

SITE GEOTECHNICAL CONSIDERATIONS FOR EXPANSION OF THE STRATEGIC PETROLEUM RESERVE (SPR) TO ONE BILLION BARRELS

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ABSTRACT

Eight Gulf Coast salt domes have emerged as candidate sites for possible expansion of the Strategic Petroleum Reserve (SPR) to one billion barrels. Two existing SPR sites, Big Hill, TX, and Weeks Island, LA, are among the eight that are being considered. To achieve the billion barrel capacity, some 25 new leached caverns would be constructed, and would probably be established in two separate sites in Louisiana and Texas because of distribution requirements.

Geotechnical factors involved in siting studies have centered first and foremost on cavern integrity and environmental acceptability, once logistical suitability is realized. Other factors have involved subsidence and flooding potential, loss of coastal marshlands, seismicity, brine injection well utility, and co-use by multiple operators.

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Introduction and Purpose

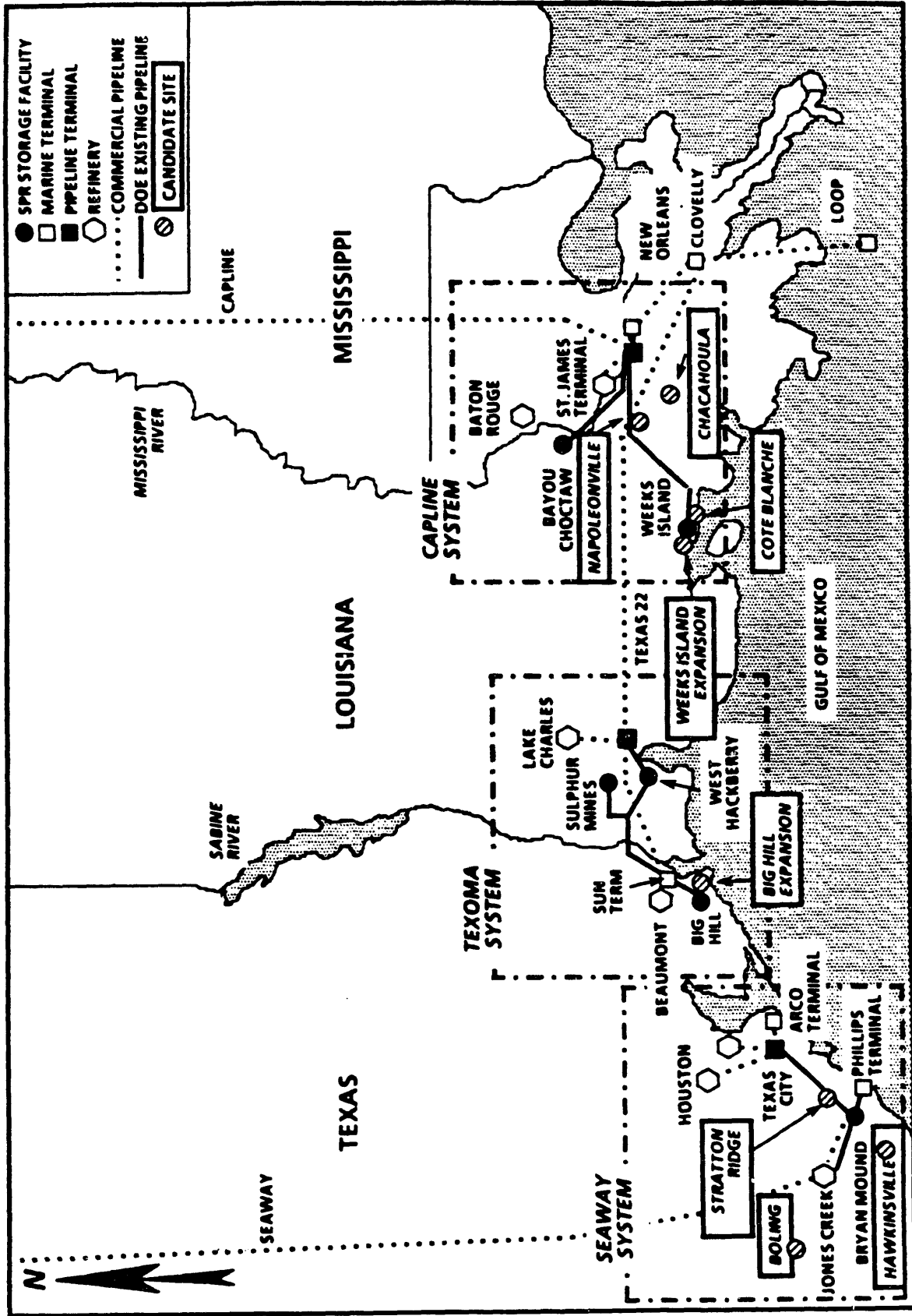
Initial site geotechnical information needed for expansion of the SPR to one billion barrels was provided in the 1989 report by DOE [1], the primary reference for DOE's report to Congress [2]. The information that was provided in these reports was produced rapidly during December 1988, using readily available information. Expediency precluded detailed examination of the geometry of individual domes, which must be interpreted from well records and from company files. In most cases such information could not be provided. As a result, considerable uncertainty remained regarding conclusions on additional storage potential at individual sites. Chacahoula dome, LA, was the only site that received follow-up study [3], and appropriate modifications were made to the 1989 conclusions.

