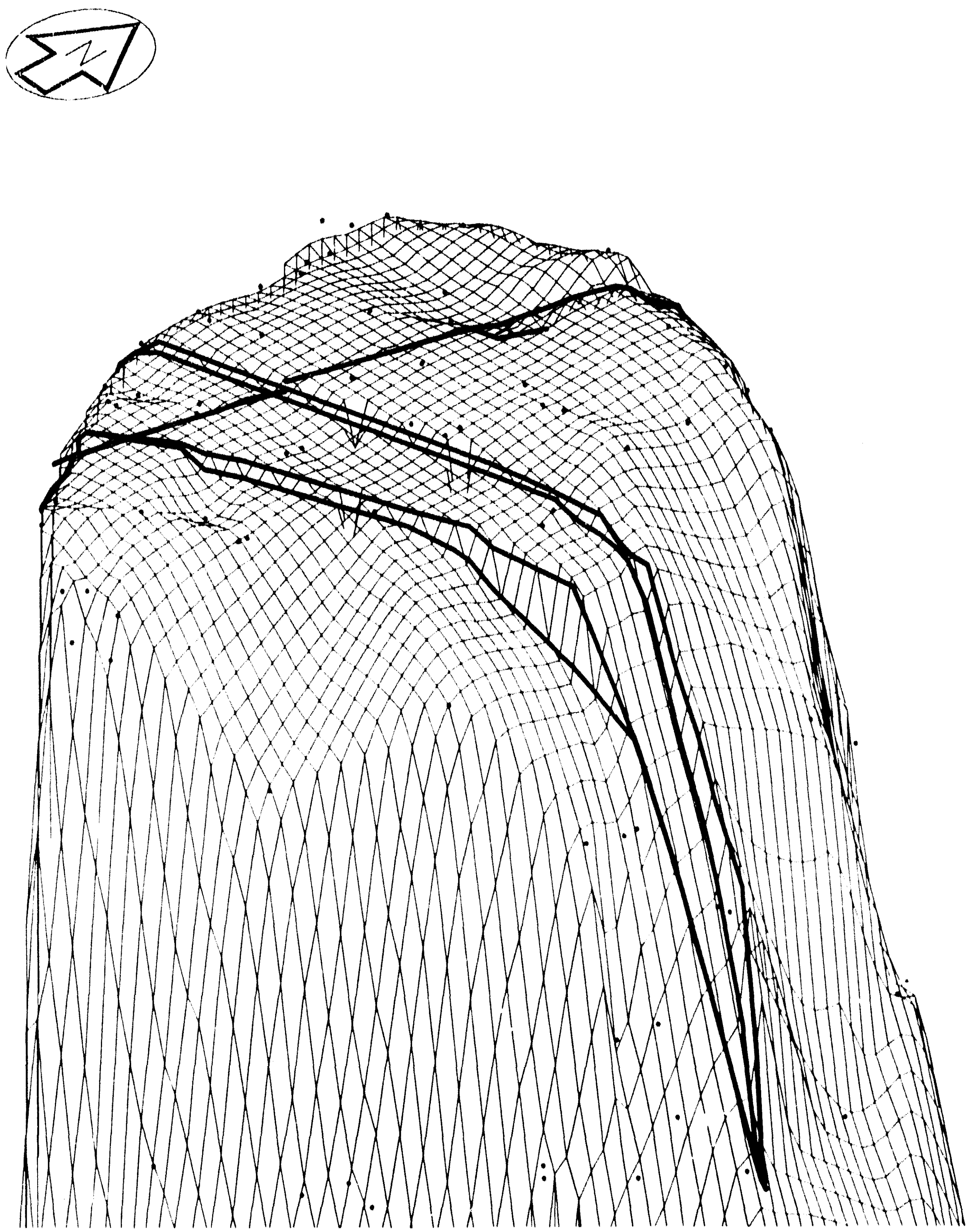

FIGURE 6a

Surface Model for Top of Salt

Bayou Choctaw Salt Dome

THOMAS R. MAGORIAN, 1993 ACRES

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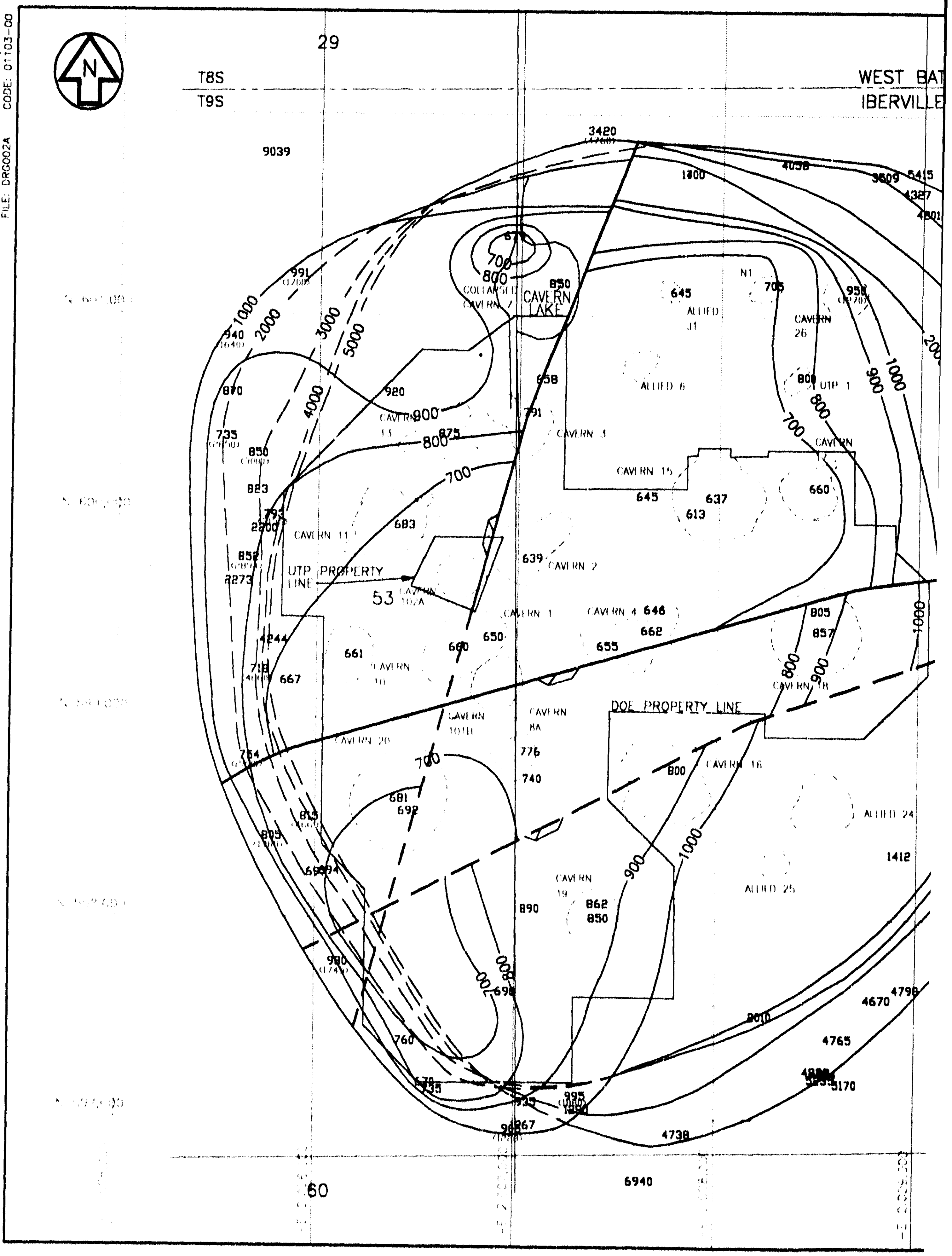
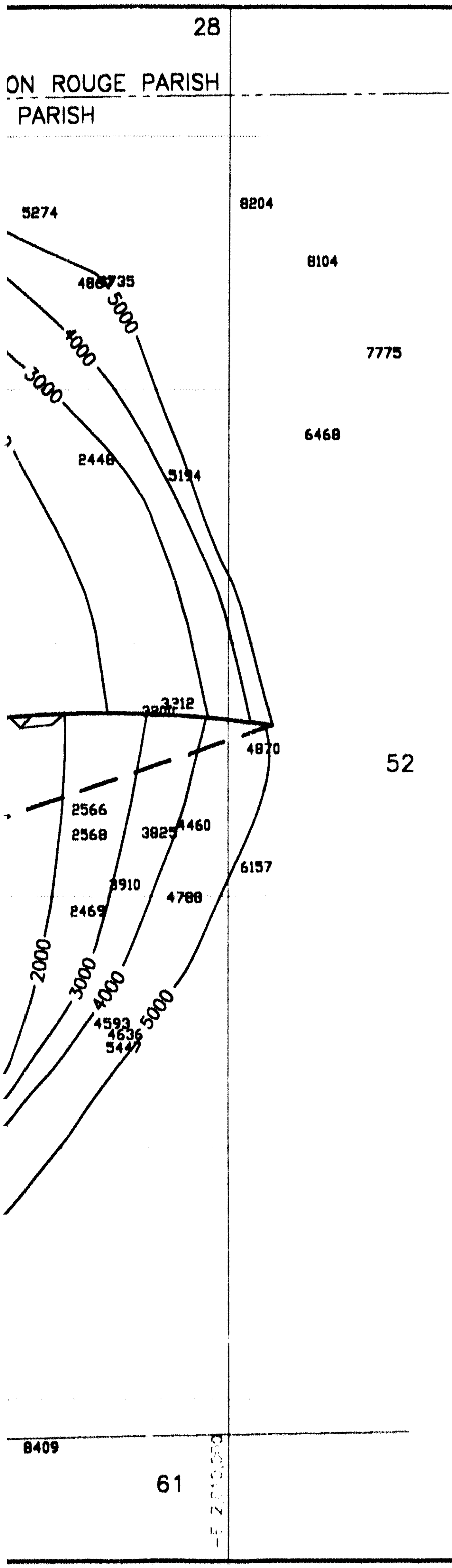




LEGEND

805	TOP OF SALT (FEET BELOW MEAN SEA LEVEL)
1988	BOTTOM OF SALT (FEET BELOW MEAN SEA LEVEL)
52	LEASE CODES
—4000—	SALT CONTOUR (FEET BELOW MEAN SEA LEVEL)
	FAULT
	PROBABLE FAULT
	PARISH BOUNDARY
	PROPERTY LINE

0 600 1200

FEET

FIGURE 6b

SALT

BAYOU CHOCTAW SPR SITE

ACRES

THOMAS R. MAGORIAN, 1993

the relations of the sediments to the salt on the flanks of the dome and from which the geometry of the salt stock has been deduced. This knowledge of dome geometry allows assessments to be made of storage cavern safety.

Section 1 (Fig. 7) is an east-west view through the center of the dome, and shows essentially the same features as Section G-G' in the 1980 report, although the latter trended slightly northwest-southeast. The new section is simpler and does not attempt to delineate very minor flank faulting, as suggested along the eastern flanks in the 1980 report. Fault F-2 in the 1980 report offset the caprock at the western edge of the dome by some 100 ft; the revised interpretation suggests this fault probably does not cut through the salt into the overhang. This kind of fault cutting through a salt overhang is known best at Stratton Ridge, TX, and has a much larger displacement on the top of the salt than any of the Batou Choctaw faults. The major fault that is shown on the caprock and salt maps (Figs. 5 and 6) crosses the section about at the vicinity of Cavern 4 and is likely responsible for the elongation of the cavern.

The westward tilt of the entire dome is most evident on Section 1, leaving most of the undeveloped salt in the northeast portion. The small remnants of caprock found deep on the east flank may not be as continuous as shown. They are relicts of old erosion surfaces on the salt, buried by subsequent deposition. The caprock is thickest at the edges of the flat top of the salt stock, as in most domes. Because of the westward tilt, this makes the caprock shallowest over Cavern 18 in this section.

Section 2 (Fig. 8) trends north-south through Cavern 19 on the south and Cavern Lake on the north. The flanking structure is again simplified, as with Section 1. The major east-west trending anomalous zone shows appreciable fault displacement on this section. The fault in the vicinity of Cavern Lake shown in the earlier 1980 report (F-1) may be less prominent than believed earlier. The apparent discordant bedding on the north flank is due to the Heterostegina reef or atoll ringing the salt stock. It has a maximum thickness of 400 feet. The north flank also shows the unconformity at the top of the Miocene, under the basal Pliocene sand, the Goliad of Texas. There is almost no overall tilt to the dome in this direction, although the lip of the west overhang extends just far enough east to be cut by this section.

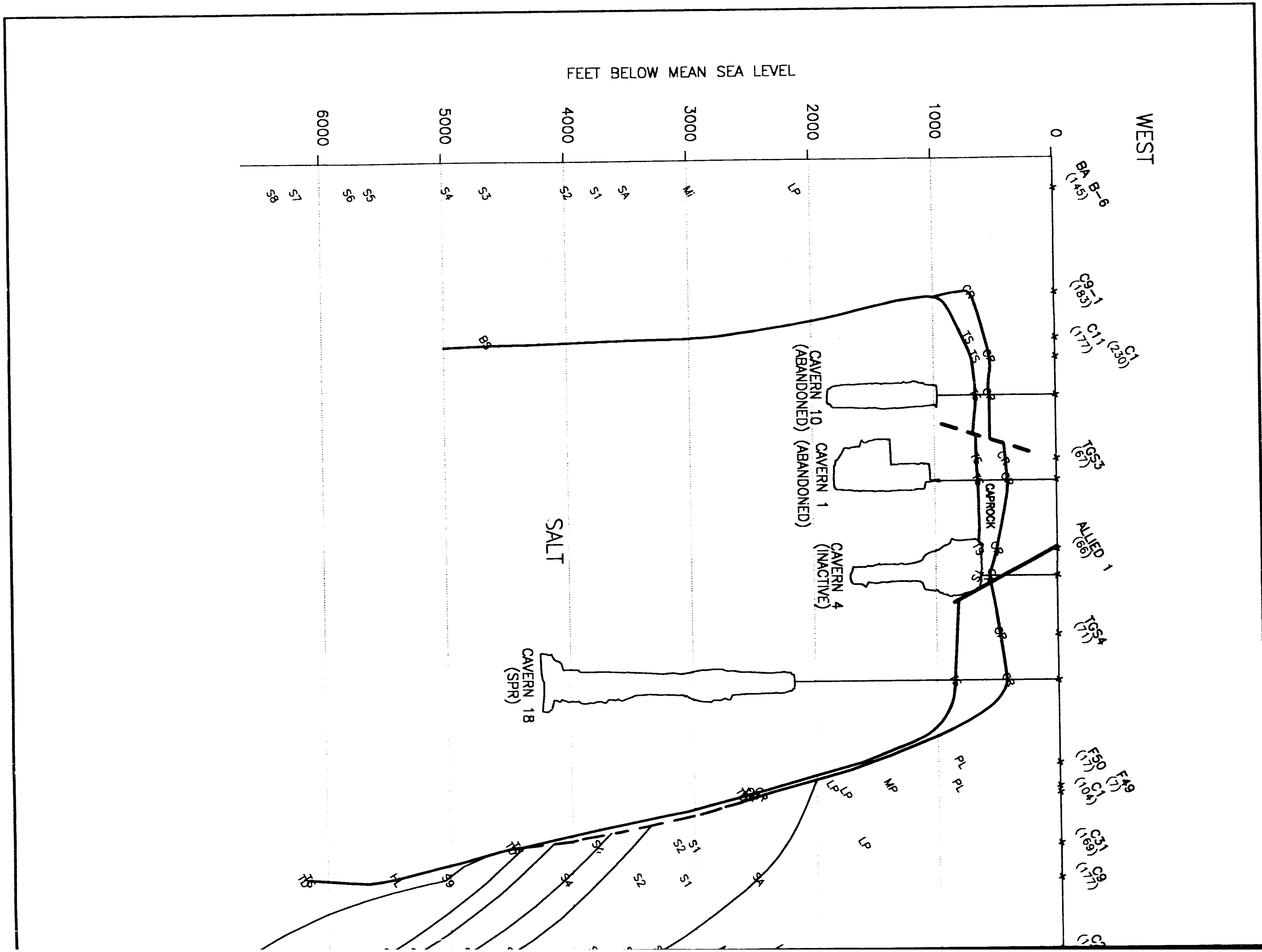
Section 3 (Fig. 9) trends southwest-northeast through Caverns 20, 8, 4, 15/17, and 26. The southwest overhang is very steep and shows the proximity of the dome edge outboard of Cavern 20. Cavern 26 on the northeast flank, UTP's new brining cavern, appears to have adequate buffer, although one interpretation by a geotechnical consultant claimed that salt had been penetrated, exited, and then reentered. As noted earlier, our interpretation does not support this model.

The deep interpretation of the west-side overhang is based primarily on the uplift of the flank sediments in Freeport well 62, which was drilled to the Heterostegina limestone reef. An alternate interpretation, in which the west flank parallels the east at least as deep as 8000 ft as found in Carter (Exxon) well 19, would make the reef at least 500 feet thick. These beds could

TABLE 1 BAYOU CHOCTAW STRATIGRAPHIC CORRELATION CHART

Unit	Symbol	Lithology
Holocene: *Recent river alluvium*		peat, muck & mud
Pleistocene		
Wisconsin		
Alton/Peorian: *Prairie Fm.*	a	sand and gravel
Sangamon: *Montgomery Fm. (U. Lissie)*	s	mud
Illinoian	i	sand and gravel
Yarmouthian: *Bentley Fm. (L. Lissie)*	(p)	mud
Kansan	ka/ks	sand and gravel
Aftonian: *Williana Fm.*	-	mud
Nebraskan	ne	sand and gravel
Lafayette: *Citronelle Fm*		gravel
Pliocene	PL	silt, mud, and sand
Miocene	MI	mud & sand
Upper		
Bigenerina floridana	A (S1)	sand and gravel mud
	B (S2)	sand and gravel mud
Textularia	L (S3)	marine sand
Bigenerina nodosaria	2	deltaic sand mud
Textularia stapperi	W	deltaic sand mud
Middle		
Bigenerina humblei	BH (S4)	unconformity shale
Cristellaria	CI	thin sands
Cibicides carstensi opima	CO (S5)	sand
Amphistegina	AB	shale
Lower		
Robulus	RL (S6)	marine sand
Operculinoides	OP	
Cibicides	CA (S7)	sand and shale
Marginulina ascensionensis	MA (S8)	sand shale
Siphonina davisi	SD (S9)	thin sand
- - - U N C O N F O R M I T Y - - -		
Anahuac (*Discorbis "restricted"*)	DR	shale
Oligocene		
Heterostegina	H	coral atoll
Marginulina howei	MH	sand shale
Frio	F	sands
Miogypsinoides	MG	thick sand
Cibicides hazzardi	CH	marine sands
Marginulina texana	MT	thin sands
Pontic facies		near geopressure
Bolivina mexicana	BM	thin oil-bearing sands
Nodosaria blanpedi	NB	" " "

HCN 07/14/93 P07984.12
FILE: DRG004 CODE: 01103-00



EAST

LEGEND

C11 WELL NUMBER

(71) OFFSET (FT) FROM SECTION LINE ROTATION SHOWN ABOVE INDICATES WELL IS SOUTH OF SECTION LINE – WELLS ROTATED IN OTHER DIRECTION ARE NORTH OF SECTION LINE.

* GROUND LEVEL

CAVERN OUTLINE

SUB–SURFACE FAULT

SURFACE FAULT

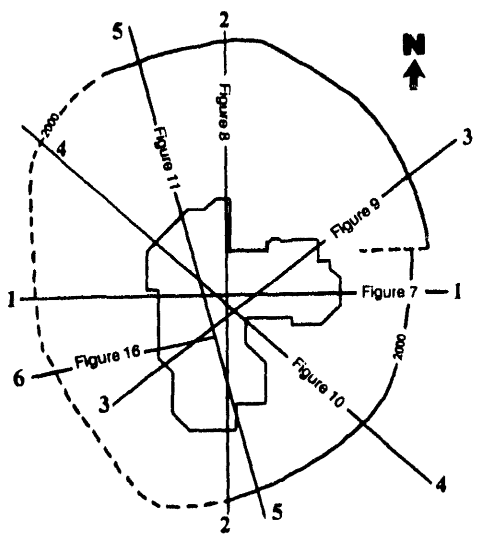
GROUND LINE

STRATIGRAPHIC SYMBOLS ON TABLE 1

REFER TO FIGURE 1 FOR SECTION LINES

0 1000 2000

FEET



PROFILE LOCATION

FIGURE 7

SECTION 1

BAYOU CHOCTAW SPR SITE

ACRES

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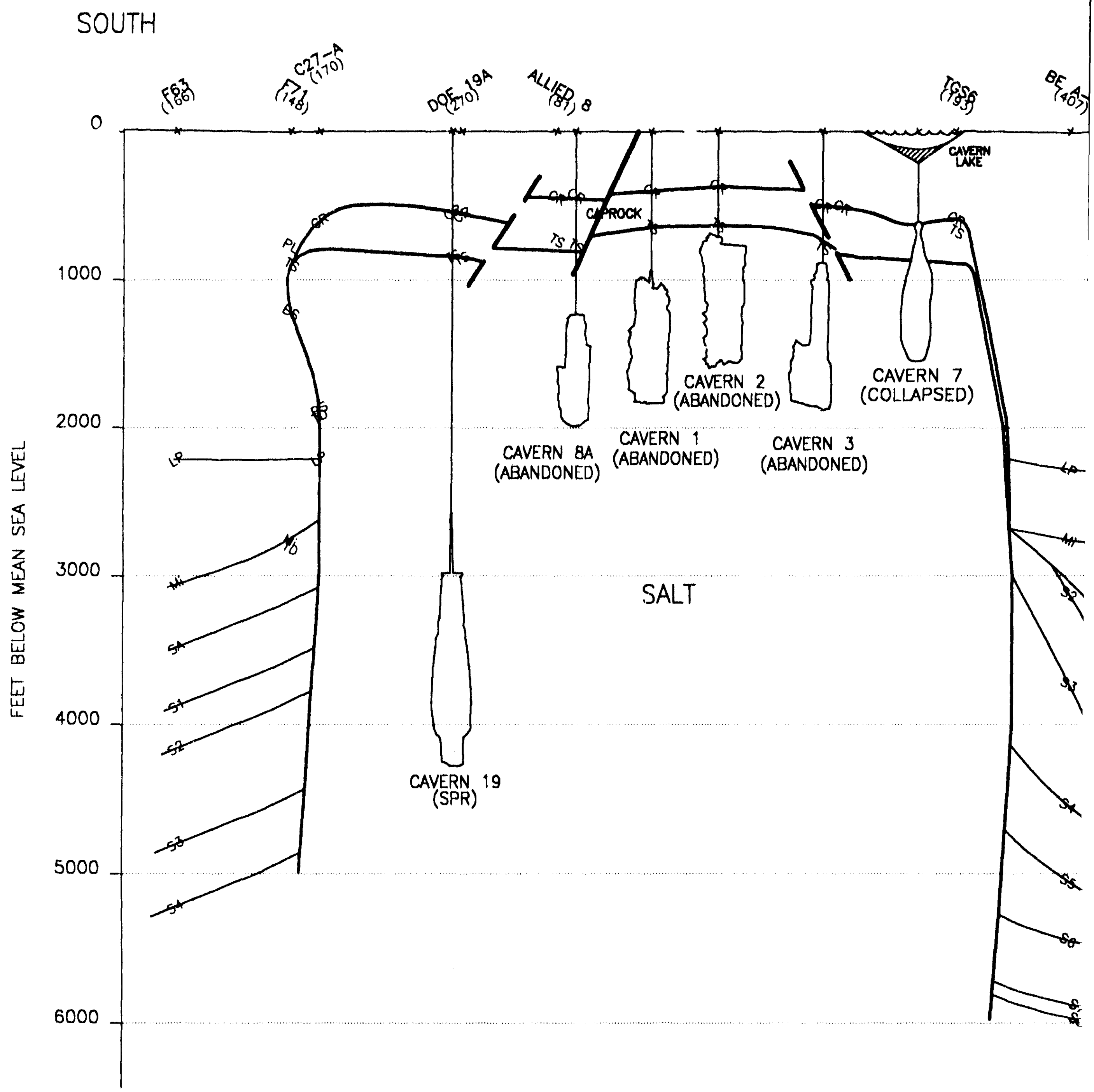
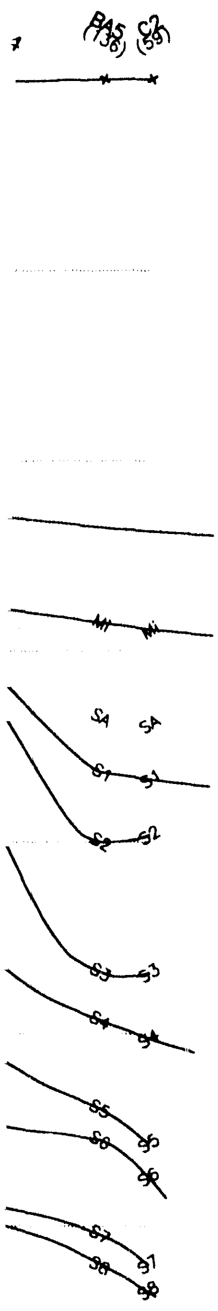
HCN 07/13/93 FILE: DRG005
P07984.12 CODE: 01103-00



NORTH



LEGEND

C11 — WELL NUMBER

(71) — OFFSET (FT) FROM SECTION LINE ROTATION SHOWN ABOVE INDICATES WELL IS EAST OF SECTION LINE – WELLS ROTATED IN OTHER DIRECTION ARE WEST OF SECTION LINE.

GROUND LEVEL

CAVERN OUTLINE

SUB-SURFACE FAULT

SURFACE FAULT

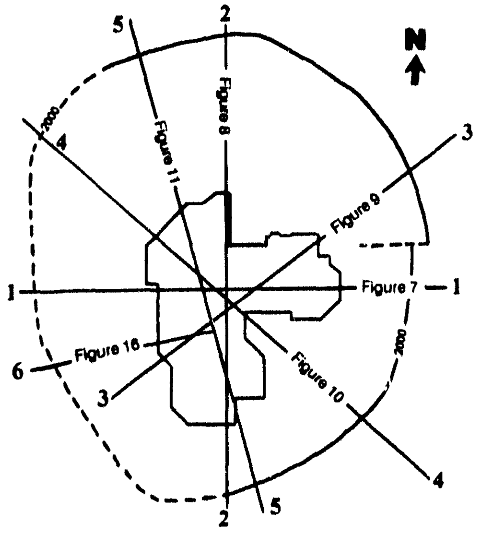
GROUND LINE

STRATIGRAPHIC SYMBOLS ON TABLE 1

REFER TO FIGURE 1 FOR SECTION LINES

0 1000 2000

FEET



PROFILE LOCATION

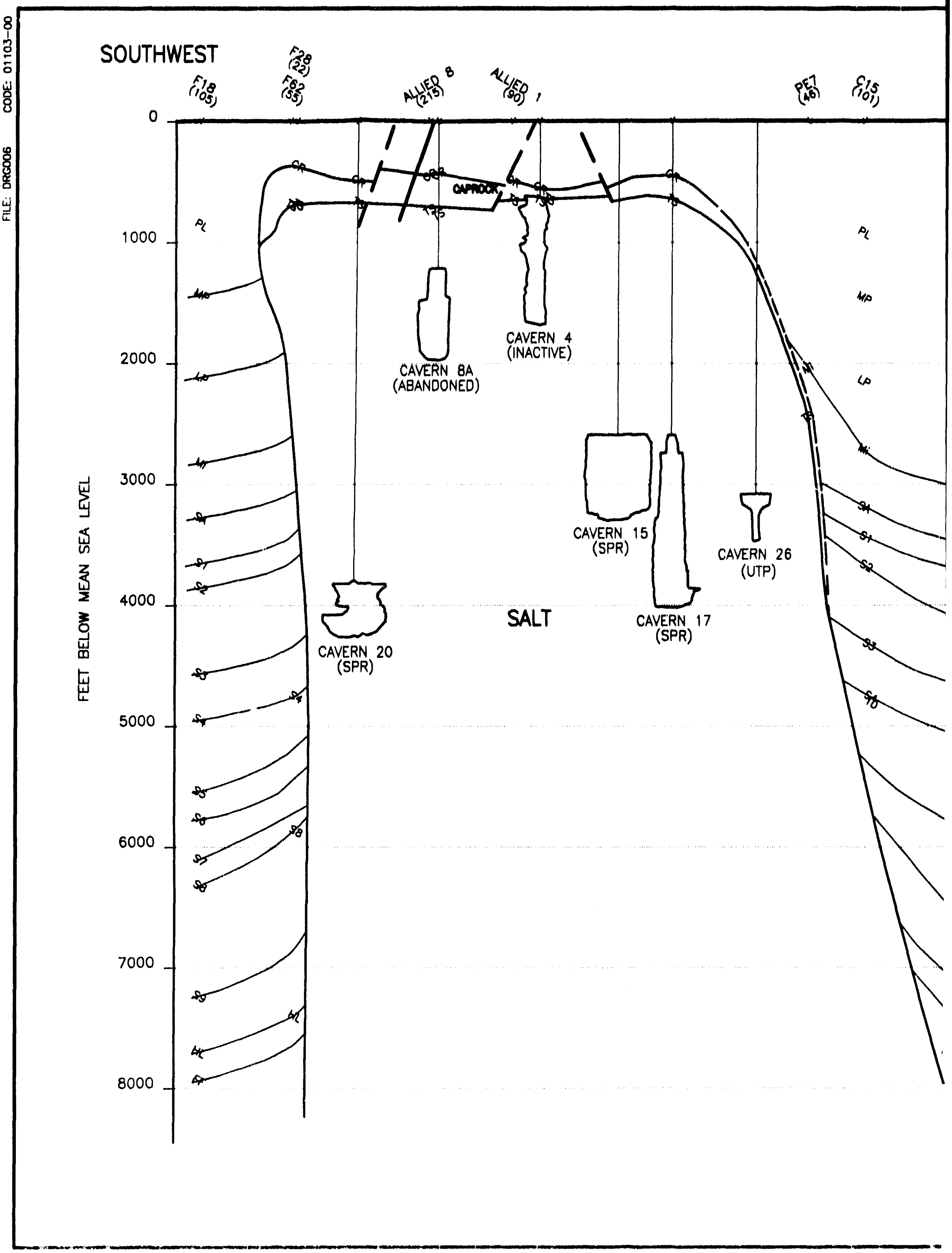
FIGURE 8

SECTION 2
BAYOU CHOCTAW SPR SITE

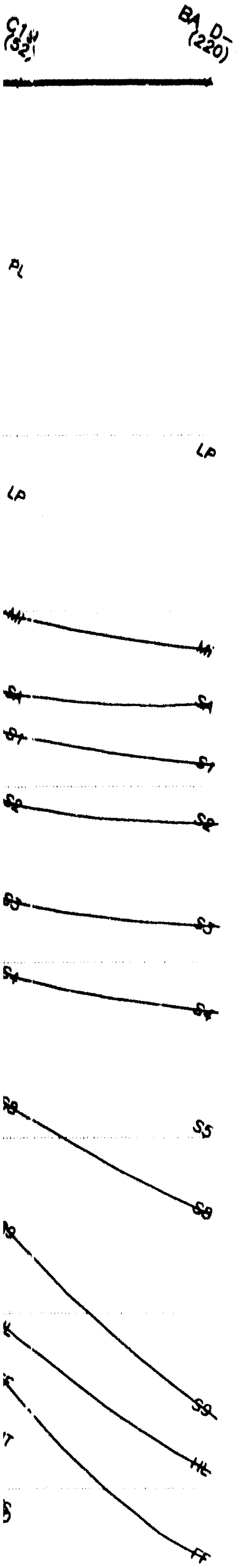
ACRES

THOMAS R. MAGORIAN, 1993

P07984.12
CODE: 01103-00
RAK 8/23/93
FILE: DRG006



NORTHEAST



LEGEND

PE7 — WELL NUMBER

(71) — OFFSET (FT) FROM SECTION LINE ROTATION SHOWN ABOVE INDICATES WELL IS SOUTHEAST OF SECTION LINE – WELLS ROTATED IN OTHER DIRECTION ARE NORTHWEST OF SECTION LINE.

GROUND LEVEL

CAVERN OUTLINE

SUB-SURFACE FAULT

SURFACE FAULT

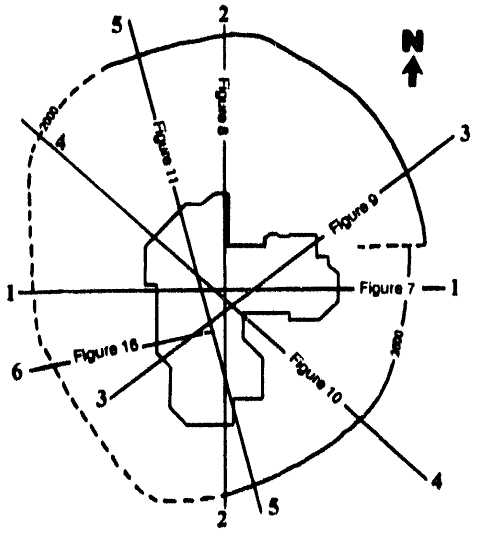
GROUND LINE

STRATIGRAPHIC SYMBOLS ON TABLE 1

REFER TO FIGURE 1 FOR SECTION LINES

0 1000 2000

FEET



PROFILE LOCATION

FIGURE 9

SECTION 3

BAYOU CHOCTAW SPR SITE

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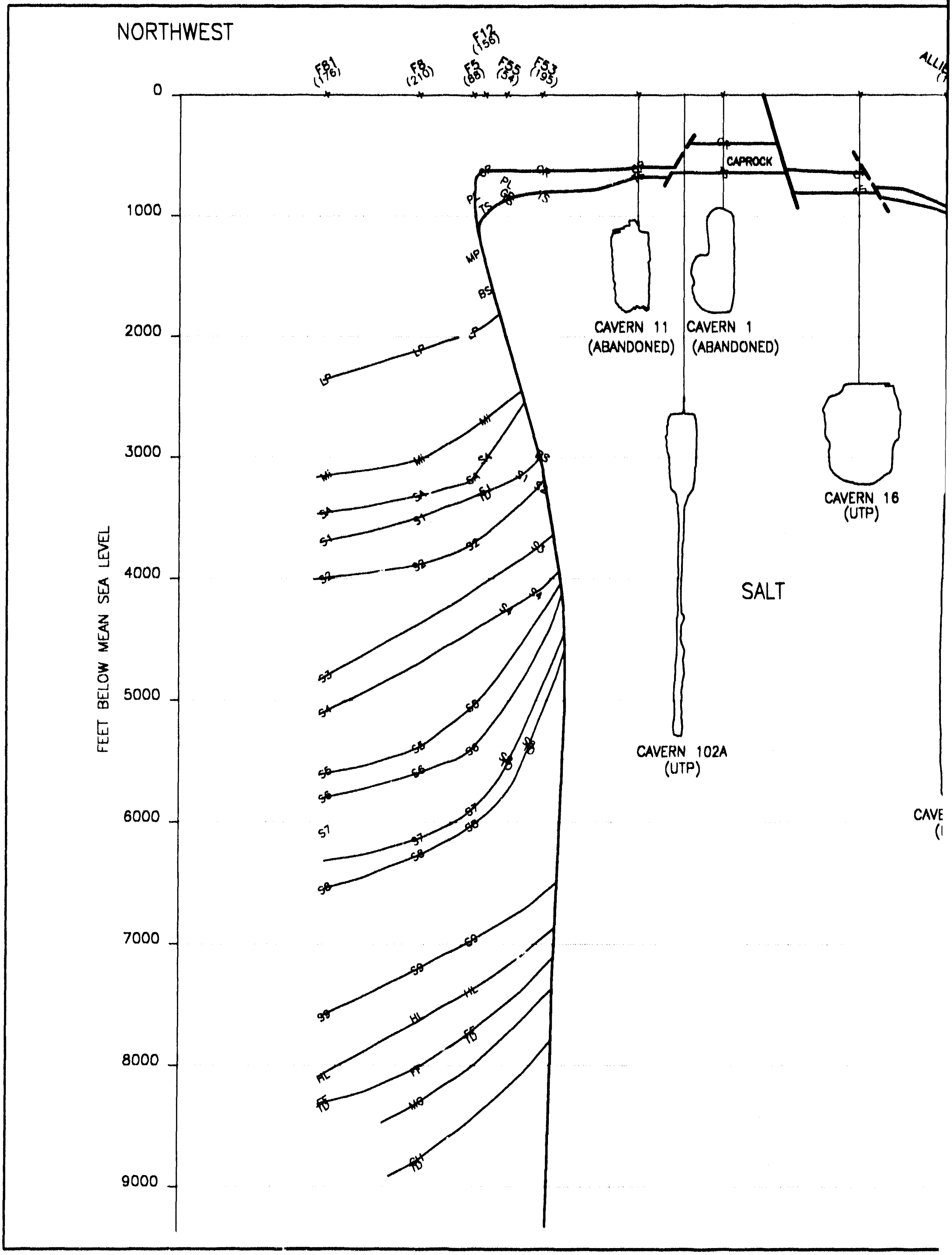
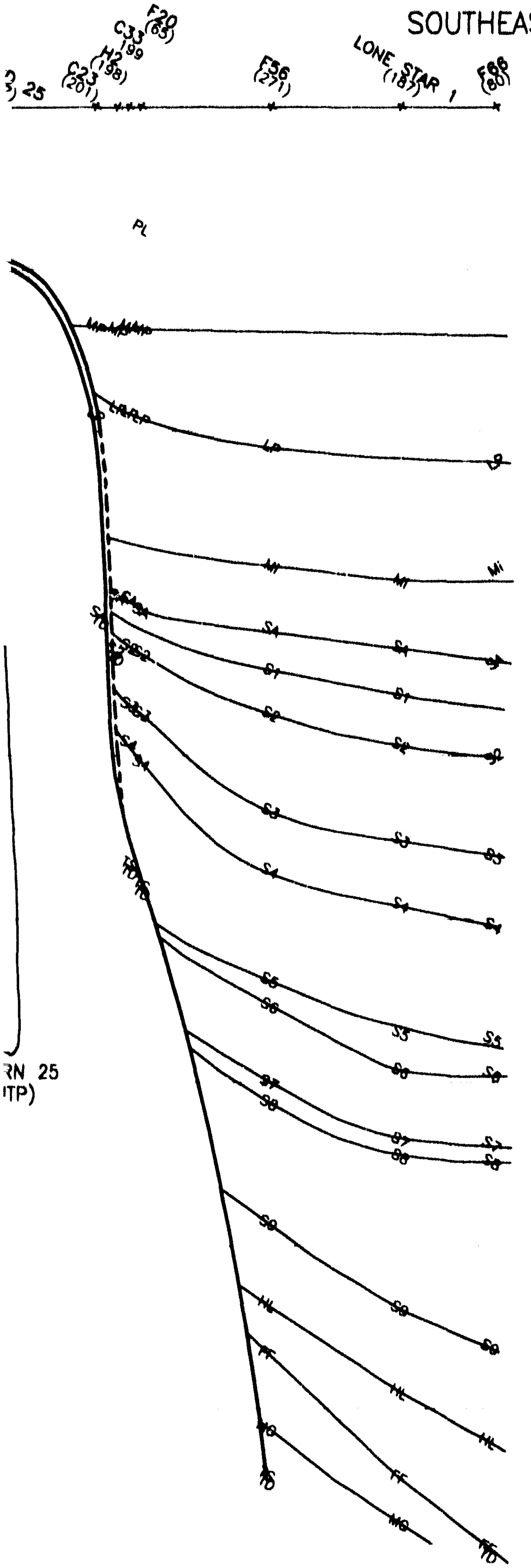
ACRES



NORTHWEST
F12 (156)
FB1 (176)
F8 (210)
F5 (88)
F55 (34)
F53 (193)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
FEET BELOW MEAN SEA LEVEL
CAPROCK
CAVERN 11 (ABANDONED)
CAVERN 1 (ABANDONED)
CAVERN 16 (UTP)
CAVERN 102A (UTP)
SALT



LEGEND

F8 WELL NUMBER

(71) OFFSET (FT) FROM SECTION LINE ROTATION SHOWN ABOVE INDICATES WELL IS NORTHEAST OF SECTION LINE — WELLS ROTATED IN OTHER DIRECTION ARE SOUTHWEST OF SECTION LINE.

GROUND LEVEL

CAVERN OUTLINE

SUB--SURFACE FAULT

SURFACE FAULT

GROUND LINE

STRATIGRAPHIC SYMBOLS ON TABLE 1

REFER TO FIGURE 1 FOR SECTION LINES

0 1000 2000

FEET

FIGURE 10

SECTION 4

BAYOU CHOCTAW SPR SITE

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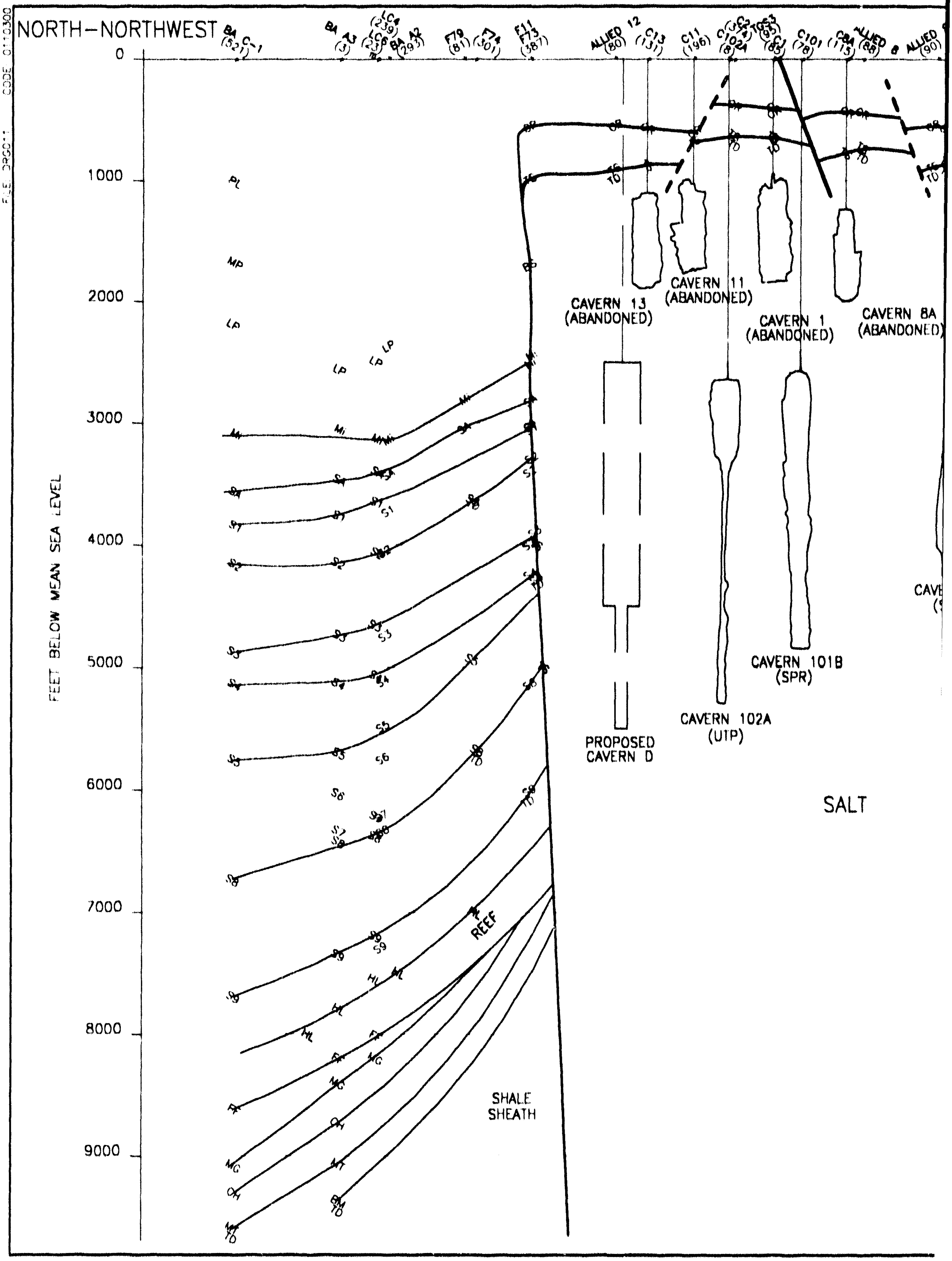
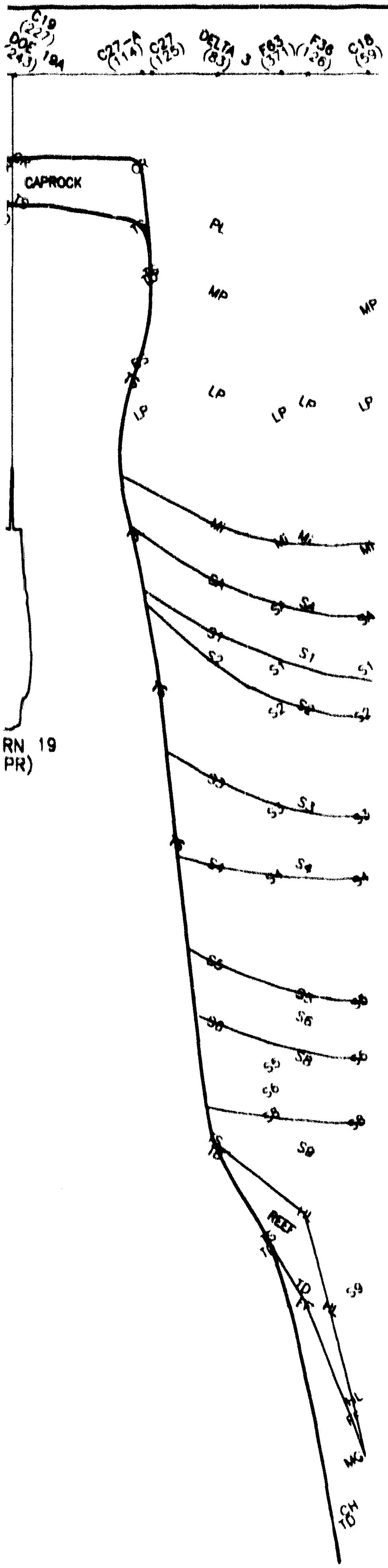

NORTH–NORTHWEST
FEET BELOW MEAN SEA LEVEL
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
CAVERN 13
(ABANDONED)
CAVERN 11
(ABANDONED)
CAVERN 1
(ABANDONED)
CAVERN 8A
(ABANDONED)
CAVERN 101B
(SPR)
CAVERN 102A
(UTP)
PROPOSED
CAVERN D
SALT
REEF
SHALE
SHEATH
ALLIED 12
(80)
C13
(131)
C11
(196)
C101
(78)
ALLIED 8
F79
(81)
F74
(301)
F11
F73
(387)

SOUTH-SOUTHEAST



LEGEND

4450 WELL NUMBER

(71) OFFSET (FT) FROM SECTION LINE ROTATION SHOWN ABOVE INDICATES WELL IS SOUTHWEST OF SECTION LINE – WELLS ROTATED IN OTHER DIRECTION ARE NORTHEAST OF SECTION LINE.