The Energy Policy and Conservation Act Amendments passed by Congress in 1990 authorized further study for expanding the SPR to one billion barrels. The summary presented here updates reference [1], and attempts to look at potential candidate sites in more detail, similar to that provided in the Chacahoula study [3]. Time constraints also limited the scope of this study; appropriate qualifications were made where geotechnical uncertainty remained.

A number of geotechnical concerns affect the sites in varying degrees, but not necessarily the same concerns at every site. The concerns were discussed in appendices to each applicable site report; they are discussed together here to provide a perspective on the overall siting implications.

Summary information was provided for ten domes: Chacahoula, Cote Blanche, Napoleonville and Weeks Island in Louisiana, and Big Hill, Hawkinsville, Clemens, Stratton Ridge, Boling, and Gyp Hill in Texas [4]. The purpose of this report was to enable a focusing of knowledge about specific sites, and provide basic geotechnical data for making comparisons between sites. Possible cavern locations and depths are shown on maps in each of the separate site reports, but must be considered tentative, pending more comprehensive study of suitability.

The geotechnical information leading to the identification of eight candidate sites (Fig. 1) was summarized in DOE's 1991 report to Congress [5]. Clemens and Gyp Hill domes in Texas were excluded because of low capacity and remoteness, respectively.



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FIGURE 1. LOCATION OF EXISTING AND CANDIDATE STRATEGIC PETROLEUM RESERVE SITES

SITE GEOTECHNICAL SUMMARY

The following preliminary summary considers primarily the geotechnical aspects of candidate sites for an SPR expansion to one billion barrels, but also includes other pertinent data that affects site suitability. Table 1 summarizes these findings.

CAPLINE DISTRIBUTION GROUP (LOUISIANA)

Weeks Island (Fig. WI-1) has space for 200 MMB in leached caverns on the east side of the dome, but requires careful analysis regarding compatibility with existing mining and oil storage. Limited additional storage on the north and south perimeter of the existing oil storage may be possible, but this encroaches on existing mining and oil production facilities. Geotechnical uncertainty remains regarding an apparent major east-west shear zone which transects the dome.

Cote Blanche (Fig. CB-1) has space for up to 200+ MMB in leached caverns, is geotechnically similar to Weeks, and conceivably the salt could have more value than at Weeks because the salt is immediately adjacent to an operating mine. The room-and-pillar mine has several major drawbacks for oil storage, and though it now has nearly 75 MMB capacity, it is not recommended as a candidate storage site for geotechnical reasons.