GROUND LEVEL

CAVERN OUTLINE

SUB-SURFACE FAULT

SURFACE FAULT

GROUND LINE

STRATIGRAPHIC SYMBOLS ON TABLE 1

REFER TO FIGURE 1 FOR SECTION LINES

0 1000 2000

FEET

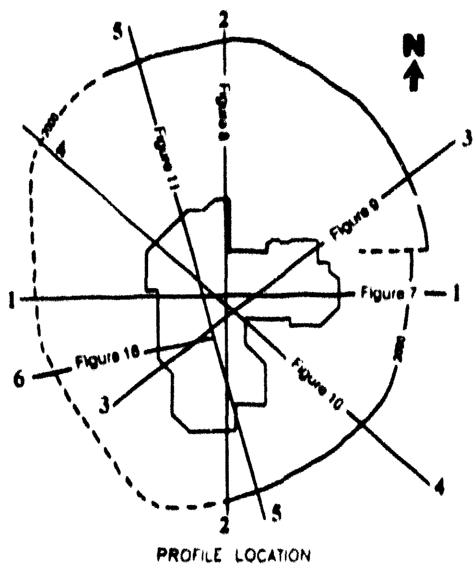


FIGURE 11

SECTION 5

BAYOU CHOCTAW SPR SITE

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contain considerable quantities of "attic" oil, which has been explored in several deviated holes under the overhang, but never found. Cavern 20 is just above the point where these interpretations deviate.

Section 4 (Fig. 10) is a northwest-southeast transect through abandoned Caverns 11 and 1, and then through UTP Caverns 16 and 25. There is fundamentally no difference in the flanking structure as compared with 1980 section D-D', but the central anomalous zone and fault offset is indicated on the revision. The same uncertainty of deep interpretation occurs as on Section 3. It affects the salt web available at the base of Cavern 102 and any other caverns along this side of the dome. Fault F-7 on the 1980 section may not exist.

Section 5 (Fig. 11) is rotated clockwise some 30° from Section 4 and reveals nuances in the dome structure even with this small shift. The crowded nature of the dome is best shown in this section. Proposed cavern location "D" will fill the available space. If there is a ledge at the reef level on the northwest side like that found on the southeast, the resultant necking of the salt stock is too deep to destroy this location. The lip of the west overhang shows at the southeast edge of the section as a notch between 2000 and 3000 feet south of Cavern 19.

3 SPR SYSTEM CONSIDERATIONS

The effects of regional and local geology may influence the SPR operations in a variety of ways. These aspects are discussed in the following pages.

Cavern Configurations

Fifteen active and 10 abandoned caverns exist at Bayou Choctaw, with a total cavern volume of some 160 million barrels. This includes 79 MMB in SPR, 32 MMB in UTP, and about 50 MMB in abandoned caverns, excluding Cavern 7, which collapsed in 1954 and filled with overburden. The total cavern volume has practical interest, as this void space affects total creep closure (and consequent subsidence) in the Bayou Choctaw salt mass, a relatively small feature as compared with most other domes.

SPR Caverns

The six operating SPR caverns are listed in Table 2; all were acquired from Allied Chemical and subsequently modified, with the exception of Cavern 101, which was leached in 1990-91. Cavern shapes are shown diagrammatically on Figure 12, locations are shown on Figures 1, 5, and 6, and on appropriate cross sections. An experimental approach to graphical representation of cavern geometry is shown at Appendix D, Cavern 101 sonar results are shown in shaded relief.

UTP Caverns

Union Texas Petroleum (UTP) operates seven hydrocarbon storage caverns and two brine caverns on the dome, closely interspersed with the SPR caverns, which were formerly owned by

TABLE 2 BAYOU CHOCTAW CAVERN GEOTECHNICAL PARAMETERS

CAVERN	SPR BC 15	SPR BC 17	SPR BC 18	SPR BC 19	SPR BC 20	SPR BC 101
DATE STARTED	1953	1955	1967	1967	1970	1990
CAVERN VOLUME, MMB	16.39	11.31	17.42	12.24	8.96	12.92
TOP CAPROCK	-477	-445	-430	-550	-500	-452
TOP SALT	-626	-648	-805	-856	-700	-726
CASING SEAT	-2405	-2482	-1787	-2305	-2100	-2403
TOP CAVERN	-2605	-2600	-2125	-2935	-3830	-2550
BOTTOM CAVERN (DATE)	-3296 (3/93)	-4023 (3/93)	-4219 (6/93)	-4228 (6/93)	-4225 (3/93)	-4830 (6/93)
CAVERN HEIGHT (H)	691	1423	2094	1293	395	2280
DIAMETER (D)	412	238	244	260	514	201
H/D	1.68	5.98	8.58	4.97	0.77	11.34
NEAREST CAVERN	17	15	17	16	101	20
PILLAR THICKNESS (P)	109	109	320	420	300	300
P/D	0.26	0.46	1.31	1.62	0.58	1.49
ROOF THICKNESS (B)	1979	1952	1320	2079	3282	1824
B/D	4.80	8.20	5.41	8.00	6.39	9.07
DISTANCE TO EDGE (E)	1400	800	900	610	225	789
E/D	3.40	3.36	3.69	2.35	0.44	3.93
DISTANCE TO PROPERTY LINE	78	88	310	240	190	1870
BHF ELEVATION JAN 1993	12.99	10.95 (4/91)	13.47	9.56	10.88	11.04

Data current to July, 1993

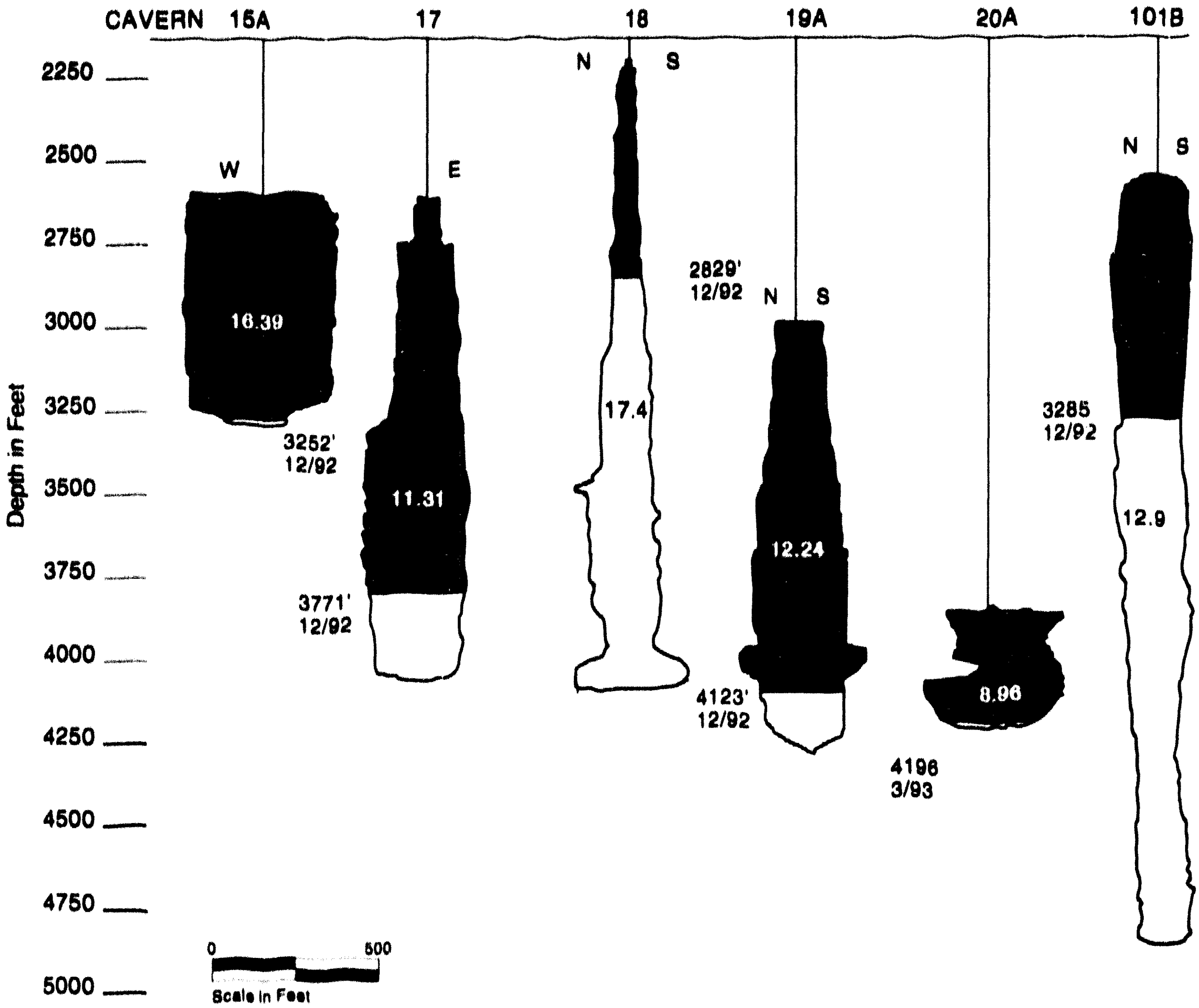

FIGURE 12

Strategic Petroleum Reserve Caverns, Bayou Choctaw

1) Caverns shown diagrammatically, not in true relationship to one another spatially, except 15/17
2) Refer to Figure 1 for locations.
3) Cavern volumes in million barrels, eg. 16.39
4) Oil/ Brine depths in feet.
5) Vertical and horizontal scales equal.

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ACRES

Allied Chemical, UTP's predecessor (Figure 1). UTP's operations on the dome support the nearby petrochemical industry, supplying feedstock to those plants.

Since the last characterization report in 1980, UTP exchanged their Cavern 17 for 102, which had been constructed by DOE. They also initiated brine production in 1990 from Cavern 26 on the northeast side of the dome. And in 1992 Cavern 24 was converted from brine production to natural gas storage; it contained 1.0 BCF of gas in late 1992. Cavern 25 could be similarly converted, but is currently in brine production.

UTP's cavern parameters are summarized in Table 3 and graphically displayed on Figure 13. UTP's cavern engineering practices have been conservative and there have been no issues regarding cavern integrity.

A rock mechanics analysis by PB-KBB (1991) concluded that Caverns 24 and 25 were suitable for natural gas storage provided that mechanical integrity was demonstrated and that 200 ft (minimum) pillar separation was maintained, with P/D ratios greater than 1.0. In 1992 the average separation was about 350 ft and the P/D ratios exceeded 1.0 by a factor of two or more. The estimated distance to the dome edge was 575 ft for both caverns and thus the safety margins are more than adequate. Because natural gas is more compressible than brine or other hydrocarbon products, creep closure and associated subsidence can be expected to increase (Heffelfinger, 1990), especially if cavern pressures are at lower values. PB-KBB [1991] recommended that UTP resume its measurement of surface subsidence, which had been suspended in 1971 after several years of monitoring very small values.

Cavern 6 was converted from brine extraction to propylene storage in 1990. The abandoned Brine Well 14 is located nearby, some 215 ft away, but its condition is unknown as it has been inactive for nearly forty years. Only a small amount of brine had been extracted from two different depths, prior to its abandonment because of high magnesium. The web thickness to the next closest cavern (J) is not determinable in the usual sense as there is substantial difference (1650 ft) in the depths of the two caverns (see Fig. 13).

Cavern 25 is a possible candidate for conversion from brine to natural gas, but no immediate plans exist. PB-KBB (1991) considered the structural integrity relationships of this cavern at the same time they were looking at Cavern 24 and found very similar conditions as existed there. A P/D ratio of 2.33 exists between Caverns 25 and 24, the closest neighbor at about 250 ft.

Cavern 26 is the newest UTP brining cavern; it was constructed in 1990 at the northeast edge of the dome. A possible overhang was penetrated at this location at about 3600 ft when shale was encountered in the original borehole. The VSP survey and the well log raise questions regarding the interpretation, and it is possible that shale inclusions internal to the salt were penetrated, rather than exterior domal sheath. In any event, the shale marks the effective limit of brining and this cavern will not ever be allowed to get very large, for reasons of conservatism. Its exterior location on the dome has little impact on any other caverns, either UTP or SPR.

Cavern 102 was originally planned for the SPR program but was leached according to UTP specifications and swapped for Cavern 17, as it was shown during integrity testing that Caverns 15/17 had some degree of pressure interaction, and would become a single gallery if leaching through the thin (~110 ft) pillar ever occurred. Engineering judgment suggested that Caverns 15/17 needed to be operated at near-equal pressures and contain the same product in case of coalescence; thus the swap was arranged. Ehgartner [1993] has reexamined this issue in light of refined analytical methods; discussion follows later.

Abandoned Caverns 1, 2, 3, 5, 8, 10, 11, 13, 14

No new information is available on these former caverns, and all of the wells have been plugged and abandoned. None of these are considered to be reclaimable for development of storage. Their history and status are fully described in the 1980 characterization report.

Cavern Integrity Issues

Cavern 4 Status:

Cavern 4 has no salt roof and also experienced erosion into the caprock prior to its abandonment in 1957, following the collapse of Cavern 7 and the formation of Cavern Lake in January, 1954. Because of similarities in the geology and cavern size, the 1980 characterization report concluded that a similar collapse could occur over Cavern 4, resulting in an 800 ft diameter lake and affecting some of the non-critical SPR facilities. Because of this potential, several site and system changes were introduced, and a collapse warning system was engineered and installed [Todd and Smith, 1988].

Some 12 years of safe SPR operations have taken place, and although there have been no hints of instability or abnormal subsidence over or near Cavern 4, substantial uncertainty has existed regarding the geometry of the cavern roof area, especially the amount of additional caprock removal by leaching or rockfall. PB-KBB, in its 1978 analysis of the situation, suggested it was reasonable to assume that hydrologic communication in the lost circulation zone at the caprock/salt interface would continue to promote removal of caprock over the cavern roof. This prediction was based in part on the apparent enlargement of the caprock/roof area between 1963 and 1977, as determined from sonar measurements. Between the 1977 and 1980 sonar surveys, there appeared to have been no further change of significance [Todd and Smith, 1988]. The 1977 volume estimate from sonar was about 5.85 MMB, but 1980 sonar volume measurements indicated 5.94 MMB, an increase of about 1.5 % -- which could represent further dissolutioning, or more likely be within the error range of the survey. Estimates from production records suggested the volume should have been approximately 14.8 MMB, a major inconsistency [PB-KBB,1978]. PB-KBB suggested that salt solutioning not observable on sonar might be responsible for the disparity. Mills [1993] notes the plan view cross sections in the 1992 sonar report are extremely irregular and support the notion of hidden volume. The shape also makes radius and volume interpretations more difficult and variable.

TABLE 3: Union Texas Petroleum Cavern Geotechnical Data Base, Bayou Choctaw

CAVERN NO.	UTP-1	6	16(a)	J	N	24	25	26	102A
COORDINATES X	2,008,238	2,007,677	2,007,803	2,007,777	2,008,227	2,008,533	2,008,345	2,008,616	2,006,700
COORDINATES Y	600,663	600,793	598,736	601,122	601,126	598,642	598,168	601,109	599,710
ORIGINAL DRILLING	1967	1942	1954	1972	1972	1979	1979	1990	1981
VOLUME GROSS	1.41	0.82	10.49	0.75	0.49	5.59	7.08	0.71	4.20
USE/PRODUCT	ethylene	propylene	ethylene	ethane/ propane	ethylene	natural gas	brine	brine	ethane
ELEVATION TOP SALT	-700	-685	-849	~-800	~-800	-855	-854	~-900	-672
ELEVATION TOP CAVERN	-2360	-1195	-2612	-2854	-2670	-3100	-3575	-3076	-2640
ELEVATION BOTTOM CAVERN	-3502	-1562	-3228	-3945	-3590	-4337	-5790	-3470	-5339
CAVERN HEIGHT	1142	367	616	1091	920	1247	2215	394	2699
TOTAL DEPTH	3500	1585	3481	3984	3590	4382	5978	3600	5388
DIAMETER MAXIMUM	150	192	480	110	166	295	190	250	223
DIAMETER AVERAGE	94.0	126.4	349.1	69.9	61.9	179.1	151.2	113.2	105.5
NEAREST CAVERN	N	J	19	6	26	25	24	N	101
PILLAR THICKNESS	385	NA	440	NA	301	353	353	301	448
P/D	4.10	NA	1.26	NA	4.86	1.97	2.33	2.66	4.24
DISTANCE TO EDGE	~700	~740	~600	~525	~390	~575	~575	~175	~850
LAST SONAR	Aug-89	Nov-90	Mar-89	Jul-89	Jan-87	Apr-92	Jun-92	Sep-91	Oct-84
REMARKS									Exchange w/DOE for Cavern 17

NA = Not applicable to these caverns because of substantial depth variation

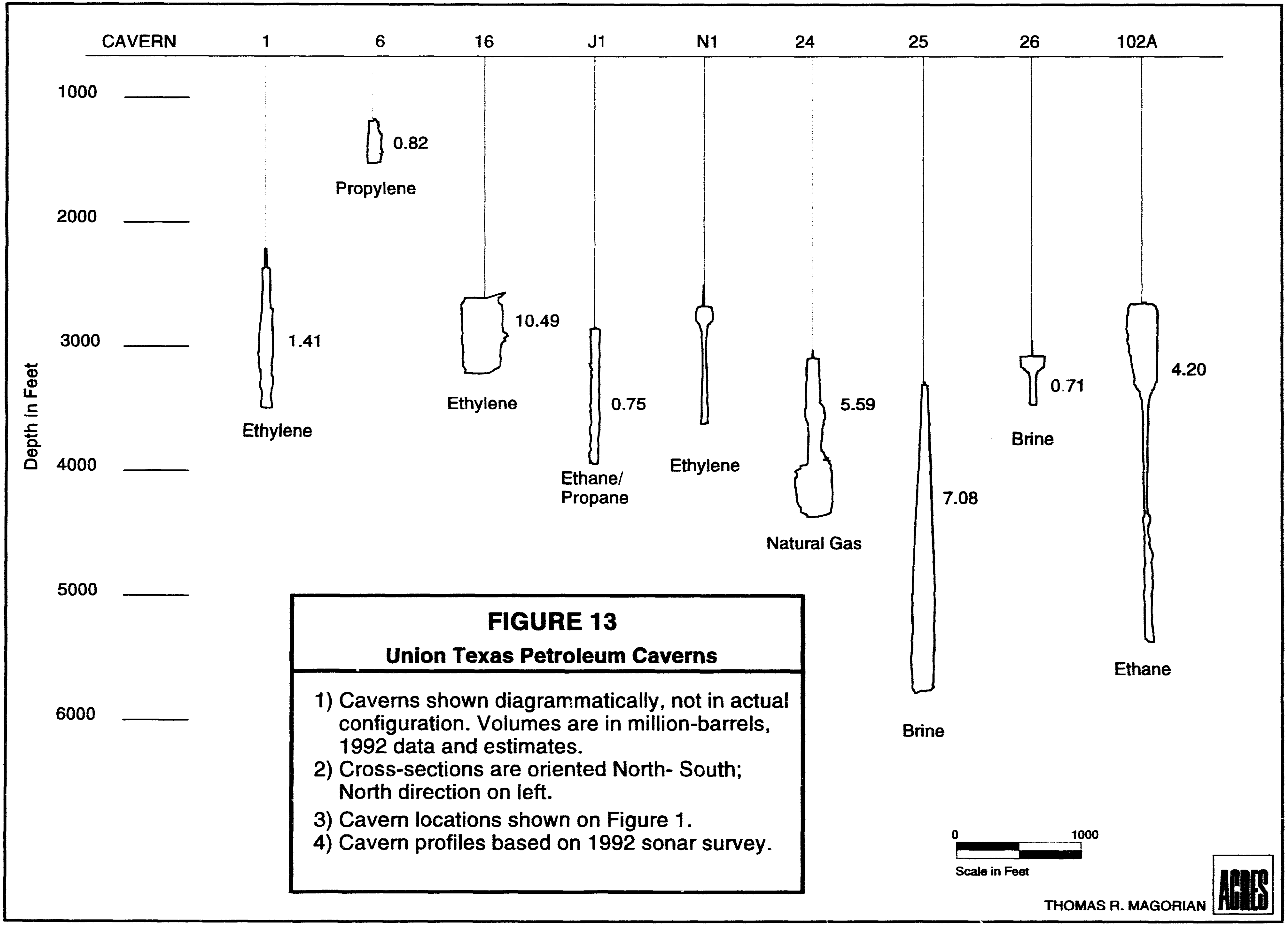


FIGURE 13

Union Texas Petroleum Caverns

1) Caverns shown diagrammatically, not in actual configuration. Volumes are in million-barrels, 1992 data and estimates.
2) Cross-sections are oriented North- South; North direction on left.
3) Cavern locations shown on Figure 1.
4) Cavern profiles based on 1992 sonar survey.

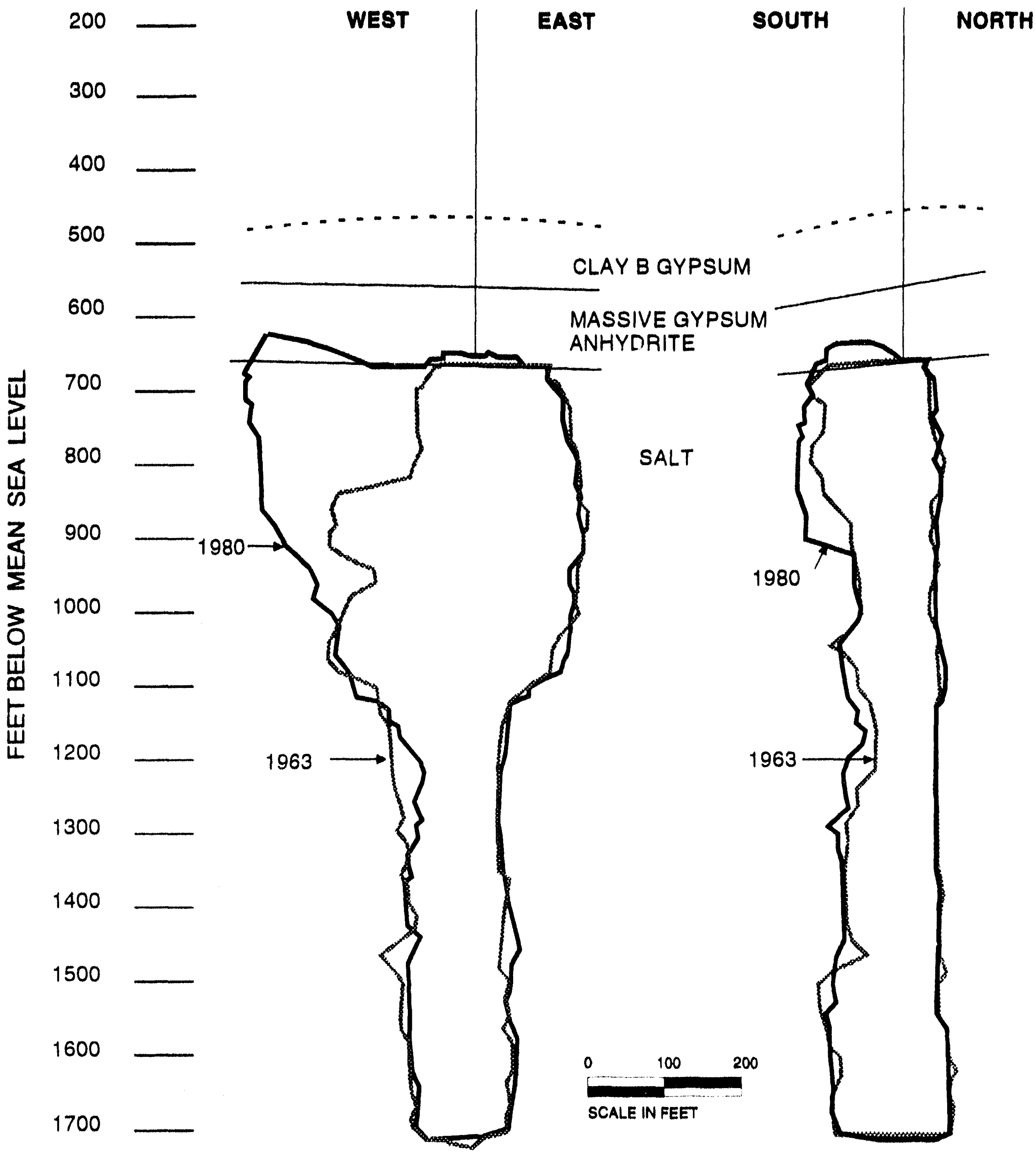
Even though there is little new information at Bayou Choctaw, there is increased understanding of anomalous zones in salt domes in general [Kupfer, 1980, 1990]. The 1980 report identified a major fault zone (F2), possibly active, that intersects the dome in the vicinity of Cavern 4. The revised caprock and salt maps (Figs. 5 and 6) clearly show the subsurface expression of this fault as it traverses the top of the dome. It is likely that this external fault is manifested within the salt mass as as a shear zone or anomalous zone, and may be a boundary between two discrete spines of salt. Such conditions could account for the pronounced west-extending wing that appears in the sonar profiles (Figs. 14, 15). Cavern 1, 800 ft west of Cavern 4 also has a westerly-extending wing paralleling the trend of the fault zone, possibly further substantiating the notion that an anomalous zone exists in that vicinity. The revised caprock map in this report shows this fault transects the entire dome and effectively passes directly through the cavern; also the fault azimuth is directly in line with the axis of elongation of the cavern. This correlation is apparently more than coincidence, and suggests that the enlargement potential of Cavern 4 could be influenced by the nature of materials along this fault.

To resolve some of these uncertainties, a re-sonar of Cavern 4 was conducted in August 1992 to determine what changes occurred in the caprock since 1980. The survey showed that no major change has occurred in the comparative appearance on sonar profile graphics, although there is some evidence of a roof fall about 150 ft west of the wellbore [Todd, 1992]. The overall 6% enlargement in volumetric calculations from 1980 may indicate some additional solutioning in the cavern, although much of the 6% can be attributed to the expected survey inaccuracy and allowable error. Another factor to consider is that cavern creep closure should have reduced the volume by about one percent over the 12-yr period between surveys. About one-third (150,000 bbl) of the reported 6% increase from 1980 is at or above the -600 ft level. Slezak [personal communication, 1992] cautions that the several surveys are not comparable in that different tools were used; the 1963 survey apparently employed only horizontal look angles, and the volume at the top of the cavern above -648 ft is not included in the reported cavern volume, even though the horizontal accuracy was more precise. Todd [1993, Appendix C] considered the evidence and concluded that there is no basis to believe that significant change occurred between 1980 and 1992.

Thus a degree of uncertainty remains, and shows that some caprock dissolutioning may have occurred during the preceeding 12 years. If change could be proved to have occurred, possible stabilization measures might be considered and mitigation instituted. But little additional action seems justifiable at this time in view of the facts as are known. The injection of grout into the remaining overlying caprock and overburden roof is one course of action that might be considered at a future date, but this may be impractical. The authors of this report believe a re-sonar of the cavern would be prudent in about three to five years, providing a rational basis for planning.

<u>**Cavern 15/17:**</u>

An exchange agreement between Allied Chemical (now UTP) and the Department of Energy was reached in November, 1982, wherein Allied's Cavern 17 was exchanged for DOE's newly leached Cavern 102. Originally, only Cavern 15 was purchased for SPR, but it was soon



Note: Dates refer to Sonar Surveys
Date Drilled: 1935
Elevation (Mean Gulf Level): + 7.4 Feet
Top of Caprock: 551 Feet
Top of Salt: 662 Feet
Original Total Depth: 1990 Feet
Cavern Top (1980): 620 Feet
Cavern Base (1980) : 1710 Feet
Cavern Volume (1980) : 5 .94 mm Barrels

FIGURE 14
PROFILES OF CAVERN 4
BAYOU CHOCTAW SPR SITE

THOMAS R. MAGORIAN

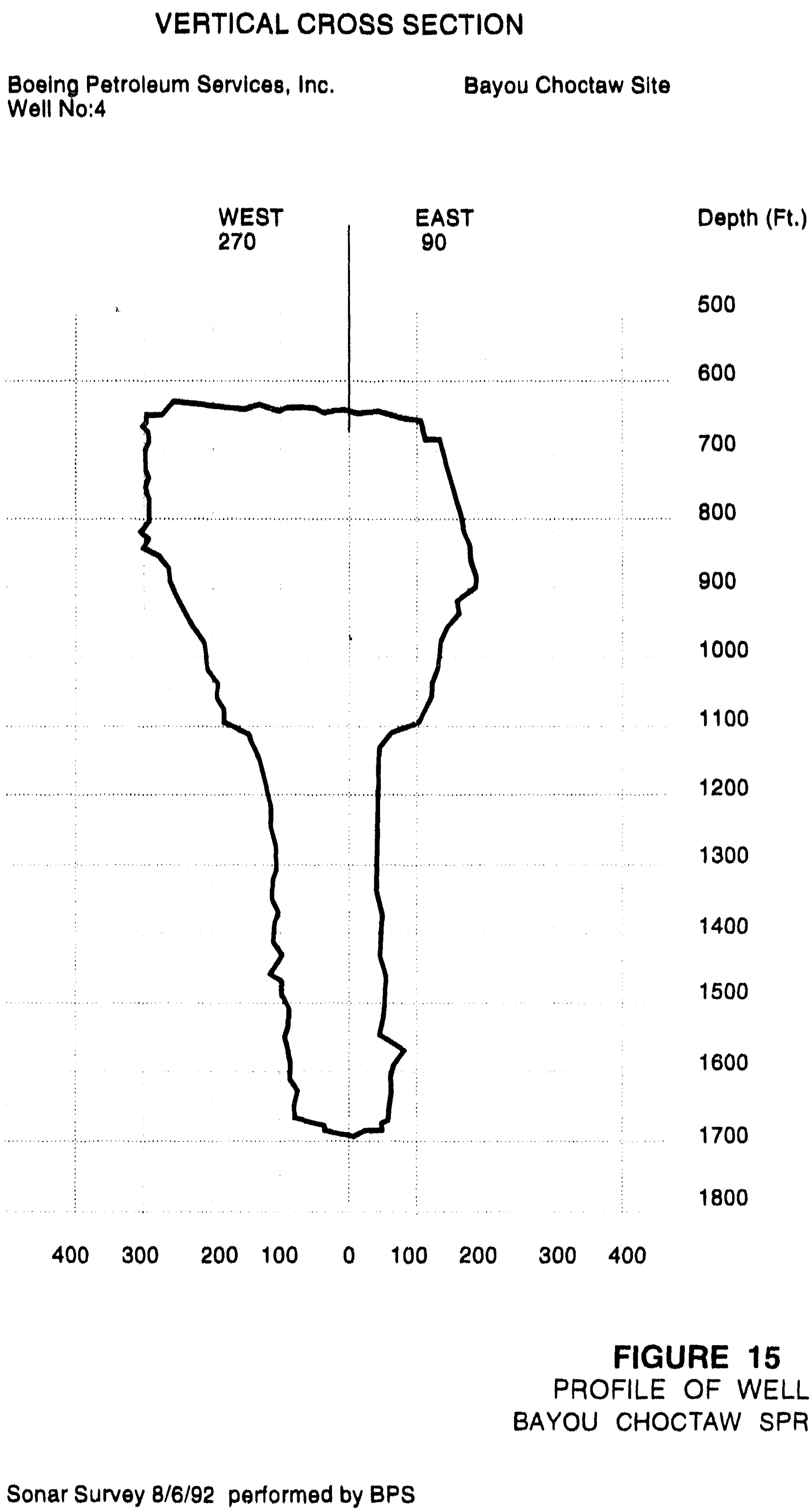


FIGURE 15
PROFILE OF WELL 4
BAYOU CHOCTAW SPR SITE

realized that differential pressures between Caverns 15 and 17 (containing ethane) could effect the stability of the already thin salt web separating the caverns.

These two caverns at closest approach are within about 110 ft of each other (Fig. 12). This is not anticipated to be a problem for SPR storage as additional drawdown and refill cycles may eventually coalesce these caverns. However, there is some uncertainty regarding the actual web thickness, and it does affect the manner in which the caverns are operated. Presently the two caverns are operated at near-equal pressures, but during integrity testing in 1985 [Goin and Buchanan, 1986] believed there was indication of possible pressure communication, as anomalous responses were observed during integrity testing when unequal pressure existed between the two caverns. This suggests that the web could be somewhat thinner than the ~100 ft that sonar profiles imply. Or possibly there is some fracturing or physical connection in the salt that is responsible for the anomalous pressure readings.

A 2-D plane strain analysis of the salt web between the caverns [Ney, 1979] showed that when Cavern 15 was depressurized while Cavern 17 had a wellhead pressure of 1250 psig, a tensile area occurred on the Cavern 15 side of the web. However, when the model assumed a 150 ft web thickness, no tensile area occured. Thus, based on this analysis, the present thickness would appear to be only marginally acceptable.

Ehgartner [1993] studied the question of web behavior, using more recent calculational methods which had been validated with underground data from the Waste Isolation Pilot Plant [Munson, et al., 1989]. Web stability was evaluated for the current, mature condition (~30 yrs), and after three successive 5-yr intervals of drawdowns and workovers. The simulation assumed an initial web thickness of 156 ft at 3000 ft depth, and considered representative conditions that are apt to occur in such an operating environment, even though hypothetical.

Ehgartner's results of web stability suggest a compressive failure mode rather than tensile failure as previously thought. At the end of the three drawdowns, web thickness had diminished to 56 ft and was predicted to breach. Workovers of Cavern 15 most affected web stability and decreased safety factors to one and below (a 30 to 40% reduction), whereas workovers of Cavern 17 only decreased safety factors by 3-5 %. These comparative values show that it is significantly more important to maintain pressures in Cavern 15 than in Cavern 17. The results also showed that drawdowns initially *improved* the minimum safety factor in the web by approximately 20% by leaching away the highly strained salt at the cavern walls. But the narrower web also crept faster than before the drawdown, so the benefit was temporary. For the simulated history, the minimum post-drawdown safety factors returned to the minimum pre-drawdown values after about 0.5 to 2.5 yrs. Ehgartner [1993] suggests that when failure of the salt in such metastable web situations is anticipated, leaching to remove the highly strained salt may be beneficial. For example, leaching could prevent a failed portion of the web from damaging a hanging string as it falls, but at the expense of a shortened web life.

A re-sonar of these caverns might clarify some of the geometric uncertainties that affect calculations, but would need to be accomplished during a drawdown cycle, or else when sonar-in-oil techniques become routinely possible and credible. Routine integrity testing was completed in

1993. At this time no other actions are indicated in changing operating procedures for these two caverns.

Cavern 19:

A lowering of the concrete pad surrounding the wellhead sumps was noted around both cavern wells in 1988. By 1990-91 the separation between the pad and the sumps had increased to as much as five inches, but apparently stabilized and had not progressed any further as of December 1992. Because somewhat larger than average (for the site) subsidence values had been noted previously around Cavern 19 [Goin and Neal, 1988], concern was commensurately greater. However, the measured rate of decrease in subsidence at these wellheads has not changed at all, so this condition seems to involve only the pad. It seems probable that this pad lowering may be related entirely to underlying soil compaction, possibly combined with decaying organic materials. Continuing surveillance of this condition is ongoing, and no further action is required at this time. There is no indication that this condition is related to the cavern below.

Cavern 20:

Cavern 20 was leached very close to the edge of the dome, approaching within approximately 135 ft, according to sonar and well records [1980 characterization report and BPS Cavern Data Base]. Mills (1993) noted that directional deviation surveys in Cavern Well 20A showed a drift of 90 ft eastward and 70 ft northward at a depth of 3826 ft (the point near the cavern roof from which the sonar tool was suspended). This indicates that the earlier sonar profiles plotted from the surface showing maximum cavern extent may have effectively decreased the true web thickness from the western dome edge by 90 ft; thus the revised thickness is about 225±50 ft. This web thickness is critical because either value (135 or 225 ft) effectively limits the cavern to one drawdown cycle, unless only the upper reaches of the cavern above 4,000 ft are cycled. However, any additional safety factor is beneficial. Existing sonar records are probably sufficiently accurate to map the cavern interior dimensions, but, the external dome geometry and salt quality might be mapped better with modern seismic profiling techniques. Results of such surveys could improve the understanding of operational limitations.

A profile section through Cavern 20 (Figure 16) shows its relation to the overhang; it is the closest cavern to the edge of the salt, with the possible exception of UTP Cavern 26. All of the oil wells drilled along this portion of the overhung west flank of the dome are shown projected into the line of the section: Carter (now Exxon) 16 and Freeport 21 and 25. At the maximum extent of the cavern, just below 4000 ft depth, the edge of the salt is 100 ft farther east than originally believed, plus or minus 50 ft, the inherent accuracy of the well deviation surveys (25 ft in each well). The projection shows a scatter of less than 50 feet. The smooth shape of the overhang is apparent with its westernmost extent near 2500 ft depth.

The 1980 report also showed faults on the dome periphery that could affect the salt quality and cavern integrity within the web. This updating of the 1980 report has reexamined the issue of faulting on the west flank; Figure 9 (Cross-section #3) shows that the previous interpretation of faulting is unnecessary, and any that does occur is probably minor.

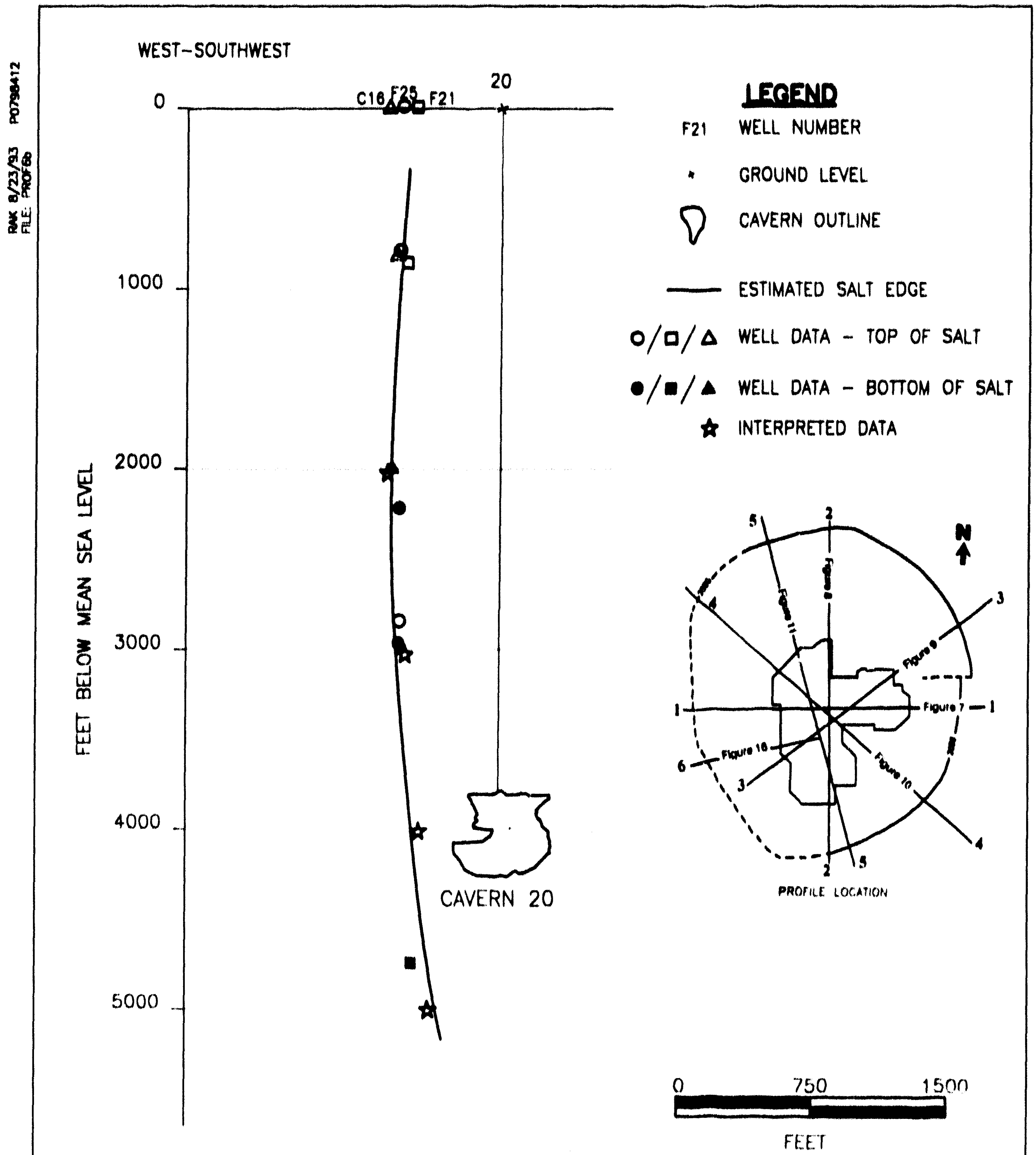


FIGURE 16

PROFILE THROUGH CAVERN 20

BAYOU CHOCTAW SPR SITE

THOMAS R. MAGORIAN, 1993

ACRES

An unexpected pressure drop of 30 psi was noted on 7 Jun 92 and was similar to a prior drop in 1986. The most plausible explanation for this is a sudden release of gas, similar to gas outbursts in domal salt mines [Thoms and Martinez, 1978]. No other scenarios have been able to account for these anomalous occurrences.

Some fresh-water leaching occurred in 1992 and this was projected to have leached some 5-6 feet of the web [Linn, 1992], in some lower portions the amount would likely be greater. March 1993 sonar surveying of the bottom portion of the cavern below 4150 ft show that new volume was created and some insolubles accumulated at the bottom but the maximum extension at about 4150 ft was not increased. This geometry is highly significant at this particular location and for this cavern, as the minimum distance to the edge should not be lessened.

Cavern 20 showed excessive gas content had accumulated within the oil in 1993. Its location at the edge of the dome may influence this since this flank of the dome produces gas from sands against the salt, and which also leaks into water wells. The cause of the gas in Cavern 20 is speculative, but the exterior location astride an anomalous zone may be conducive to gas penetration.

Gas in Oil

In early 1993 it was learned that a number of caverns within the SPR system had excessive amounts of gaseous hydrocarbons dissolved in the oil. The oil would require degassing prior to refining in many cases, and because the processing rate may be less than drawdown rate criteria, cycling of oil and concomitant degassing is anticipated in order to maintain readiness [Oil and Gas Journal, 1993].

In a number of instances the gas content had increased, leading to the conclusion that the source could be from within the salt. Gas in salt has long been a problem in conventional mining, leading to several fatal accidents following outbursts of gas and associated saltfalls [Molinda, 1988]. At Bayou Choctaw, Caverns 18 and 20 showed higher than allowable gas content in March and May, 1993, and were identified as requiring treatment prior to drawdown. A possible correlation of gassy caverns and the N 75° E trending shear zone shown on Figure 6 exists, similar to that occurring at Bryan Mound [Thoms, 1993]. This correlation is similar to that noted by Iannacchione et al. [1984] in his study of gas associated with salt outbursts in conventional mining. This correlation suggests that gas is able to migrate through these anomalous zones and into the adjacent salt at a faster rate than in normal salt. At Bayou Choctaw Caverns 18 and 20 are evidently in the salt adjacent to the anomalous zone. As noted earlier, Cavern 20 is also located near the edge of the salt and adjacent to gas-producing sands. The rate of increase in gas content in these two caverns is unknown but will be monitored in the future.

Subsidence

Subsidence is of special interest at Bayou Choctaw because of the large number (25) of active and abandoned caverns with substantial total volume (~160 MMB), the generally low site elevation (under 10 ft m.s.l.) with associated potential for flooding, and the uncertain (although remote) possibility for collapse of Cavern 4, similar to the Cavern 7 incident of 1954.