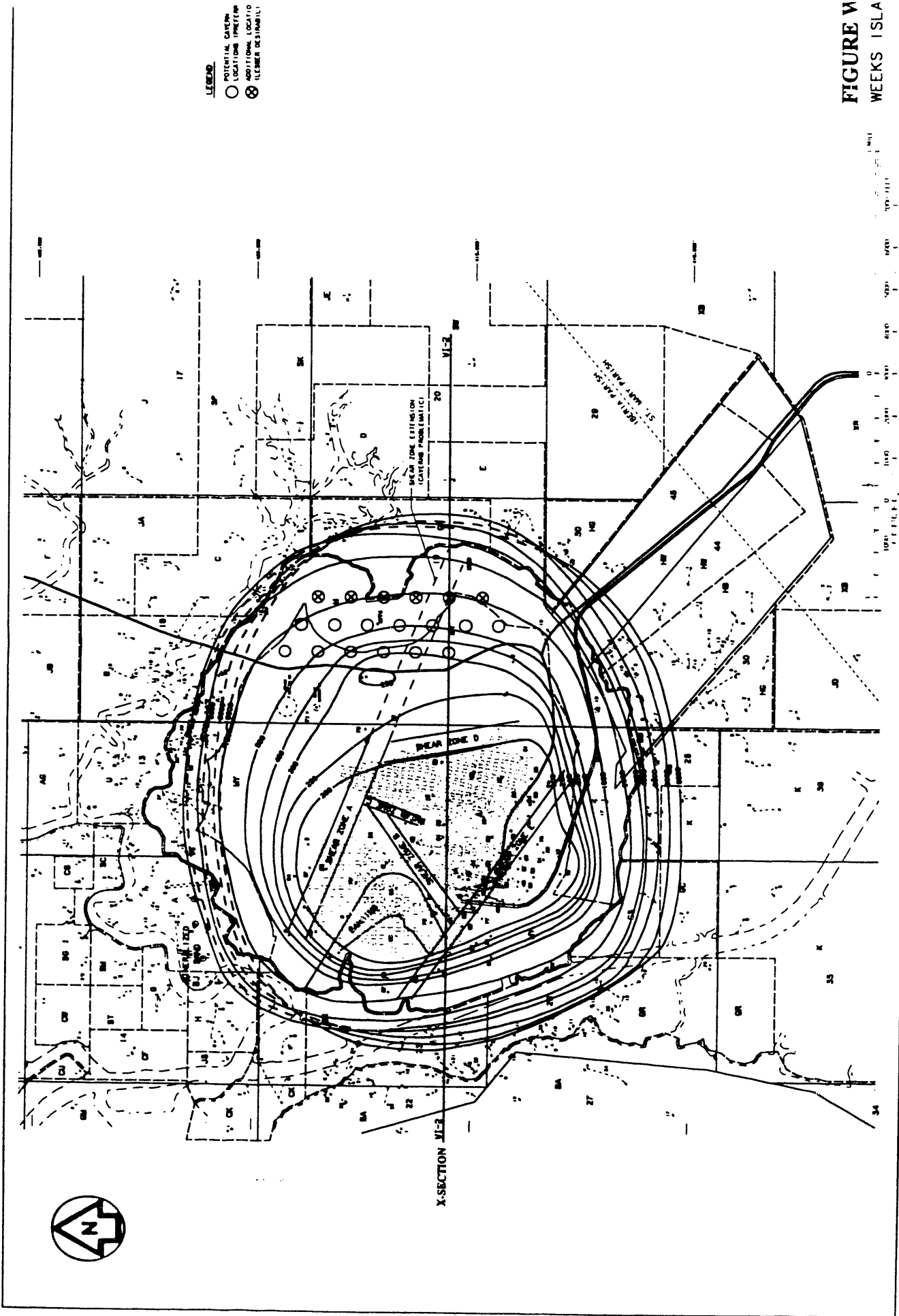
Use of Weeks Island or Cote Blanche dome for SPR would presumably require indemnification of ongoing mining operations. Both of these domes are essentially tied to the existing distribution system, but would have to be treated as new sites with respect to leached cavern systems. Both would require ~40 mi brinelines to the Gulf. Both are progressively becoming (within ~40-50 yrs) true islands, not just islands in the coastal marsh.

Chacahoula (Fig. Ch-1) has space for 250+ MMB and has no serious geotechnical flaws, but brine disposal would be either via an elaborate well injection system, or long (60+ mi) and costly pipeline to the Gulf. Subsidence and flooding in this area will become progressively more serious after about 2015, regardless of SPR usage.