Independent of SPR or other sources of local subsidence, regional subsidence is occurring throughout coastal Louisiana, resulting in some 2 to 17 mm (0.007 - 0.054 ft) of lowering each year. Several sources contribute to this and have been discussed by Penland et al., (1989). In the Baton Rouge area, including the Bayou Choctaw site, the regional subsidence is at the very low end of the scale, being in the 1-2 mm/yr range [Penland et al., 1989, Holdahl and Morrison, 1974]. Thus the location further inland at Bayou Choctaw is quite different than all of the other SPR sites, which are nearer the coast and subject to greater sediment compaction and associated subsidence. The regional subsidence value at Bayou Choctaw is not only very small, it is very difficult to measure because of survey accuracy and monument stability problems.

The other source of subsidence at Bayou Choctaw which may be involved is that caused by hydrocarbon extraction. The amount of production to date is some 30,000,000 BBL, not a large amount as compared with many other domes. Presumably this would have little effect directly over the dome, as the production has been around the periphery.

The Baton Rouge fault is considered by many to be active, and while it may be moving in geological time, there is no documented evidence of vertical motion in historical time. Nonetheless, in the Baton Rouge area, there is abundant geological evidence of its presence. Some of the radial faults around the Choctaw dome are considered by Magorian [1980] to be subsidiary to the Baton Rouge fault and are also potentially active. As a result, these may influence the local subsidence environment, but given the inconclusive data set, such effects can not be seen at this time. Other local subsidence effects may have been induced previously from injection wells disposing fluids into the caprock, this was thought to have caused shifting in the caprock and associated casing failures. Upon cessation of the injection, these problems stopped (Slezak, personal communication, 1988).

Subsidence measurements commenced in 1982 and have been repeated about yearly, initially at some 60 stations, but the number has declined as monuments have been damaged or destroyed. The data reveal that there are problems in interpreting trends; reason suggests that some changes are obviously anomalous and inconsistent, and therefore must be looked at with skepticism. Based on experience at other SPR sites and storage operations at other domes, there should be an observable and steadily downward trend. That is because of steady-state cavern creep closure which is universally present in all underground caverns in salt [Neal, 1991], and seen in laboratory tests and modelling experiments. Some explanations for data inconsistencies have been advanced, but only a few stations have provided steady-state trends and even these data may be suspect. A summary of 16 of the less ambiguous survey stations that provide beginning and ending values is shown on Table 4.

TABLE 4 ELEVATION CHANGE AT SELECTED SUBSIDENCE STATIONS: 1982-93

#	Location	Elevation, Feet 12/82*	01/93+	Change	Rate/Yr
1B	SE Corner, intake structure	10.30	10.302	(0.002)	------
2B	SE corner, heliport	8.62	8.56	0.06	0.0060
4C	SE corner, mini leaching pumps	8.03	7.936	0.094	0.0093
6A	NW corner, security building	10.78	10.582	0.198	0.0196
7B	East end, filter pumps	8.86	8.751	0.109	0.0108
9	East edge of well pad 15	11.12	11.033	0.087	0.0086
10B	NW corner of brine pond	14.64	14.378	0.262	0.0260
11A	SW corner, maintenance bldg.	9.06	8.915	0.145	0.0144
12D	SE corner, control room bldg.	9.08	8.934	0.146	0.0145
13B	North edge of brine tanks	9.21	8.863	0.347	0.0344
15B	East edge of pump base	10.72	10.272	0.448	0.0444
22B	SW corner of pump base	10.77	10.318	0.452	0.0448
31A	NE corner, well pad 19	12.26	11.526	0.734	0.0728
32	NE corner, well pad 19	12.30	11.737	0.563	0.0558
BC18	"L" flange, cavern 18	13.81	13.472	0.338	0.0335
SMS6	Subsidence monument	5.17	4.550	0.620	0.0615

* Benchmark US C&GS Z-208 on Bayou Plaquemine RR bridge abutment

+ Benchmark DOE No.35, assumed stable elevation @13.183 ft (1988- 1993), with initial reference to Z-208 above [BPS, 1993]

The 60 DOE subsidence monuments at Bayou Choctaw are subsiding an average of about 0.03 ft/yr (9 mm/yr) over a 121-month monitoring period, if 11 questionable survey values are excluded. This rejection of values is arguable in that some of the survey values may be correct (many of these are plugged and abandoned wellheads); however, they appear sufficiently spurious with respect to the rest of the site that their inclusion would distort the averages. Including all values yields an average of some 0.050 ft/yr (15.0 mm/yr), a departure from the adjusted value, but still overall low subsidence. Even with the larger average, the difference would be only 0.2 ft in ten years. McHenry [personal communication, 1992] believes that site averages here have little meaning, because of the very small values and the accuracy error of the survey (Second Order, First Class standards would allow data scatter of 0.10 ft). However, they do provide a comparison between sites, and show trends that may be correlative with other data.

The average subsidence rate is less than any other SPR site except Bryan Mound (very nearly the same). The only laboratory creep data from Choctaw showed rates nearly as low as the data for Bryan Mound, the lowest of any SPR site [Wawersik and Zeuch, 1984]. This is a possible clue to explain the low amount of observable subsidence. This average rate is consistent with the values that Hoffman et al. calculated for a group array of 19 caverns [Hoffman and Ehgartner, 1993]. The 1971 subsidence values were reported by Allied Chemical to range between 0.01 and 0.02 ft/yr, at a time when the total cavern volume was about 100 MMB, substantially less than the 1992 estimate of about 160 MMB. Thus, the previously measured values are consistent both with currently measured amounts, and with numerical calculations.

Nonetheless, the subsidence values measured near Cavern 19 (already surrounded by perennially flooded swamp), are sufficiently high to possibly require long-term mitigation in the form of enhanced diking or localized infilling. At a rate approaching 0.10 ft/yr, the total subsidence in 30 yrs would approach 3.0 ft. With increased subsidence anticipated from the adjacent UTP Cavern 24 (now containing variable pressure and more compressible natural gas), the combined cavern effects in the adjacent swampland may become more widespread.

Cavern 101 is among the deepest in the SPR system, with the bottom at -4824 ft. At such depths, creep closure is predictably greater; consequently, subsidence should be expected to be more in the future around this cavern than at other more shallow caverns [Hoffman, 1992]. The leaching of this cavern was not completed until 1990; as a result very little monitoring data is available. However, measurements between October 1988 and January 1993 show no subsidence, which is difficult to reconcile, because of the theoretical higher rate that should occur at this cavern. Longer-term measurements are needed to establish valid trends, both at this and other caverns.

January 1993 survey results were examined and showed virtually no change from that acquired in 1988, suggesting there may be difficulties with the datum being used. The datum (DOE 35) elevation used in the 1993 survey was tied to the monument located on the Bayou Plaquemine Railroad trestle when it was first used in October 1988 and subsequent elevations were assumed to be stable. The apparent explanation of the very questionable subsidence history at Bayou Choctaw is that the datum elevation(s) is not accurate. It is reasonable to assume that the 1993 survey is accurate, because of the good data consistency; the results can be adjusted at a future date when the datum is accurately determined and compared with updated First Order Geodetic standards.

The relatively small salt mass and steeper sides of the salt stock at Bayou Choctaw (as compared with West Hackberry, for example) may lead to less creep and consequently less vertical subsidence over the top of the dome. A 3-D finite element analysis of an array of seven typical SPR caverns showed that subsidence decreases more than 30% when the diameter is reduced from 1 mile to 1/2 mile in the model [Hoffman, 1993]. The details of the seven cavern model in an infinitely large dome are documented in another study [Hoffman and Ehgartner, 1993] that examined the effects of the number of caverns in a field on subsidence. This same phenomenology may occur at Bryan Mound where salt volume relative to cavern void space is similar to Bayou Choctaw, but the average subsidence is also very low as compared with other domes. The paradox at Bryan Mound is that it has largest cavern volume (~250 MMB) and also the lowest subsidence of all the SPR sites.

Flooding

Periodic and temporary flooding is a fact of life in Iberville Parish, resulting from severe rainstorms, hurricanes, and floodwater backup from the Atchafalaya basin. Overbank flooding from the Mississippi River has not been a problem since 1927 when record floods forced subsequent construction of levees, along with the diversion control measures into the Atchafalaya basin. With major diversion from the Mississippi, the Atchafalaya can backup canal levels to nearly 10 ft NGVD (National Geodetic Vertical Datum), higher than many surface elevations on the site. The top of the brine pond embankment is right at 14 ft, the highest site elevation, so virtually everything else is under water during extreme flooding events (see Frontispiece).

The humid subtropical climate in Iberville Parish produces an average 59 inches of precipitation annually, which is usually evenly distributed throughout the year, but heavy rains of 1.5 to 4.0 inches can be expected every year and often more than once each year. A rainfall of at least 6.4 inches in a 48-hour period is expected to occur an average of once in two years; 8.0 inches once in 5 years; and 11.5 inches, once in 25 years. The heaviest rains are often associated with tropical storms and hurricanes; Hurricane Hilda in 1964 caused headwater overflows in the swamp and marshland areas within an elevation range of 5 to 10 ft NGVD, flooding nearly 29 percent of the Parish. Hurricane Carla in 196l, even though centered several hundred miles west, flooded seven percent of the Parish, with local rains of nearly 8 inches in Baton Rouge over a five day period. These statistics serve to expain why flooding is a recurrent theme at this SPR site.

The baseline 100 year flood height is 8.1 ft NGVD; the entire dome and area surrounding it are in this zone on the flood insurance rate maps for Iberville Parish, published by the U. S. Department of Housing and Urban Development [U.S. HUD, 1977]. Because of the environmental reasons enumerated above, water levels sufficient to produce temporary flooding can be expected frequently at the site.

Speculation on increased hurricane frequency was rampant following the summer 1992 occurrence of three major hurricanes affecting the United States and its territories in 19 days. There is lack of agreement on cyclical trends, but there is general agreement that warmer oceans will increase severity of tropical storms, and probably the frequency [Emanuel, 1988]. Thus, understanding of greenhouse warming trends, if it exists, has implications on tropical storm generation, and consequent flooding effects.

Seismicity

In the thirteen years since the previous characterization, a small earthquake of Modified Mercalli Intensity V (MM V) occurred in October 1983 near Lake Charles, about 17 mi north of the West Hackberry facility. The temblor was not felt at all at the SPR site and produced only minor effects at the epicenter, such as cracked plaster and broken dishes [Magorian et al., 1991].

Events such as the Lake Charles earthquake and even stronger (up to MM ~VI) can occur anywhere along the Gulf Coast, according to most geophysicists. Most likely these events originate in deep basement faults, or in combination with more shallow growth faults. Such a mechanism was postulated for the 19 Oct 30 Donaldsonville earthquake (MM VI-VII), 40 mi southeast of the Bayou Choctaw site. The 1980 report concluded that an event of this magnitude would not produce any significant damage to surface or underground structures even at the epicenter; the Lake Charles event near West Hackberry supports this prediction for Bayou Choctaw, even though the latter event was slightly smaller.

A further evaluation of the ground motion effects at Bayou Choctaw from a New Madrid (1811-12) event with Richter Magnitude 8+ concluded there would be less peak horizontal acceleration than from a repeat Donaldsonville event at the epicenter. The latest earthquake maps for the United States show that for Bayou Choctaw, with a 90% probability of non-exceedance in 250 yrs, the mean horizontal acceleration in rock is 0.03 G [Algermissen, et al.] Thus seismicity is not a factor of geotechnical risk at Bayou Choctaw.

Environmental Considerations

Bayou Choctaw is the only SPR site located in an alluvial environment, at the edge of the Mississippi River levee and the Atchafalaya backswamp, rendering it vulnerable to flooding from those sources. Flooding considerations were discussed in an earlier section.

The extensive diversions and control structures added elsewhere to protect populated areas have made water levels at the site particularly uncertain. The original cypress backswamp was clearcut long before SPR, so that today the environmental classification of this wetland/industrial area is naturally confusing.

Natural gas seeps occur along the dome edges, as at many other domes, but to date no adverse effects on any of the caverns have been observed, such as gas leaking into the caverns. As discussed earlier, Caverns 17 and 20 have higher than desired gas contents, but this does not appear to be related to these gas seeps. The possibility of either natural or stored product gas communicating through caprock voids has been expressed, but this has not been detected anywhere.

Expansion Possibilities

Bayou Choctaw has distinct location advantages near distribution points; consequently the question of additional cavern space has arisen periodically. A cursory glance at the salt map (Figure 6) shows that nearly all of the space has been used, so at this point the siting of more caverns may be analogous to "shoehorning." Further, the placement of additional caverns puts them ever closer to the dome edge, which experience shows to be at greater risk than interior locations. This is because salt conditions at the dome edge deteriorate rapidly at the contact with the exterior sediments. Problem caverns at other domes have often been situated at boundary conditions near dome edges, or near contacts with anomalous zones [Neal, et al., 1993]. In event that any additional cavern development were pursued, it would be necessary to institute highly controlled leach procedures, with more-than-normal monitoring.

Notwithstanding the above disadvantages, the possible locations A and D marked on Figure 1 were identified in the 1980 report for possible SPR expansion. However, they could only be considered viable options after essential exploration is accomplished to verify the precise geometry and salt web thickness between the caverns and the edge of dome. The location (D) north of abandoned Cavern 13 (Figure 11, Section 5) was considered potentially suitable for a

10 million barrel cavern, and that judgment has not changed. The buffer distance between this potential cavern and the dome edge would be approximately 500 ft. It was noted in the 1980 report that this area of the dome has experienced extensive pressure leakage of caverns, as shown by the relatively large number (9) that have been abandoned or collapsed (Cavern 7). This possibly is related to faulting in the caprock which affected well casings, but it may also be due to the rather shallow depth of these caverns and minimal salt roof thicknesses. Because of these reasons and others stated earlier, this location along the dome periphery would need to receive more complete geotechnical evaluation than usual, with special attention given to salt quality, etc. Also, collapsed Cavern 7 and Cavern Lake are less than 1000 ft away, but the effects from them would be limited to depths above 1500 ft. There should be minimal influence on deeper caverns with tops at 2000 ft and more.

Locations B and C, which had been identified in the 1980 report, were subsequently developed as Caverns 101 and 102, respectively. The former was moved outboard slightly, to stay away from the zone of influence around Cavern 4, in event it experienced failure similar to Cavern 7.

A potential location on an azimuth of 115° ESE of Cavern 19 would initially be some 400 ft from the dome edge, and about the same distance from both SPR Cavern 19 and UTP Cavern 25. These distances are less than the SPR Phase III criteria; therefore this location is marginally unacceptable for SPR use. However, this limitation may not apply to other applications involving smaller diameter caverns, etc. Another approach to gain additional storage volume in this portion of the dome would be to simply enlarge Cavern 19; the current volume is about 12.2 million barrels, and this could probably be enlarged by 50%.

The location west and south of Cavern 19 had similarly been discussed in the 1980 report (location A) as being potentially suitable, but the same limitations apply to it as the location discussed above. The 1980 report concluded that this location is marginal for cavern development. A vertical seismic profile could validate this location.

There is a small but unlikely possibility that an additional cavern could be constructed immediately west and below abandoned Cavern 10. The principal uncertainty is in the shape of the salt overhang here and a VSP survey would be needed to determine the geometry and thickness of the buffer between the dome edge and cavern. Such practices amount to "shoehorning" and should only be attempted when other storage is not available. An exterior cavern location here would have pitfalls similar to those noted above. There is much uncertainty in the west overhang and our dome mapping suggests this location would be unsuccessful.

Mills (1993) points out that Cavern 20 could be enlarged above its present configuration, as the depth now ranges from 3830 to 4246 ft (Fig. 9). This option would create a cylindrical space above the current storage, possibly to a depth of ~2500 ft, which would be about 6 million barrels of new space. This location at the edge of the salt stock has inherent limitations as noted previously. This cavern was also noted in 1993 to have absorbed more gas into the oil than allowable, and degassing measures were being planned. Cavern 20 in its current configuration is already closer to the edge of salt than desirable, and effectively limits oil drawdowns to one or two cycles. While this option is physically possible, the potential difficulties would seem to outweigh any advantages.

Another possibility suggested by Mills (1993) would place a new cavern between and below abandoned Caverns 2 and 3. To maintain adequate separation from Caverns 15 and 102, this location would have to be very close to Cavern 3, possibly compromising recommended standoff distances. Section 2 (Fig. 8) shows this concept is possible and suggests it may be worth further consideration if more storage space is needed. Nonetheless, it would be a very tight fit, as with all the other locations discussed above.

Assuming location D is suitable and Cavern 19 were enlarged slightly, the existing SPR capacity conceivably could be expanded by about 15 million barrels. Other options are less promising and would require more study.

4 SUMMARY OF SIGNIFICANT FEATURES AFFECTING SPR

The Bayou Choctaw salt mass appears to be comprised of at least two lobes that are separated by a major fault transecting the entire dome and which joins the regional fault system. This fault displaces the caprock to some extent and has apparently influenced several solution caverns, most noticeably in elongating Caverns 4 and 1 (abandoned). It does not seem to have affected the integrity of any operational caverns, but may have contributed to earlier unstable caprock. Smaller radial faults related to the piercement process in the rising salt mass have been omitted from the new maps for reasons of simplification; further, they have no bearing on integrity and safety of the storage operations.

Subsidence over the 160 million-barrel (total) cavern field is lowering the surface less than an inch per year, a rate lower than other SPR sites except Bryan Mound, but the 10-foot surface elevation requires continuing surveillance for flood protection. As this dome is near capacity, the rate of subsidence is not apt to increase much, unless volume is expanded as a result of drawdown of SPR oil, etc.

There is room for only a few more caverns on this dome, and several existing ones could be enlarged slightly. At this time, SPR had no plans for enlargement of their storage volume, and Union Texas Petroleum was considering one additional cavern. The co-use of this dome for storage of crude oil and hydrocarbon products has continued safely for nearly fifteen years, in large part because good communication exists between operators.

Cavern 4 has similar features to collapsed Cavern 7, and concern was expressed earlier that continuing erosion of the caprock could lead to failure, resulting in another collapse crater and lake around the cavern. A reexamination of the cavern dimensions in an August 1992 sonar profile showed virtually no change since 1980 and provides confidence in the continuing stability. Reevaluation of this cavern environment is recommended every five years.

Cavern 20 has the thinnest salt web between the cavern and the outside of the dome of any SPR cavern and is limited to a single raw water drawdown. Special procedures can extend the operational life of this cavern if only the upper reaches of the cavern are used, or if saturated brine is used in displacing the oil. The latter option is not available for offsite drawdown at this time because of limited brine pond capacity, but a dedicated brine cavern could be a possibility for product cycling. Other alternatives could also be developed, using other caverns in combination.

Cavern 15 and 17 are adjacent and separated by a web which may be a small as 100 fect at closest approach. The caverns are now operated at essentially equal pressure, as earlier integrity testing showed that pressure communication may have occurred. In the event of drawdown and additional leaching, the caverns will eventually coalesce and become one very large cavern. The thin web does not present any special operating difficulty when operating as an effective gallery. The larger-diameter Cavern 15 was predicted to dominate the stability of the web when the caverns are operated at a differential pressure. When operating under a differential pressure, it is more important to maintain pressure in Cavern 15 than it is in Cavern 17.

Eleven injection wells are used for brine disposal, but are limited to about 100,000 barrels per day total. This is substantially less than desired and one third the predicted capacity. Operating problems have led to very sluggish yields and have required very expensive cartridge filtering. The wells could be recompleted in the Lafayette gravels without screens and should achieve much higher injectivity values.

Temporary flooding is a fact of life in Iberville Parish, owing to normal cylclonic storms and periodic severe thunderstorms. Continuing subsidence may exacerbate already unfavorable conditions in low-lying areas; diking and road heightening is the only recourse.

5 ACKNOWLEDGMENTS

We are grateful to Bob Haley, Union Texas Petroleum, who was generous in sharing his time and information on Bayou Choctaw. We also thank Ken Mills and Matt Slezak of DynMcDermott Petroleum Operations Company, for reviewing the report and especially for sharing their ideas about the site. Brian Ehgartner and Jim Todd provided peer review and their helpful suggestions are appreciated.

6 REFERENCES

Algermissen, S. T., D. M. Perkins, P. C. Thenhaus, S. L. Hanson, and B. L. Bender (1990) Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico. U. S. Geol. Surv. Map MF-2120.

BPS (1992, 1993) Annual Subsidence Report, SPR, Fiscal Year 1992. Pub. No. D506-03165-09, Oct. 1992, Boeing Petroleum Services, New Orleans. 1993 data from Bayou Choctaw obtained from J. McHenry and discussed informally.

Ehgartner, B. L. (1993) Bayou Choctaw Caverns 15 and 17 Web Analysis. Sandia National Laboratories Report SAND92-2890, ALbuquerque, NM. 1992.

Ehgartner, B. L. (1993) Personal Commumication, Sandia National Laboratories, Department 6113, Albuquerque, NM.

Goin, K. L. and D. K. Buchanan (1986) Letter to DOE SPR PMO from Sandia National Laboratories dtd 20 Feb 86, Subject: Documentation of Results of Brine Pressure Test of Bayou Choctaw Cavern 17.

Goin, K. L. and J. T. Neal (1988) Analysis of Surface Subsidence of the Strategic Petroleum Reserve Crude Oil Storage Sites From December 1982 to January 1988. Sandia Nat'l Labs. Report SAND88-1309, Albuquerque, NM.

Heffelfinger, G. S. (1991) Creep Closure of Salt Caverns in the U.S.DOE Strategic Petroleum Reserve. Sandia Nat'l. Labs. Report SAND90-2614. Albuquerque, NM.

Hoffman, E. L. (1992) Effects of Cavern Depth on Surface Subsidence and Storage Loss of Oil-Filled Caverns. Sandia Nat'l. Labs. Report SAND92-0053, Albuquerque, NM.

Hoffman, E. L. and B. L. Ehgartner (1993) Effect of the Number of Caverns on Storage Loss and Subsidence of Oil Filled Caverns. U. S. National Rock Mechanics Symposium, Madison, WI, June 1993.

Hoffman, E. L. (1993) Personal communication: results of preliminary calculations. Sandia Nat'l. Labs., Albuquerque, Dept. 1561.

Hogan, R. G. et al. (1980) Strategic Petroleum Reserve (SPR), Geologic Site Characterization Report, Bayou Choctaw Salt Dome. Sandia National Laboratories Rept. SAND80-7140.

Holdahl, S. R., and N. R. Morrison (1974) Regional Investigations of Vertical Crustal Movements in the U. S. Using Precise Relevelings and Mareograph Data. in Recent Crustal Movements and Associated Seismic and Volcanic Activity: Tectonophysics, Vol. 23, P. 373-90.

Iannacchione, A. T. et al. (1984) Assessment of Methane Hazards in an Anomalous Zone of a Gulf Coast Salt Dome. U. S. Bur. Mines Report of Investigations No. RI-8861.

Kupfer, D. H. (1980) Problems Associated with Anomalous Zones in Louisiana Salt Stocks, USA. 5th Intl. Sympos. on Salt, Hamburg, Germany, 1978; N. Ohio Geol. Soc., Cleveland; V. 1, p. 119-134.

Kupfer, D. H. (1990) Anomalous Features in the Five Islands Salt Stocks, Louisiana. Trans. Gulf Coast Assoc. of Geol. Societies, V. 40, p. 425-436.

Linn, J. K. (1992) Analysis of BC-20 Pressure Drop on 7 June 1992. Sandia National Laboratories Memo to DOE, New Orleans SPR Proj. Mgt. Office, 15 June 92.

Magorian, T. R. et al. (1991) Strategic Petroleum Reserve (SPR), Additional Geologic Site Characterization Studies, West Hackberry Salt Dome, Louisiana. SAND90-0224; Sandia Nat'l. Labs., Albuquerque, NM.

Mills, K. E. (1993) DynMcDermott Petroleum Operations Company, New Orleans, LA; Personal communication.

Molinda, G. M. (1988) Investigation of Methane Occurrence and Outbursts in the Cote Blanche Domal Salt Mine, Louisiana. U. S. Bur. Mines Report of Invest. RI-9186, Pittsburgh.

Munson, D. E., A. F. Fossum, and P. E. Senseny (1989) Approach to First Principles Model Prediction of Measures WIPP in Situ Room Closure in Salt. SAND88-2535; Sandia Nat'l. Labs.; Albuquerque, NM.

Neal, J. T. (1991) Prediction of Subsidence Resulting from Creep Closure of Solution-Mined Caverns in Salt Domes. Proc. 4th Int'l. Symp. on Land Subsidence. Int'l. Assoc. Sci. Hydrology, IAHS Pub. no. 200,.p. 225-234.

Neal, J. T., T. R. Magorian, R. L. Thoms, W. J. Autin, and R. P. McCulloh (1993) Anomalous Zones in Gulf Coast Salt Domes with Special Reference to Big Hill, TX, and Weeks Island, LA. Sandia Nat'l Labs. Report SAND92-2283, Albuquerque, NM.

Nye, J. F. (1979) Memo from Sandia National Laboraties to R. W. Mazurkiewicz, DOE APR PMO, 27 Nov 79, Subject: Cavern 15-17 Depressurization.

Oil and Gas Journal (1993) DOE to Degassify 200 Million Barrels of SPR Crude. 3 May 93, p. 130.

PB-KBB, Inc. (1978) Salt Dome Geology and Cavern Stability Analysis, Bayou Choctaw, Louisiana. Prepared for US Dept. of Energy, Strategic Petroleum Reserve, New Orleans.

PB-KBB, Inc. (1989) Long Term Requirements for Brine Disposal; Bayou Choctaw SPR, Iberville Parish, Louisiana. Prepared for Boeing Petroleum Services, New Orleans.

PB-KBB, Inc. (1991) Rock Mechanics Analysis, Bayou Choctaw Salt Dome, Iberville Parish, LA. Unpublished report prepared for Union Texas Petroleum by PB-KBB, Houston, TX.

Penland, Shea et al. (1989) Relative Sea Level Rise and Subsidence in Louisiana and the Gulf of Mexico. Coastal Geology Technical Report No. 3, Louisiana Geological Survey, Baton Rouge.

PGA and Associates (1978) Commercially available microgravity survey.

Slezak, M. (1988-1992) Personal Communication, Boeing Petroleum Services, Bayou Choctaw, LA.

Thoms, R. L. and J. D. Martinez (1978) Blowouts in Domal Salt. 5th Symp. on Salt, Hamburg, Germany. N. Ohio Geol. Soc., Inc., Cleveland.

Thoms, R. L. (1993) Effects of Anomalous Features (AFs) on Solution Mining of Storage Caverns in Domal Salt; p. 41-53 in Neal et al., op. cit.

Todd, J. L. and K. H. Smith (1984) Collapse Warning System for Bayou Choctaw Cavern 4. Sandia Nat'l. Labs Report SAND88-1510; Albuq., NM.

Todd, J. L. (1992) Internal memorandum dated 11 Aug 92, Sandia Nat'l. Labs. Dept. 6113, Albuquerque, NM.

U. S. Department of Housing and Urban Development (1977) Flood Insurance Study, Iberville Parish Louisiana (Unincorporated Areas). (1988) Flood Insurance Rate Map, Community Panel Number 220083 0004 B, effective 1 June 1978.

Wawersik, W. R. and D. H. Zeuch (1984) Creep and Creep Modeling of Three Domal Salts -- A Comprehensive Update. Sandia National Laboratories Report SAND84-0568. Albuquerque, N.M.

APPENDIX

APPENDICES

APPENDIX A

APPENDIX A

Bayou Choctaw Regional Geologic History

Introduction

This overview is intended for those readers desiring general information, and for those with limited background in the geosciences. It is not detailed and is uneven in presentation by design. The reader who desires more complete information should refer to the original characterization report [Ref. 1, main report], or to more recent general references on Gulf Coast geology and tectonics [Ref. A-1].

Paleozoic Era (570-245 my)

Pangaea ("all lands"), the single protocontinent that drifted together at the end of the Paleozoic, resulted in a huge mountain mass, probably somewhat like the Himalayas today. It lay to the north (relative to today), including the center of north America, and is thought to have been glaciated periodically, tying up much ocean water in icefields. No rocks of Paleozoic age are expected to underlie the site.

Mesozoic Era (245-66 my)

The weight of this crustal mass (or possibly a huge astrobleme collision) melted the underlying mantle so that it broke apart, forming volcanic rifts and creating new ocean floor, similar to the African rift valleys and Red Sea today. The Gulf Coast Geosyncline was one of a string of rift basins created by the opening of the Atlantic in the breakup of Pangaea. This drifting apart of the present continents occurs at a more or less steady rate, as it has since the end of the Paleozoic.

Triassic Period: The initial deposits underlying the salt are oceanic basalts and red beds of Triassic age, called Eagle Mills in the Gulf Coast (Newark Series where better exposed on the East Coast). These deposits may extend out onto the new oceanic crust underlying the site.

Jurassic Period: The overlying redbeds of early Jurassic age are called Norphlet in the Gulf Coast. The original depositional basin of the Jurassic Louann salt and evaporites was one of the string of rift basins, similar to some evaporite basins in East Africa today.

The anhydrite overlying the Louann salt is called Buckner and the overlying dolomite is known as Smackover, the Gulf Coast correlative of the Arab limestone pay of the Persian Gulf, the most oil-productive horizon in the world. The remainder of the overlying Jurassic consists of a thick sequence of Cotton Valley limestone and bituminous shale. Although the salt in the Bayou Choctaw dome is of Jurassic age, it may have been deposited to the north so that only oceanic basalts of this age or even younger were ever deposited here.

The salt from which the Bayou Choctaw salt dome formed is probably not in its original depositional position. It appears to have migrated southward and upward as a sill through the sediments described above or outside, seaward of the thick sediment wedge at a depth of two or three to six or seven miles. This sill is believed to be exposed at the toe of the sediment pile on the floor of the Sigsbee Deep (a trough in the Gulf of Mexico) today.

Continental rafting and seafloor spreading have revolutionized the concept of the origin of basins like the Gulf Coast Geosyncline; this concept of deep horizontal salt migration and intrusion is one of the most innovative and important ideas today affecting hydrocarbon exploration.

Cretaceous Period: The updip Cretaceous sequence of Hosston clastics and limes, Sligo oolites, Pine Island shale, James lime reef and Ferry Lake anhydrite, Glen Rose limes is overlain unconformably by the upper chalk section: Austin, Ozan or Annona, and Nacatoch or Arkadelphia with intervening Blossom or Tokio sands and thick shales. The shallow-water reef carbonates are equivalent to basinal shales to the south which may underlie Bayou Choctaw.

The sands on the middle Cretaceous unconformity produce gas in the deep Tuscaloosa trend just north of the Baton Rouge fault and Bayou Choctaw, at a depth of greater than five miles. Metamorphism in these thick Appalachian-source basinal sediments is so extensive that the clean sands have been converted to tight quartzite while the originally-shaly or dirty sands have retained some gas-filled porosity as the clay minerals have been metamorphosed to chlorite mica schist. At this depth, production is only economic on four square-mile units so that geologic features the size of Bayou Choctaw dome can be completely missed.

The chalk probably underlies the site in normal position, and may underlie the salt sill and thereby contain producibile oil and gas -- which DOE has acquired along with the salt.

Cenozoic Era (66-2 my)

Tertiary Period: The downdip surface section of the Gulf Coast proper in Louisiana and Texas is a thick pile of Tertiary sands and shales, correlative with the carbonates of Florida and the Bahamas. All of these deposits face the active east-west tectonic zone running from the Mexican volcanoes through the greater Antilles from Cuba to the Virgin Islands. The ocean floor here was welded in place by the end of the Cretaceous, so that a full, normal Tertiary section underlies the site.

Paleocene Epoch: The Tertiary sequence of the Gulf Coast starts with Midway shale, a normal marine deposit which preceeds the Laramide orogeny, the plate collision which created the Rocky Mountains and flooded the Gulf with coarse clastic debris.

Eocene Epoch: These are the oldest sediments deposited in the Gulf Coast delta sequence. As sediments accumulate on the north shore of the Gulf of Mexico, the older sediments are depressed and compacted, increasing their dip toward the Gulf. Ultimately, a thick sedimentary section accumulates on the edge of the continent, often referred to as a geosyncline. This simple regional picture is complicated by the instability of the underlying salt which forms domes and other features such as ridges and squeeze-ups.

Wilcox deltaic deposits as much as a mile thick, including coal measures which have been penetrated in central Louisiana and adjoining southwestern Mississippi, 40 miles north, represent the Laramide deposits. These are overlain by downdip Yegua shales which in turn are overlain by Jackson shale. None of these deposits have been penetrated yet at Bayou Choctaw.

Oligocene Epoch: The lowermost Oligocene Vicksburg shale is overlain by the deepest sediments penetrated in the vicinity of the dome, the deepwater shales of the Nodosaria Embayment, the oldest and most northeasterly of a series of Frio depressions. These shales are overpressurred despite a series of deltaic sands: Nodosaria at least a thousand feet above the base of the shale, followed locally by *Bolivina mexicana*. Above this sand sequence is the Pontic deepwater facies under the *Marginulina texana* sands, the eastern equivalent of the Hackberry facies. This is the deepest horizon which is penetrated in enough wells to map the domal structure (Figure 6, main report). Table 1, the stratigraphic correlation chart, lists the principal stratigraphic horizons important to the geological interpretation.

The upper Frio is a shallow-water sand and shale section topped by the Anahuac shale, the uppermost sealing horizon against the salt (Figure 3, main report) above the *Marginulina howeli* sand, capped by the *Heterostegina* reef (Figure 4). The reef is a ring of coral as much as 400 feet thick built up around the domw, It is used for toxic waste disposal in the vicinity. Bayou Blue dome to the west has a *Heterostegina* atoll three times as thick with lost circulation requiring extra strings of casing to reach the oil and gas pays.

Miocene Epoch: The outer edge of the shelf grew southward past Bayou Choctawest in lower Miocene time, so that the atoll is overlain by a sand pile. This sand pile being dumped off the south edge of the North American continent at least since the Miocene has deformed the underlying Jurassic salt into ridges and domes of which West Hackberry is one of the largest and Bayou Choctaw one of the smallest. Dips in these sands are limited to 35 degrees, even against the near-vertical salt face, except possibly at the west end of the dome. The base of the sand pile is paleontologically marked by the disappearance of Discorbis "restricted," the last far-offshore deposit in the stratigraphic sequence. The rest of the lower Miocene is represented by thick alluvial sands. The lower part has marine shale breaks including Siphonina davisi, correlated on some logs.

TABLE 1 BAYOU CHOCTAW STRATIGRAPHIC CORRELATION CHART

Unit	Symbol	Lithology
Holocene: *Recent river alluvium*		peat, muck & mud
Pleistocene		
Wisconsin		
Alton/Peorian: *Prairie Fm*	a	sand and gravel
Sangamon: *Montgomery Fm (U. Lissie)*	s	mud
Illinoian	i	sand and gravel
Yarmouthian: *Bentley Fm (L. Lissie)*	(p)	mud
Kansan	ka/ks	sand and gravel
Aftonian: *Williana Fm*	-	mud
Nebraskan	ne	sand and gravel
Lafayette: *Citronelle Fm*		gravel
Pliocene	PL	silt, mud, and sand
Miocene	MI	mud & sand
Upper		
Bigenerina floridana	A (S1)	sand and gravel
		mud
	B (S2)	sand and gravel
		mud
Textularia	L (S3)	marine sand
Bigenerina nodosaria	2	deltaic sand
		mud
Textularia stapperi	W	deltaic sand
		mud
Middle		
Bigenerina humblei	BH (S4)	unconformity
		shale
Cristellaria	CI	thin sands
Cibicides carstensi opima	CO (S5)	sand
Amphistegina	AB	shale
Lower		
Robulus	RL (S6)	marine sand
Operculinoides	OP	
Cibicides	CA (S7)	sand and shale
Marginulina ascensionensis	MA (S8)	sand
		shale
Siphonina davisi	SD (S9)	thin sand
- - - U N C O N F O R M I T Y - - -		
Anahuac (*Discorbis "restricted"*)	DR	shale
Oligocene		
Heterostegina	H	coral atoll
Marginulina howei	MH	sand
		shale
Frio	F	sands
Miogypsinoides	MG	thick sand
Cibicides hazzardi	CH	marine sands
Marginulina texana	MT	thin sands
Pontic facies		near geopressure
Bolivina mexicana	BM	thin oil-bearing sands
Nodosaria blanpedi	NB	" " "

The middle Miocene is represented by the last marine shale breaks, particularly those containing the Amphistegina B fauna with volcanic ash from the Mexican orogeny. This is the shallowest paleontologic data point available around the dome. Table 1, the stratigraphic correlation chart, shows younger zones by their standard paleontological name, even though the marker microfossil is not found in the non-marine sediment at Bayou Choctaw. These units have been correlated around the dome but have no other recognized name.

The upper Miocene alluvial sands are are all stacked point bars deposited by the ancestral Mississippi, separated by silts. These thick, permeable sands are only partially mineralized close to the salt face. They do not represent a threat for oil leakage from the caverns which are not leached close to the edge of the salt.

Pliocene Epoch: The alluvial section continues through the Pliocene, with slightly more backswamp silt. The basal unit is a thick gravel corresponding to the Goliad of Texas. The apparent unconformity below this gravel is eroded deeply into the Miocene close to the dome, indicating the dome had extensive surface expression during this onshore alluvial deposition.

Quaternary Period; Pleistocene Epoch:

The basal pre-glacial unconsolidated Lafayette gravel (Citronelle Fm.) erodes into the underlying Pliocene. The overlying sediments were deposited during and after each of the glaciations of the continent to the north, when sea level was as much as 450 ft lower than today, and in the following interglacial stages as the sea returned to near its present level. Thus the basal sand of each sedimentary sequence, outwash brought down to the Gulf, is correlated with the glacial stage and the overlying mud with the following interglacial. Some or all of the glacial stage is actually represented by the basal unconformity below each channel sand [Ref. A-2]. These sediments are occasionally called Willis in this part of the Gulf Coast.

Nebraskan Stage: The oldest glacial sequence is Nebraskan, found at the top of or just above the Lafayette gravel. The overlying Aftonian mud contains a distinctive volcanic ash marker like those of the middle Miocene, which has been tied to the volcanic or orogenic theory of glaciation.

Kansan Stage: The Kansan, where marine, is the Lenticulina sand, at a depth of some 1350 ft on the flanks of the dome. The Yarmouth (lower Lissie) or Angulogenerina clay, which represents the long interglacial interval in the middle of the Pleistocene, is at a depth of 1100 ft on the flanks of the dome. It contains the uppermost glauconite marker in the sedimentary section, indicative along with the microfauna, of the most recent open marine sedimentation.

Illinoian Stage: Montgomery (Upper Lissie) or Trimosina sands, at some 900 ft depth, were deposited during the following glaciation. Sangamon clay was deposited during the following interglacial interval.

Wisconsin Stage: The Prairie outwash sands of which the basal Alton (Beaumont "B"), at a depth of 200 ft on top of the dome and 400 ft on the flanks, is the thickest and most massive, having been correlated over almost every onshore salt dome. At the surface to the north, they make up the plain which runs from Beaumont through Lake Charles to Lafayette.

The sands were formed at the lower sea level which occurred when the continental icecap extended to the Ohio and Missouri Rivers, the main sediment sources for the Mississippi and the Gulf Coast. Most of them are thick alluvial point bars with basal gravels, although there is some beach sand in the sequence. More than 1600 ft of them are found in the canyon cut through Timbalier Bay just west of the Lafourche Delta.

These unconsolidated sediments are found across the top of the dome, uplifted but not fully breached by the salt intrusion and its overlying residual caprock. The active faults inherent in the caprock extend upward as the salt continues to intrude, deforming these overlying sediments, all the way to the surface.

Holocene Stage: The Pleistocene sands are overlain by Atchafalaya muck (four deltas) deposited in the last 5000 yrs, during which time sea level rose some 450 ft as the earth's continental icecaps melted, leaving only the ice cover in Greenland and Antarctica. This was deposited in the swamp as a, highly-organic black gumbo or incipient coal. Water content in these unconsolidated sediments is still as high as 70%.

The active shallow fault originating in the caprock and salt shear zones have only displaced the Holocene sediments a few feet. They do not pose any apparent risk to the storage caverns by themselves, but subsidence along them could conceivably damage surface facilities and well casings, as has occurred at other domes used for storage of LPG products, e. g., Stratton Ridge, TX.

References to Appendix A

[1] Worrall, D. M. and S. Snelson (1989) Evolution of the Northern Gulf of Mexico, with Emphasis on Cenozoic Growth Faulting and the Role of Salt. Chapt. 7, In The Geology of North America - An Overview; Geol. Soc. Amer., Boulder, CO, p. 97-138.

[2] Bernard, H. A. and R. J. Leblanc (1965) Resume of the Quaternary Geology of the Northwestern Gulf of Mexico Province. In The Quaternary of the United States; Princeton Univ. Press, Princeton, NJ, p. 137-186.

[3] Ginn, R. (1991) Personal communication, and failure report of Oxy Chem. Inc., Railroad Commission of Texas, Austin, TX.

APPENDIX B

INDEX OF BAYOU CHOCTAW WELL DATA USED IN

CONSTRUCTION OF CONTOUR MAPS AND SECTIONS

PART 1, p. B-2 thru B-4: listing of individual wells, identification number (on Figure 1, well location map), and ownership

PART 2, p. B-5 thru B-17: listing of stratigraphic marker horizons by depth, as determined from well logs

NOTE: stratigraphic correlation symbols are summarized on Table 1, p. A-4, Appendix A

BAYOU CHOCTAW SALT DOME PROJECT

Acres #	Well Identification #	Owner
2801	BA 1	Levert Heirs
2802	BA B-1	Levert Heirs
2803	BA C-1	Levert Heirs
2804	BA D-1	Levert Heirs
2805	BE 2	Levert Heirs
2806	Penton 1	Levert Heirs
2807	Roussel 1	Levert Heirs
2808	BA 1	Morley Cypress Company
2809	BA 2	Morley Cypress Company
2810	BA 3	Morley Cypress Company
2811	BA 4	Morley Cypress Company
2812	BA 5	Morley Cypress Company
2813	BA 6	Morley Cypress Company
2814	BA 7	Morley Cypress Company
2815	BA 8	Morley Cypress Company
2816	BA B-1	Morley Cypress Company
2817	BA B-2	Morley Cypress Company
2818	BE 9	Morley Cypress Company
2819	BE 10	Morley Cypress Company
2820	BE 11	Morley Cypress Company
2822	BE 12	Morley Cypress Company
2824	C 2	Morley Cypress Company
2825	C 3	Morley Cypress Company
2827	C 4	Morley Cypress Company
2901	C 1	Morley Cypress Company
2902	BA 1	E. B. Schwing
2904	BA A-2	E. B. Schwing
2907	BA A-3	E. B. Schwing
2908	BA C-1	E. B. Schwing
2909	BE 1	E. B. Schwing
2910	BE A-4	E. B. Schwing
2911	LC 1	E. B. Schwing
2912	LC 2	E. B. Schwing
2913	LC 3	E. B. Schwing
2914	LC 4	E. B. Schwing
2915	LC 5	E. B. Schwing
2916	LC 6	E. B. Schwing
2917	Strata 1	E. B. Schwing
4400	C 1	Wilbert's Myrtle Grove
4401	C 2	Wilbert's Myrtle Grove
4402	C 3	Wilbert's Myrtle Grove
4403	C 4	Wilbert's Myrtle Grove
4404	C 5	Wilbert's Myrtle Grove
4405	C 6	Wilbert's Myrtle Grove
4406	C 7	Wilbert's Myrtle Grove
4407	C 8	Wilbert's Myrtle Grove
4411	C 10	Wilbert's Myrtle Grove
4414	C 19	Wilbert's Myrtle Grove
4415	C 20	Wilbert's Myrtle Grove
4416	C 21	Wilbert's Myrtle Grove
4417	C 22	Wilbert's Myrtle Grove
4419	C 23	Wilbert's Myrtle Grove
4420	C 24	Wilbert's Myrtle Grove
4423	C 25	Wilbert's Myrtle Grove
4425	C 26	Wilbert's Myrtle Grove
4427	C 27	Wilbert's Myrtle Grove
4428	C 27 A	Wilbert's Myrtle Grove
4429	C 28	Wilbert's Myrtle Grove
4430	C 30	Wilbert's Myrtle Grove
4431	C 31	Wilbert's Myrtle Grove
4432	C 32	Wilbert's Myrtle Grove
4433	C 33	Wilbert's Myrtle Grove
4434	C 34	Wilbert's Myrtle Grove
4435	C 35	Wilbert's Myrtle Grove
4436	C 36	Wilbert's Myrtle Grove
4437	C 37	Wilbert's Myrtle Grove
4438	C 38	Wilbert's Myrtle Grove
4439	C 39	Wilbert's Myrtle Grove
4440	C 40	Wilbert's Myrtle Grove
4441	C 41	Wilbert's Myrtle Grove
4442	C 42	Wilbert's Myrtle Grove
4443	C 43	Wilbert's Myrtle Grove
4444	C 44	Wilbert's Myrtle Grove
4446	H 2	Wilbert's Myrtle Grove
4447	H 3	Wilbert's Myrtle Grove
4448	H 4	Wilbert's Myrtle Grove
4449	PE 7	Wilbert's Myrtle Grove
4450	TGS 4	Wilbert's Myrtle Grove
4451	DOE CH 1	Department of Energy
4452	DOE CH 2	Department of Energy
4453	Cavern 2	Department of Energy
4454	Cavern 3	Department of Energy
4455	Cavern 4	Department of Energy
4456	Cavern 5	Department of Energy
4457	Cavern 6	Department of Energy
4458	Cavern 8	Department of Energy
4459	Cavern 8A	Department of Energy
4460	Cavern 9	Department of Energy
4461	Cavern 15	Department of Energy
4462	DOE 15 A	Department of Energy
4463	Cavern 18	Department of Energy
4464	DOE 18A	Department of Energy
4465	Cavern 19	Department of Energy
4466	DOE 19A	Department of Energy
4467	Allied 1	Wilbert Minerals Corp.
4468	Cavern 7	Wilbert Minerals Corp.