Napoleonville (Fig. Na-1) barely has space for 100 MMB in leached caverns, and has a major concern in brine disposal, either by well injection or 80 mi brineline to the Gulf. A major environmental concern involves crowding with other co-users of the dome, with its 45 commercial brine and LPG caverns, and the potential exists for major subsidence in a few years.

TABLE 1 SUMMARY OF POTENTIAL EXPANSION SITES

Site	Location	Storage, MMbbl (Confidence)	Existing Facilities	Cap Salt Depth	Caprock	Dome Configuration	Proter Cave Shale Sheath	Concerns
Chacaboula, LA Lafourche Parish	10 mi SW of Thibodaux, LA	250+ (H)	3 small brine caverns; peripheral oil and gas	875/1100	thin on W; former sulphur mining on east; probably hot	elliptical; N overhang	deep	- brine disposal - subsidence
Cote Blanche, LA St. Mary Parish	18 mi SE of New Iberia, LA	200+ (H)	N. Amer. Salt Co. mine; peripheral oil and gas	none/290	none	elliptical; N overhang	deep	- proximity to mine
Napoleonville, LA Assumption Parish	16 mi W of St. James Terminal	100 (M)	45 LPG and brine caverns - peripheral oil and gas	415/618	minimal thickness	elliptical S/SW o'hang	middle Miocene	- brine disposal - co-use; subsid
Weeks Island, LA Iberia Parish	14 mi S of New Iberia, LA	200 (H)	Morton Salt Co. mine; peripheral oil and gas	none/43	none	circular; N overhang	deep	- - - - -
Big Hill, TX Jefferson County	17 mi SW of Port Arthur, TX	125 (H)	14 SPR caverns; 2 small LPG caverns (UNOCAL)	200/1600	thick and faulted; problems solved	circular; S&W o'hang	Anahuac	- - - - -
Boling, TX Wharton County	9 mi E of Wharton, TX	100+ (H)	SULPHUR: 4 gas caverns; caprock oil production	383/975	extensive sulphur mining on east; hot	elliptical; N overhang?	deep	- co-use; capro - S mining effe
Clemens, TX Brazoria County	12 mi NW of Bryan Mound, TX	30 (M)	17 LPG & 2 brine caverns; minor oil and gas	520/1373	former mining; hot	elliptical; NW overhang	deep	- dome size/spac - co-use; subside
Gyp Hill, TX Brooks County	5 mi SSE of Falfurrias, TX	100 (M)	none; former gypsum quarry	surf/900	former gypsum quarry	uncertain size/shape	deep	- dome definitio
Hawkinsville, TX Matagorda County	18 mi W of Bryan Mound, TX	100 (L)	none; power line crossing	95/420	thin	elliptical NE o'hang	unknown	- dome definitio - size overhang
Stratton Ridge, TX Brazoria County	6 mi N of Freeport, TX	150 (H)	57 LPG & brine caverns; peripheral oil and gas	870/1130	faulted	circular; E overhang	reef	- active faults; - co-use; subside
EXISTING SITES								
Bayou Choctaw, LA Iberville Parish	13 mi SW of Baton Rouge, LA	20 (M)	8 LPG & brine caverns; peripheral O & G; SPR	237/629	gypsum	circular; SE overhang	deep	- co-use; crowd - subsidence
West Hackberry, LA Cameron Parish	20 mi SW of Lake Charles, LA	50+ (H)	10 LPG caverns (oxy); peripheral O & G; SPR	1200/1700	minimal; few problems	elliptical N overhang	Hackberry	- subsidence; - co-use
Bryan Mound, TX Brazoria County	4 mi SW of Freeport, TX	50 (M)	SPR is the only activity	680/1136	hot; former mining	circular; S overhang	Anahuac	- overhang def'n - available spac



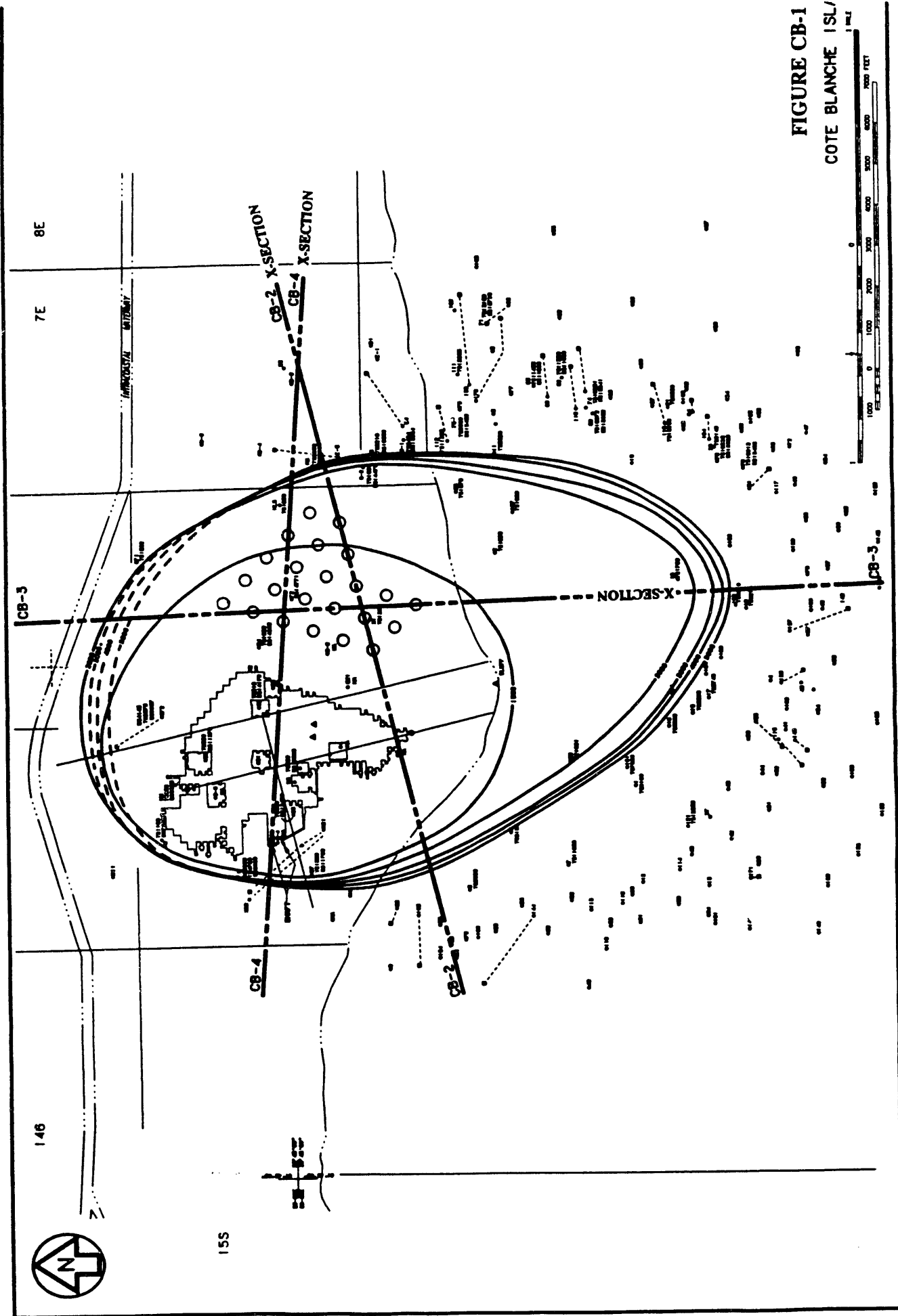


FIGURE CB-1
COTE BLANCHE ISL.