Acres #	Well Identification #	Owner
4469	Cavern 16	Wilbert Minerals Corp.
4470	Cavern 17	Wilbert Minerals Corp
4471	Allied 24	Wilbert Minerals Corp
4472	Allied 25	Wilbert Minerals Corp
4473	J 1	Wilbert Minerals Corp.
4474	N 1	Wilbert Minerals Corp
4475	UTP 1	Wilbert Minerals Corp
5201	C 1	Gay Union Corp.
5202	C 2	Gay Union Corp.
5203	C 3	Gay Union Corp.
5204	C 4	Gay Union Corp.
5205	C 5	Gay Union Corp.
5206	C 6	Gay Union Corp.
5208	C 7	Gay Union Corp.
5210	C 8	Gay Union Corp.
5212	C 9	Gay Union Corp.
5213	C 10	Gay Union Corp.
5215	C 11	Gay Union Corp.
5216	C 12	Gay Union Corp.
5217	C 13	Gay Union Corp.
5219	C 14	Gay Union Corp.
5220	C 15	Gay Union Corp.
5221	C 16	Gay Union Corp.
5222	C 17	Gay Union Corp.
5223	C 18	Gay Union Corp.
5224	C 19	Gay Union Corp.
5225	C 20	Gay Union Corp.
5226	C 21	Gay Union Corp.
5230	C 22	Gay Union Corp.
5231	C 23	Gay Union Corp.
5233	C 24	Gay Union Corp.
5234	C 25	Gay Union Corp.
5235	C 26	Gay Union Corp.
5236	C 27	Gay Union Corp.
5237	C 28	Gay Union Corp.
5238	C 29	Gay Union Corp.
5239	C 30	Gay Union Corp.
5240	C 31	Gay Union Corp
5241	C 32	Gay Union Corp
5242	C 33	Gay Union Corp.
5243	C 34	Gay Union Corp.
5244	C 35	Gay Union Corp.
5245	C 36	Gay Union Corp.
5246	C 37	Gay Union Corp.
5247	C 38	Gay Union Corp.
5248	C 39	Gay Union Corp.
5249	C 40	Gay Union Corp.
5250	C 41	Gay Union Corp.
5251	C 42	Gay Union Corp
5252	C 43	Gay Union Corp
5253	C 44	Gay Union Corp.

Acres #	Well Identification #	Owner
5254	C 49	Gay Union Corp.
5255	C 50	Gay Union Corp.
5256	C 51	Gay Union Corp.
5257	Gulf 1	Gay Union Corp.
5259	F 1	Wilbert Minerals Corp.
5260	F 16	Wilbert Minerals Corp.
5261	F 20	Wilbert Minerals Corp.
5262	F 22	Wilbert Minerals Corp.
5263	F 23	Wilbert Minerals Corp.
5264	F 24	Wilbert Minerals Corp.
5265	F 26	Wilbert Minerals Corp.
5266	F 29	Wilbert Minerals Corp.
5267	F 30-1	Wilbert Minerals Corp.
5269	F 31	Wilbert Minerals Corp.
5270	F 32	Wilbert Minerals Corp.
5271	F 33	Wilbert Minerals Corp.
5273	F 35	Wilbert Minerals Corp.
5274	F 37	Wilbert Minerals Corp.
5275	F 38	Wilbert Minerals Corp.
5276	F 39	Wilbert Minerals Corp.
5277	F 40	Wilbert Minerals Corp.
5278	F 41	Wilbert Minerals Corp.
5279	F 42	Wilbert Minerals Corp.
5281	F 43	Wilbert Minerals Corp.
5282	F 44	Wilbert Minerals Corp.
5283	F 45	Wilbert Minerals Corp.
5284	F 46	Wilbert Minerals Corp.
5285	F 47	Wilbert Minerals Corp.
5286	F 48	Wilbert Minerals Corp.
5287	F 49	Wilbert Minerals Corp.
5288	F 50	Wilbert Minerals Corp.
5289	F 52	Wilbert Minerals Corp.
5290	F 54	Wilbert Minerals Corp.
5291	F 56	Wilbert Minerals Corp.
5292	F 58	Wilbert Minerals Corp.
5293	F 59	Wilbert Minerals Corp.
5295	F 71	Wilbert Minerals Corp.
5296	F 72	Wilbert Minerals Corp
5297	F 82	Wilbert Minerals Corp.
5299	Unknown	
5301	BA B-1	E. B. Schwing et al
5302	BA B-2	E. B. Schwing et al
5303	BA B-3	E. B. Schwing et al
5304	BA B-4	E. B. Schwing et al
5305	BA B-5	E. B. Schwing et al
5307	BA B-6	E. B. Schwing et al
5308	BA B-7	E. B. Schwing et al
5309	BE 2	E. B. Schwing et al
5310	Choctaw 1	E. B. Schwing et al
5311	Hall & Damson 1	E. B. Schwing et al
5312	State 1	E. B. Schwing et al

Acres #	Well Identification #	Owner
5313	Texas 1	E. B. Schwing et al
5314	Texas 2	E. B. Schwing et al
5315	Texas Levy 1	E. B. Schwing et al
5316	Cavern 1	Department of Energy
5317	Cavern 10	Department of Energy
5318	Cavern 11	Department of Energy
5319	Allied 12	Department of Energy
5320	Cavern 13	Department of Energy
5321	Cavern 20	Department of Energy
5322	DOE 20A	Department of Energy
5323	F 2	Wilbert Minerals Corp.
5324	F 3	Wilbert Minerals Corp.
5325	F 4	Wilbert Minerals Corp.
5326	F 5	Wilbert Minerals Corp.
5327	F 6	Wilbert Minerals Corp.
5328	F 7	Wilbert Minerals Corp.
5329	F 8	Wilbert Minerals Corp.
5330	F 9	Wilbert Minerals Corp.
5331	F 10	Wilbert Minerals Corp.
5332	F 11	Wilbert Minerals Corp.
5335	F 12	Wilbert Minerals Corp.
5336	F 12-1	Wilbert Minerals Corp.
5337	F 13	Wilbert Minerals Corp.
5339	F 14	Wilbert Minerals Corp.
5340	F 15	Wilbert Minerals Corp.
5341	F 17	Wilbert Minerals Corp.
5342	F 18	Wilbert Minerals Corp.
5344	F 19	Wilbert Minerals Corp.
5345	F 21	Wilbert Minerals Corp.
5346	F 25	Wilbert Minerals Corp.
5348	F 28	Wilbert Minerals Corp.
5349	F 51	Wilbert Minerals Corp.
5350	F 53	Wilbert Minerals Corp.
5351	F 55	Wilbert Minerals Corp.
5352	F 60	Wilbert Minerals Corp.
5353	F 61	Wilbert Minerals Corp.
5354	F 62	Wilbert Minerals Corp.
5355	F 64	Wilbert Minerals Corp.
5357	F 65	Wilbert Minerals Corp.
5358	F 67	Wilbert Minerals Corp.
5359	F 68	Wilbert Minerals Corp.
5360	F 69	Wilbert Minerals Corp.
5361	F 70	Wilbert Minerals Corp.
5362	F 73	Wilbert Minerals Corp.
5363	F 74	Wilbert Minerals Corp.
5364	F 76	Wilbert Minerals Corp.
5365	F 78	Wilbert Minerals Corp.
5366	F 79	Wilbert Minerals Corp.
5367	F 81	Wilbert Minerals Corp.
5368	PE 4	Wilbert Minerals Corp.
5369	C 1	Wilbert's Myrtle Grove

Acres #	Well Identification #	Owner
5370	C 9	Wilbert's Myrtle Grove
5372	C 11	Wilbert's Myrtle Grove
5373	C 12	Wilbert's Myrtle Grove
5375	C 13	Wilbert's Myrtle Grove
5376	C 14	Wilbert's Myrtle Grove
5378	C 15	Wilbert's Myrtle Grove
5379	C 16	Wilbert's Myrtle Grove
5380	C 29	Wilbert's Myrtle Grove
5383	TGS 1	Wilbert's Myrtle Grove
5384	TGS 2	Wilbert's Myrtle Grove
5385	TGS 3	Wilbert's Myrtle Grove
5387	TGS 5	Wilbert's Myrtle Grove
5388	TGS 6	Wilbert's Myrtle Grove
5389	TGS 7	Wilbert's Myrtle Grove
5390	TGS 8	Wilbert's Myrtle Grove
6001	F 80	Wilbert Minerals Corp.
6101	BE 12	Wilbert Minerals Corp.
6103	C 18	Wilbert Minerals Corp.
6104	Delta 3	Wilbert Minerals Corp.
6105	F 34	Wilbert Minerals Corp.
6106	F 36	Wilbert Minerals Corp.
6107	F 57	Wilbert Minerals Corp.
6108	F 63	Wilbert Minerals Corp.
6110	F 66	Wilbert Minerals Corp.
6111	F 77	Wilbert Minerals Corp.
6112	Lone Star 1	Wilbert Minerals Corp.
6151	BA 1	Gay Union Corp.
6152	C 45	Gay Union Corp.
6153	C 46	Gay Union Corp.
6154	C 47	Gay Union Corp.
6155	C 48	Gay Union Corp.
8201	Delta 2	Wilbert Minerals Corp.
9991	Property Boundary Markers	
9992	Property Boundary Markers	
9993	Property Boundary Markers	
9994	Property Boundary Markers	
9995	Property Boundary Markers	
9996	Property Boundary Markers	

BAYOU CHOCTAW GEOLOGICAL CHARACTERIZATION

SUMMARY OF WELL LOG INTERPRETATIONS

WELL NAME

	2801	2802	2803	2804	2805	2806	2807	2808
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL		980	1020					
LP			2090	2105	2070	2275	2070	
Mi	3055	3135	3080	3225	3045	3108	3025	2790
SA	3625		3545	3538	3640	3598	3525	3270
S1	3878	3575	3895	3880	3882	3973	3868	3500
S2	4350	3885	4290	4210	4265	4315	4205	3890
S3	4755	4440	4825	4800	4898	4943	4882	4505
S4	5285	4950	5065	5292	5380	5248	5235	4840
S5		5545		5958		5858		5380
S6						6065		5540
S7			6190		6075	6393		5732
S8	6130		6365	6423	6230	6657	6225	6080
S9	6965		7485	7545	7426	7845	7390	6955
HL	7325		8015	7885		8325	7645	7190
FF	7695	7560	8310	8400	8155	8852	8115	7675
MG			8580	8520	8532			7885
CH			8715	8650	8632			
MT	8340		8910	8742	8790			
BM			9410	9005	9150			
TD	8390	7610	9460	9055	9200	8902	8165	7935

	2809	2810	2811	2812	2813	2814	2815	2816
REF. EL.	0	0	0	0.	0	0	0	0
SYMBOL								
PL					833		985	
LP					1908	2135	2050	
Mi	2730	3012	2860	2860	2630	2671	2605	2983
SA	3205	3240	3255	3355	3112	3160	3080	3392
S1	3420	3410	3515	3640	3340	3375	3280	3640
S2	3805	3705	3900	4005	3568	3670	3450	3955
S3	4400	4373	4595	4685	4352	4205	4045	4545
S4	4828	4715	5070	4935	4673	4495	4998	4920
S5	5320	5285	5465	5395		5067	5050	5575
S6	5580	5588	5695	5558		5235	5290	5835
S7	5785	5806	6008	6048				6230
S8	5872	5968	6210	6210	5700	5488		6445
S9	6805	6815	6820	7175	6435			7355
HL		7273	7420	7305	6930			7862
FF	7325	7550	7682	7730				8320
MG	7650		8010	8070				8460
CH	7845							8740
MT								8882
BM								9270
TD	7895	7600	8060	8120	6980	5538	5340	9320

	2817	2818	2819	2820	2822	2824	2824-ST1
REF. EL.	0	0	0	0	0	0	0
SYMBOL							
Mi	2890		2750	2790	2950	2895	
SA	3358		3198	3316	3395	3390	
S1	3648		3445	3574	3690	3680	
S2	3965		3717	3948	4098	3970	
S3	4675		4475	4478	4753	4690	
S4	5016		4945	4865	5090	5030	
S5	5624		5346	5735	5695	5575	
S6	5810		5570	5858	5898	5750	
S7	6008			6015	6235	6205	
S8	6345		5982	6268	6450	6340	
S9	7377		6580	7185	7630	7175	
HL	7890		7035	7652	8152	7495	
FF	8258			7850	8520	7980	
MG	8510			8070	8670	8250	
CH	8684			8540	9045	8465	
MT	8780						
BM	9075						
TD	9125		7085	8590	9095	10000	10000

	2825	2825-ST1	2827	2901	2902	2904	2907	2908
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL								1015
MP								1680
LP			2005		2160	2375	2560	2190
Mi			2745	2930	2900	3145	3165	3090
SA			3260	3400		3425	3468	3568
S1	3562		3420	3655	3395	3738	3752	3830
S2	3965		3640	4035	3670	4065	4155	4155
S3	4702		4480	4740	4480	4750	4740	4880
S4	5030		4695	4990	4930	5125	5130	5145
S5	5560		5250	5460	5370	5493	5698	5760
S6	5785		5505	5640	5675	5760	6038	5915
S7	6160			6160	6060	6225	6343	6315
S8	6302		5868	6320	6290	6350	6425	6745
S9	7010		6310	7390	6860	7305	7347	7700
HL	7542	7532	6715	7535	7395	7675	7798	
FF	7620	7590		7960	7530	8095	8202	8222
MG	7928	7902		8358		8290	8405	9080
CH	8215						8732	9312
MT							9068	9600
BM							9380	
TD	8216	7902	6765	8408	7580	8340	9430	9650

	2909	2910	2911	2912	2913	2914	2915	2916
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
MP			1630					
LP		2290	2150			2495		
Mi	3120	2765	3060	3050	3060	3120	3070	
SA	3614		3475	3460	3510	3390	3480	
S1	3838		3750	3725	3720	3645	3755	
S2	4230	3130	4100	4095	4055	4070	4110	
S3	4870	3738	4670	4700	4730	4655	4725	
S4	5198	4553	5040	5055	5110	5070	5022	
S5	5590	5060	5480	5450	5560		5568	
S6	5835	5455	5720	5685	5860		5735	
S7	6164	5895		6115	6365	6225	6215	
S8	6433	5985	6680	6600	6512	6395	6720	
S9	7478	6478	7440	7220	7205	7202	7365	
HL	7990	6980	7810	7705	7635	7555	7845	
FF	8370	7140	8300	8170	8160	8010	8150	
MG	8770			8390		8202		
TD	8820	7190	8350	8440	8210	8252	8200	

	2917	4400	4401	4402	4403	4404	4405	4406
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
SA	3620							
S1	3918							
S2	4255							
S3	4903							
S4	5162							
S5	5895							
S6	6177							
S7	6590							
S8	6792							
S9	7825							
HL	8433							
FF	8958							
MG	9201							
CH	9498							
MT	9680							
BM	10432							
TS		2566	4201	2469				
TD	10482	2616	4251	2519	2416			

	4407	4407-ST1	4407-ST2	4407-ST3	4411	4411-ST1	4411-ST2	4414
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
MP					1340			
LP					1905			1280
Mi								1720
SA					3005			
S2					3360			
S3					3740			
S4					4010			
TS					5235	4828	4814	
TD	10000	10000	10000	10000	10000	10000	10000	1770

	4415	4416	4417	4417-ST1	4419	4420	4420-ST1	4420-ST2
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
MP	1320	1345			1365		1285	
LP	1860	1980			1910	1410	1975	
Mi						1934		
SA	2865	2905			3142		2872	
S1	2995					2900		
S2	3120	3050				3102		
S3	3395	3405						
TS						3910		
TD	3445	3455	10000	10000	3192	3911	10000	10000

	4423	4423-ST1	4425	4427	4428	4429	4430	4431
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL	885	885	975			1190	870	
MP	1270	1187	1275			1670	1400	1385
LP			2020		2215	2190	2030	1920
Mi		2650	2805				2435	
SA			3150			3168	3160	2830
S1						3408	3395	
S2			3540			3565	3555	3210
S3			4058					
S4			4375			4485	4523	
S9						5424		
TS	2010		4743	1290	995	4735	4868	
BS					1880	5205		
TD	2060	2700	4794	1340	10000	5474	4918	3260

	4432	4433	4434	4435	4436	4437	4438	4439
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
MP		1370	1370	1345	1395	1375	1300	1380
LP	1764	1898	1902	1908	1925	1895	1920	1945
SA		3045	2998	2975	3025	2973	2950	3050
S1							3072	
S2		3338	3248	3250	3202	3140	3295	3290
S3		3695	3614	3650	3850	3595		3787
S4		3930	4015		4074	3805	3578	4195
S5					4570		4120	4500
S6					4875		4385	
S8					5155			
TS	2568	4670					4593	
TD	2618	4720	4065	3700	5205	3855	4643	4550

	4440	4441	4442	4443	4444	4446	4447	4448
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL	858							
MP	1337	1260	1400	1420	1375	1390		
LP	1975	1840	1928	1995	1895	1872		
Mi	2690							
SA	2998	2810	3028	2990	2995	3030		
S2	3140	3410	3205	3172	3160	3360		
S3	3955		3845		3660			
S4			4058	3885	3863			
S5			4445	4405				
S6			4590	4620				
S8	4725		5145	5160				
S9	5750							
TS	5275							
TD	5800	3560	5195	5210	3913	3411		

	4449	4450	4451	4452	4453	4454	4455	4456
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
Mi	2045							
TS	2448		658	646	639	791	662	645
TD	2498	530	708	696	689	1925	712	695

	4457	4458	4459	4460	4461	4462	4463	4464
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
TS		740	776	890	637	613	857	805
TD		790	2026	940	3347	663	4335	855

	4465	4466	4467	4468	4469	4470	4471	4472
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
TS	850	862	655	850	800	660		
TD	4320	912	705	900	850	4100		

	4473	4474	4475	5201	5202	5203	5204	5205
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
TS	645	705	800				3212	4881
TD	695	1123	850	1068			3262	4931

	5206	5206-ST1	5208	5208-ST1	5210	5210-ST1	5212
REF. EL.	0	0	0	0	0	0	0
SYMBOL							
PL					995		
MP					1555		
LP					2190		
Mi					2800		
SA					3218		2490
S1							3090
S2					3660		3465
S3					4392		
S4			4520		4700		4060
S5			5045		5538		
S6					5765		
S9							5030
HL							5450
TS							6162
TD	4591	10000	5045	10000		10000	6212

	5213	5213-ST1	5215	5216	5217	5217-ST1	5219	5220
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL			935					930
MP			1565	1485				1465
LP	2210		2365	2160				2155
Mi	2440		2845	2620				2715
SA	3130		3465	3300				3195
S1	3350			3575			2890	3440
S2	3590		4060	3832			3100	3682
S3	3990		4610	4360				4335
S4	4270		5090	4845	8325	8260		4770
S5	5050			5610	9327	8770		
S6						9420		
S7				6060				
S8	5740		6250	6160				
S9	6430		6940	7112				
HL				7608				
FF	6860		7395	7870				
MG	7170		7515	8095				
CH			7685					
MT			7990					
BM			8290					
NB			8710					
TS					7735	7790	3200	
BS					7140	7112		
TD	7170	7170	8760	8145	9377	9470	3250	4820

	5221	5222	5223	5224	5225	5226	5226-ST1	5226-ST2
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL	1145	1078	1062	1058	1040	1060		
MP		1512	1654		1578			
LP		2150	2315	2345	2245	2300		
Mi	2972	2762	2952	3032	2740	3002		
SA		3260	3485	3480	3295	3530		
S1			3740	3715	3555	3815		
S2	4000	3830	4140	4098	3745	4095		
S3	4499	4302	4710	4660	4325	4638		
S4	4949	4770	5175	5078	4758	5020		
S5	5540	5535				5580		
S6	5820					5775		
S7	6135	5945				6145		6145
S8	6292	6035	5886	5820	5750	6195		6192
S9		6930	6658	6530		6945	6980	6755
HL	6935	7330	6975	7085		7355	7515	7150
FF	7302	7843	7405	7390		7600	7890	7450
MG	7540	8145	7590					
CH	7820	8450						
MT	8082		7815	7718				
BM	8750							
TS			8205	8105				7775
TD	8800	8500	8255	8155	5800	10000	7891	7451

BAYOU CHOCTAW GEOLOGICAL CHARACTERIZATION

SUMMARY OF WELL LOG INTERPRETATIONS

WELL NAME

	5230	5231	5231-ST1	5233	5234	5235	5236	5237
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL	1010							
MP	1625							
LP	1990	2195		2308	2245	1480	2105	
Mi	2880	2681		2778	2855	1955	2648	
SA	3445	3106		3310	3375	2560	3158	
S1	3715	3320		3560	3650	2910	3405	
S2	4060	3825		3840	3950	3075	3670	
S3	4518	4045		4530	4635	3500	4258	
S4	5130	4240		4875	5103	3650	4668	4270
S5		5000		5315	5180		5180	
S6		5210		5535				
S7					5676		5810	
S8	5708	5720		6312	5728		5882	
S9	6735			6638	6350		6210	
HL		6250		7265	6760		6630	
FF	7336						7092	
MG	7667							
CH	7948							
TS						3825		5194
TD	7998	6251	10000	7315	6810	3875	7142	5244

	5238	5239	5240	5241	5242	5243	5244	5245
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL		1110						
MP		1705			1455	1395	1342	
LP	1680	2355	1620	2313	2247	1998	1965	1662
Mi	2198	2870		2790	2705	2670	2485	2100
SA	2550	3298		3395	3040	2978	2945	2705
S1	3095	3605	3015	3665	3245	3130	3135	3045
S2	3245	3875	3135	3970	3460	3495	3570	3200
S3	3745	4350		4430			3905	3718
S4	4008	4540	3800	4730	4082	3876	4125	4178
S5		5410		5315	4828	4510		
S6		5605			5050	4648		4590
S7	4800	6010						
S8		6145		5715	5655	5490	5695	
S9		6682		6565	6450			
HL		6973		6880				
FF		7418						
MG		7590						
MT		8160						
BM		8485						
TS			4460					4790
TD	4850	8535	4510	6930	6500	5540	5745	4840

	5246	5247	5248	5249	5250	5251	5252	5253
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL					998			
MP			1468	1535	1370		1545	
LP	1715	1560	2148	2105	2089	2255	2285	2145
Mi	2145	2050	2782	2750	2480	2770	2825	2845
SA	3045	3033	3078	3173		3158	3230	3514
S1		3145	3310	3412	2990	3450	3505	3724
S2			3510	3678	3215	3638	3762	4050
S3	3805	3490		4188		4120	4272	4630
S4	3865	3660	4075	4447	3750	4240	4606	4985
S5	4703	4250	4805	5065		5125		5445
S6		4615	5070	5295		5325		5621
S7				5783		5806		
S8	5450			5845		5880		6375
S9				6660				6930
HL				7072		6382		7155
FF				7410		6910		7565
MG						7190		7698
CH						7615		7990
MT								8155
BM								8440
TD	5500	4665	5120	7460	3800	7665	4656	8490

	5254	5255	5256	5257	5257-ST1	5259	5260	5261
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL						895	955	755
MP						1460		1385
LP	2332					1985		1935
Mi	3018					2545		
SA	3585		3570	3202		3034		3118
S1	3915			3480		3228		
S2	4280		4105	3898		3350		3380
S3	4970		4785	4405		3920		3750
S4	5286		5232	4810		4340		4055
S5	6043		5942	5345				
S6	6360		6238	5570				
S7				6118				
S8	6670		6392	6230		4980		
S9	7785		7445	7020		5585		
HL	8110		7550	7195				
FF	8663		7937	7723				
MG	9198			8125				
CH			8115					
MT			8480	8610				
BM			9045	8975				
NB			9470					
TS							1412	4798
TD	9248		9520	8975	10000	5635	1462	4848

	5262	5263	5264	5265	5266	5267	5267-ST1	5269
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL	800							840
MP	1365	1407	1383	1430	1345			1370
LP	1925	1930	2023	2005	1970			1920
Mi								2445
SA	3035	3060	3130	3020	2955			3020
S1			3378	3210	3098			3220
S2	3280	3425	3490	3470	3375			3410
S3	3730	3880	3945	3710			4150	3925
S4	4165	4250	4260	3930	3745		4435	4160
S5		4860						4670
S6		5135						4815
S7								5195
S8				5280				5305
S9								6020
HL								6220
TS	4765				5447		5170	
TD	4815	5185	4310	5330	5497	5170	5220	6270

	5270	5271	5273	5274	5275	5276	5277	5278
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL						790	775	
MP	1322	1345	1398	1418	1445	1310	1270	1328
LP	1950		1868	1932	2150	1790	1668	1788
Mi		2190	2398			2155	2105	2395
SA	2950		3000	3042	3070	2895		
S1			3340			3195		
S2	3348		3585	3245	3235	3360	3315	2935
S3	3675	3680	4045	3885	3602	3720		3702
S4	3955	3890	4480	4255	3980	3960		3902
S8				5165				4495
TS	4636		5415			4327	3515	
TD	4686	10000	5465	5215	4030	4377	3565	4545

	5279	5281	5282	5283	5284	5285	5286	5286-ST1
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL						843		
MP		1160	1175		1355	1574		
LP	1555	1720	1715	2605		1950		
Mi		2255	2235					
SA	2715							
S1		2960	2910					
S2	2885	3162	3115					
S3	3495	3678	3625					
S4		4425	3975					
S5			4625					
S8		4630						
TS	4060			935	3420			
BS					4760			
TD	4110	4680	4675	2655	4810	2000	10	10

	5287	5288	5289	5290	5291	5292	5293	5293-ST1
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL	841	820		855			810	830
MP	1398		1405	1240		1375		
LP	1872		1950	1875	2110	1960		1580
Mi				2675	2842	2850		2000
SA			3055	3000	3230	3095		
S1					3485			2595
S2			3295		3753	3347		2830
S3			3835		4348	3895		3250
S4			4250		4715	4275		
S5					5385			
S6					5540			
S7					6012			
S8			5095		6135	5668		
S9					6870	6370		
HL					7370	6762		
FF					7675	7070		
MG					8130	7330		
CH						7725		
TS					8415		1400	1700
TD	1922	870	5145	3050	8465	7775	10000	10000

BAYOU CHOCTAW GEOLOGICAL CHARACTERIZATION

SUMMARY OF WELL LOG INTERPRETATIONS

WELL NAME

	5295	5296	5297	5299	5301	5302	5303	5304
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL	780				915			
MP					1460	1720		
LP		2255	2170		2145	2325	2330	2090
MI	2770		2045		3040	3130	3068	2911
SA			3385		3430	3460	3467	3458
S1			3670		3508	3660	3660	3705
S2			4130		3885	3925	3943	3895
S3			4648		4660	4715	4650	4528
S4			5055		4930	4975	4920	4945
S5					5440	5424	5367	5318
S6					5585	5587	5510	5490
S7					5970	6073	5980	5985
S8					6350	6520	6458	6325
S9					7200	7360	7205	7265
HL					7585	7863	7610	8155
FF					7950	8160	8005	
MG					8170	8382	8223	
CH					8393	8571	8605	
MT					8592			
BM					9105			
NB					9568			
TS	905	1267		1650				
BS	1228			1270				
TD	2820	2105	5105	3760	9618	8621	8655	8205

	5305	5305-ST1	5307	5308	5309	5310	5311	5312
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL						980		
MP	1495					1530		
LP	2180		2120	2135		2160		2180
MI	2930		2982	3015		3080	3223	2970
SA	3540		3510	3553		3565	3775	3490
S1	3755		3745	3762		3815	3985	3745
S2	3988		3986	3985		4105	4305	3968
S3	4605		4650	4695		4715	4808	4545
S4	5025		4955	4992		5025	5280	4968
S5	5613		5595	5660		5648	6150	5572
S6	5765		5760	5815		5830	6455	5760
S7	6055		6200	6235			6758	6015
S8	6496	6490	6385	6425			6963	6472
S9	7345	7362	7330	7348			8240	7075
HL	7958		7780	7908			8640	7288
FF	8290	7750	8122	8262			9288	7703
MG		7854		8435			9522	8140
CH		8132		8580			10048	
MT				9055				
BM				9802				
TD	8290	8132	8172	9852		5880	10098	8190

	5313	5314	5315	5316	5317	5318	5319	5320
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
Mi	3260	3040						
SA	3495	3578	3465					
S1	3830	3794	3670					
S2	4155	4063	3955					
S3	4665	4614	4580					
S4	5055	5144	5020					
S5	5895	5798	5658					
S6	6315	6149						
S7	6515		6028					
S8	6704	6485	6405					
S9	7802	7340	7225					
HL	8458	8040	7640					
FF	8945	8470	8042					
MG	9120		8250					
CH	9690		8825					
MT	10202	8705	9110					
BM	10970	9500	9590					
NB	11445	10220						
TS				650	661	683	920	875
TD	11495	10270	9640	1860	1952	1850	970	1930

	5321	5322	5323	5324	5325	5326	5327	5328
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL				885	840	855	850	934
MP				1420	1275	1340	1351	
LP				2040	1995	1975	2076	2105
Mi				2910	2905		2940	3035
SA				3178	3170	3178	3315	
S1				3410	3360	3425	3455	3565
S2			3850	3660	3698	3725	3730	3895
S3			4265	4590	4400		4455	4506
S4				4840	4718		4810	4827
S5				5350	5280	5052	5160	5405
S6			5455	5545	5598	5410	5522	5585
S7				6005	5885	5905	5788	5855
S8			5975	6085	6040	6035	6210	6300
S9				6975	6920	6975	6973	7230
HL				7362	7318	7390	7298	7608
FF				7792	7700	7730	7648	7860
MG				8152			7830	8020
CH				8302			8192	8378
MT				8645				
BM				8940				
TS	681	692	2273	9040				
TD	4355	742	6025	9090	7750	7780	8242	8428

	5329	5330	5331	5332	5335	5336	5337	5339
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL			760					
MP			1466					
LP	2120	2130	1970				2160	2053
Mi	3025	3002	2795	2515	2695		2940	2830
SA	3320	3280	3296	2825	3015	2855	3445	3248
S1	3518	3490	3430	3062	3278		3680	3565
S2	3895	3940	3692	3405			3898	3812
S3	4820	4780	4288	4008			4540	4322
S4	4964	4970	4828	4248			4980	4795
S5	5190	5538	5355				5592	5414
S6	5588	5723	5518				5785	5548
S7	6146						6054	5886
S8	6275	6200	6025	5148				6250
S9	7210	7180	6978	6030				7002
HL	7602	7695	7167					
FF	8045	7965	7645					7485
MG	8315	8155						
CH	8785	8360						
TS				991	940			
BS				1700	1640			
TD	8835	8410	7695	6080	3328	2905	6104	7535

	5340	5341	5342	5344	5345	5346	5348	5349
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL		730	865					
MP		1385	1440					
LP	2060	1920	2125	2115				
Mi	2770	2640	2830	2920				
SA	3185	3098	3285	3442		3210		
S1	3532	3380	3660	3578		3365		
S2	3728	3584	3860	3878		3810		
S3	4412	4210	4575	4565				
S4	4870	4712	4955	4886		4386	4765	
S5	5483	5350	5552	5425				
S6	5635	5530	5775	5592				
S7	5910	5780	6115	5856				
S8	6390	6250	6330	6292			5875	5135
S9	6948	6835	7245	7276				
HL	7120	6972	7705	7475			7410	
FF	7673	7250	7945	7745				
MG	8000			7970				
CH				8302				
TS					815	2850	694	793
BS					4669	2980		3155
TD	8050	7300	7995	10000	4719	4436	7460	5185

	5350	5351	5352	5353	5354	5355	5357	5358
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL		735						
MP								1500
LP							2205	2195
Mi							3362	
SA			3000				3535	
S1		3015	3425					
S2	3255	3352	3590				4185	
S3	3750	3758	4201				4700	
S4	4135	4260	4720				5253	
S5			5068				5595	
S6			5278				5995	
S7							6208	
S8	5360	5485				7108	6323	
S9						7432	7222	
HL						8125	7460	
FF							8042	
MG							8290	
CH							8772	
TS	850	870	735	760	697			
BS	3000							
TD	5410	5535	5328	810	747	8175	8822	2245

	5359	5360	5361	5362	5363	5364	5365	5366
REF. EL.	0	0	0	0		0	0	0
SYMBOL								
MP	1425							
LP	2105						2105	
Mi				2445		2752	2960	2800
SA						3130	3305	3040
S1				3035		3440	3505	
S2			2950	3290	2895	3650	3905	3210
S3				3905	3620	4160	4806	4030
S4				4290			4941	4355
S5						4840	5430	4940
S6						5060	5585	
S7						5555	6160	
S8						5955	6295	5705
S9						6645		
HL						7057	7592	
FF						7495	8032	
TS		670	2200					
TD	2155	720	10000	4340	3670	7545	8082	5755

	5367	5368	5369	5370	5370-ST1	5372	5373	5373-ST1
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
LP	2365							
Mi	3158							
SA	3463							
S1	3696							
S2	4000							3428
S3	4815							
S4	5098							
S5	5601							
S6	5802							
S7	6086							
S8	6553							
S9	7598							
HL	8096							
FF	8301							
TS		2088	667			718		4225
BS		2212				4660		
TD	8351	2262	2740	10000	10000	10000	50	4275

	5375	5376	5376-ST1	5378	5379	5380	5380-ST1	5380-ST2
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL						835		
MP						1395		
LP						2095	2060	
Mi							2855	
SA					2748			
S1				3160			3452	
S2	3312			3350	3510		3625	
S3	3670		3675	3840	3895			
S4			4060	4200	4535			
S5			4895	4540				
S6				4860				
S7				5295				
S8				5540				
HL					6630			
TS	852	823		735	805			
BS	2894			2850	1988			
TD	3720	10000	4895	5590	6680	10000	3625	10000

	5383	5384	5385	5387	5388	5389	5390	6001
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
LP								2260
Mi								3128
SA								3525
S1								3778
S2								4033
S3								4805
S4								5301
S5								5760
S6								6198
S7								6490
S8								6630
S9								7068
HL								7678
FF								8330
TS			660	690	679			
TD			710	740	729			10000

	6101	6103	6104	6105	6106	6107	6108	6110
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL	918		985					
MP	1425	1535	1435					
LP	2060	2165	2070	2105	2145	2120	2220	2198
Mi	2925	2960	2942	3000	3032	2985	3055	2858
SA	3260	3560	3308	3350	3460	3395	3488	3432
S1	3525	3885	3645	3650	3790	3710	3885	
S2	3755	4185	3808	3915	4118	3935	4165	4015
S3	4400	4848	4605	4520	4760	4418	4808	4630
S4	4820	5240	5155	5030	5150	4735	5228	5055
S5		6040	5778	5574	5995			5750
S6		6410	6172		6138			5965
S7				6025		6052	6450	6395
S8		6820		6175	6396	6214	6772	6502
S9		7905			6990	6910		7635
HL		8615		7060	7148	7460		8218
FF		8740		7410	7845	8000		8870
MG		9005						
CH		9340						
TS			6940	7885			7570	
TD	4870	9390	6990	7935	7895	8050	7620	8920

	6111	6112	6151	6152	6153	6154	6155	8201
REF. EL.	0	0	0	0	0	0	0	0
SYMBOL								
PL								970
MP								1385
LP	2150		2270		2220	2195		2098
Mi	3090	2935	3058	3010	3320	3012	3098	3066
SA	3475	3350	3625	3615	3648	3605	3452	
S1	3798	3638	4035	3850	3932		3795	3722
S2	4076	3945	4290	4205	4173	3964	4177	4085
S3	4762	4525	4902	4910	4665	4640	4712	4690
S4	4980	4925	5425	5328	5073	5014	5250	5122
S5	5720	5710	6295	6090	5840	5815	6050	5965
S6	5986	5940			6078	6070	6352	6185
S7	6302	6363	6705	6435	6478	6252		6572
S8	6498	6465	6805	6590	6638	6417	6543	6756
S9	7478	7395	7950	7785	7690	7565	7656	7806
HL	7872	7908	8425	8220	8192	8002	8155	8302
FF		8435	8760	8916	8715	8425	8675	8780
MG		8710	9025		8910	8650	8880	8992
CH		9175	9315		9137	8890		9333
MT		9400	9520	9205	9330	9060	9112	9400
BM			9958	9990	10025	9630	9842	9980
NB					10322			
TD	7922	9450	10048	10040	10372	9680	9892	10030

	9991	9992	9993	9994	9995	9996
REF. EL.	0	0	0	0	0	0
SYMBOL						
PL	9991.019	9992.019	9993.019	9994.019	9995.019	9996.019
MP	9991.03	9992.03	9993.03	9994.03	9995.03	9996.03
LP	9991.04	9992.04	9993.04	9994.04	9995.04	9996.04
Mi	9991.05	9992.05	9993.05	9994.05	9995.05	9996.05
SA	9991.059	9992.059	9993.059	9994.059	9995.059	9996.059
S1	9991.071	9992.071	9993.071	9994.071	9995.071	9996.071
S2	9991.08	9992.08	9993.08	9994.08	9995.08	9996.08
S3	9991.09	9992.09	9993.09	9994.09	9995.09	9996.09
S4	9991.099	9992.099	9993.099	9994.099	9995.099	9996.099
S5	9991.111	9992.111	9993.111	9994.111	9995.111	9996.111
S6	9991.12	9992.12	9993.12	9994.12	9995.12	9996.12
S7	9991.13	9992.13	9993.13	9994.13	9995.13	9996.13
S8	9991.139	9992.139	9993.139	9994.139	9995.139	9996.139
S9	9991.151	9992.151	9993.151	9994.151	9995.151	9996.151
HL	9991.16	9992.16	9993.16	9994.16	9995.16	9996.16
FF	9991.17	9992.17	9993.17	9994.17	9995.17	9996.17
MG	9991.18	9992.18	9993.18	9994.18	9995.18	9996.18
CH	9991.191	9992.191	9993.191	9994.191	9995.191	9996.191
MT	9991.2	9992.2	9993.2	9994.2	9995.2	9996.2
BM	9991.21	9992.21	9993.21	9994.21	9995.21	9996.21
NB	9991.22	9992.22	9993.22	9994.22	9995.22	9996.22
TS	9991.231	9992.231	9993.231	9994.231	9995.231	9996.231
BS	9991.24	9992.24	9993.24	9994.24	9995.24	9996.24
TD	9991.26	9992.26	9993.26	9994.26	9995.26	9996.26

March 17, 1993

Sandia National Laboratories

Albuquerque, New Mexico 87185

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L.L. Todd, 6113

BC Cavern 4 -- Comparison of 1992, 1980 and 1963 Cavern Sonars

We have revisited the question of Bayou Choctaw Cavern 4 stability as part of the effort to update the geological site characterization of the Bayou Choctaw Site. The results of the August 1992 sonar survey have been compared with the surveys conducted in 1980 and 1963. In summary, we find that there is no convincing evidence to suggest that significant changes have occurred since 1980. Indicated differences in cavern volume and shape between the 1980 and 1992 survey are within the uncertainties normally expected from cavern sonar surveys.

Comparisons of the general shape of the cavern in 1963, 1980 and 1992 show the following:

1. There is no evidence of continued enlargement of the upper 350 feet of the cavern during the period of 1980 through 1992 (the cavern roof is at about - 650 feet). This is in contrast to the large increase in size noted between 1963 and 1980. This upper portion of the cavern is most critical to stability since there is evidence that the cavern roof is in caprock.

2. At several depths, the 1992 survey shows that the range to the cavern wall is about 100 feet less than that seen in the 1980 survey. This seems to agree more closely with the 1963 survey than with the 1980 survey. The discrepancy is probably due to changes in sonar technology and to variability in interpretation of the logs. Creep of this magnitude would not occur over a 12-year period in a shallow cavern like BC 4 so it is unlikely that the cavern wall moved inward 100 feet between 1980 and 1992.

3. From about - 1000 feet to - 1400 feet, comparison of the 1980 and 1993 surveys shows no consistent trend with some radii larger and some smaller (by as much as about 50 feet). However, the general cavern shape is unchanged. Again, the difference is attributed to the variability in sonar logging technique.

4. The bottom portion of the cavern and the total depth are essentially unchanged from the 1980 survey.

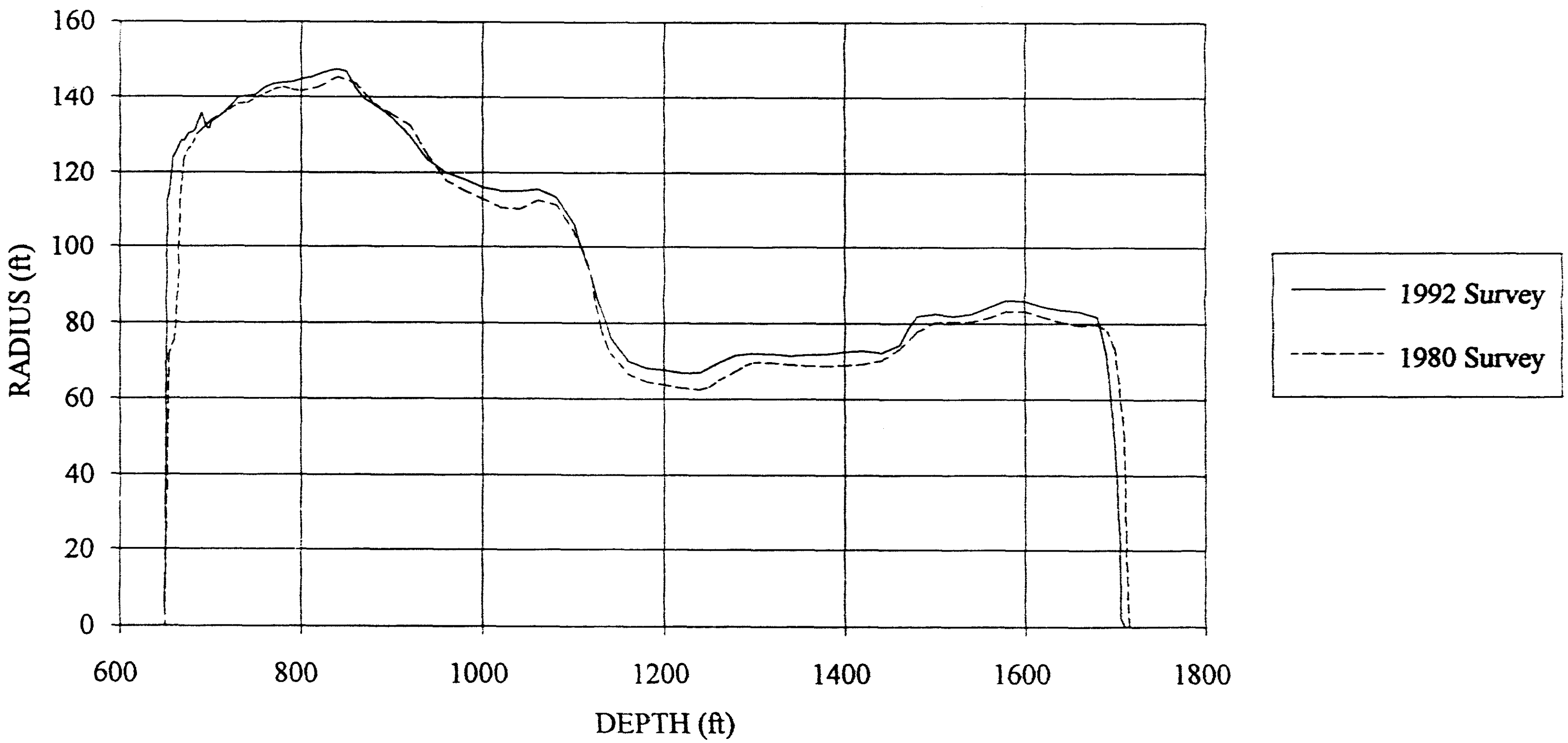
APPENDIX C

One way of graphically showing the similarity between the two surveys is to calculate an effective radius from the incremental cavern volume reported at each survey station. When presented as a function of depth, this type of plot represents a symmetrical cavern having the same vertical volume distribution as the real cavern. The attached figure shows an overlay of the profiles for the 1980 and 1992 surveys. The difference between the two profiles is generally less than 5 percent and is comparable to the advertised sonar survey accuracy. We again conclude that the surveys, taken about twelve years apart, do not show evidence of change.

copy:

J. K. Linn, 6113
J. T. Neal, 6113
J. L. Todd, 6113

CALCULATED RADIUS vs DEPTH
Bayou Choctaw Cavern 4



APPENDIX D

Computer Generated Graphical Representation of Cavern 101, Bayou Choctaw

APPENDIX D

Graphical display of Cavern 101, using sonar-derived geometry from digital tapes. View of cavern is rendered in positive relief, whereas actual geometry is negative, i.e., a void. Courtesy P.S. Kuhlman, Sandia National Laboratories.

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