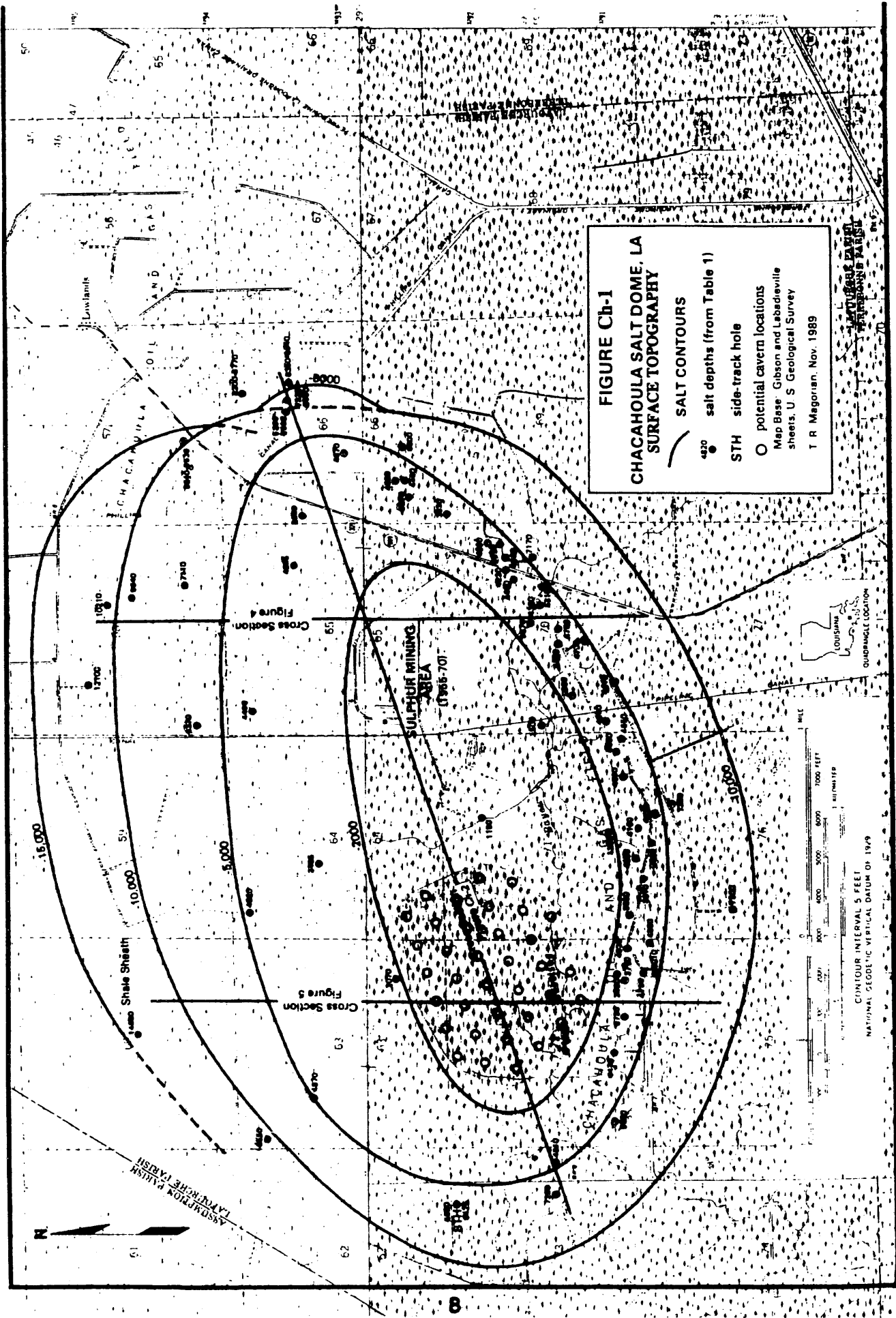


FIGURE Ch-1
CHACAHOULA SALT DOME, LA
SURFACE TOPOGRAPHY

SALT CONTOURS

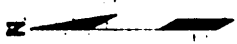
- salt depths (from Table 1)
- side-track hole
- potential cavern locations

Map Base: Gibson and Lebedeville sheets, U. S. Geological Survey
 T. R. Magorran, Nov. 1989



0 1000 2000 3000 4000 5000 6000 7000 FEET
 0 1 2 3 4 5 6 7 8 9 10 MILE

CONTOUR INTERVAL 5 FEET
 NATIONAL GEODESIC VERTICAL DATUM OF 1949



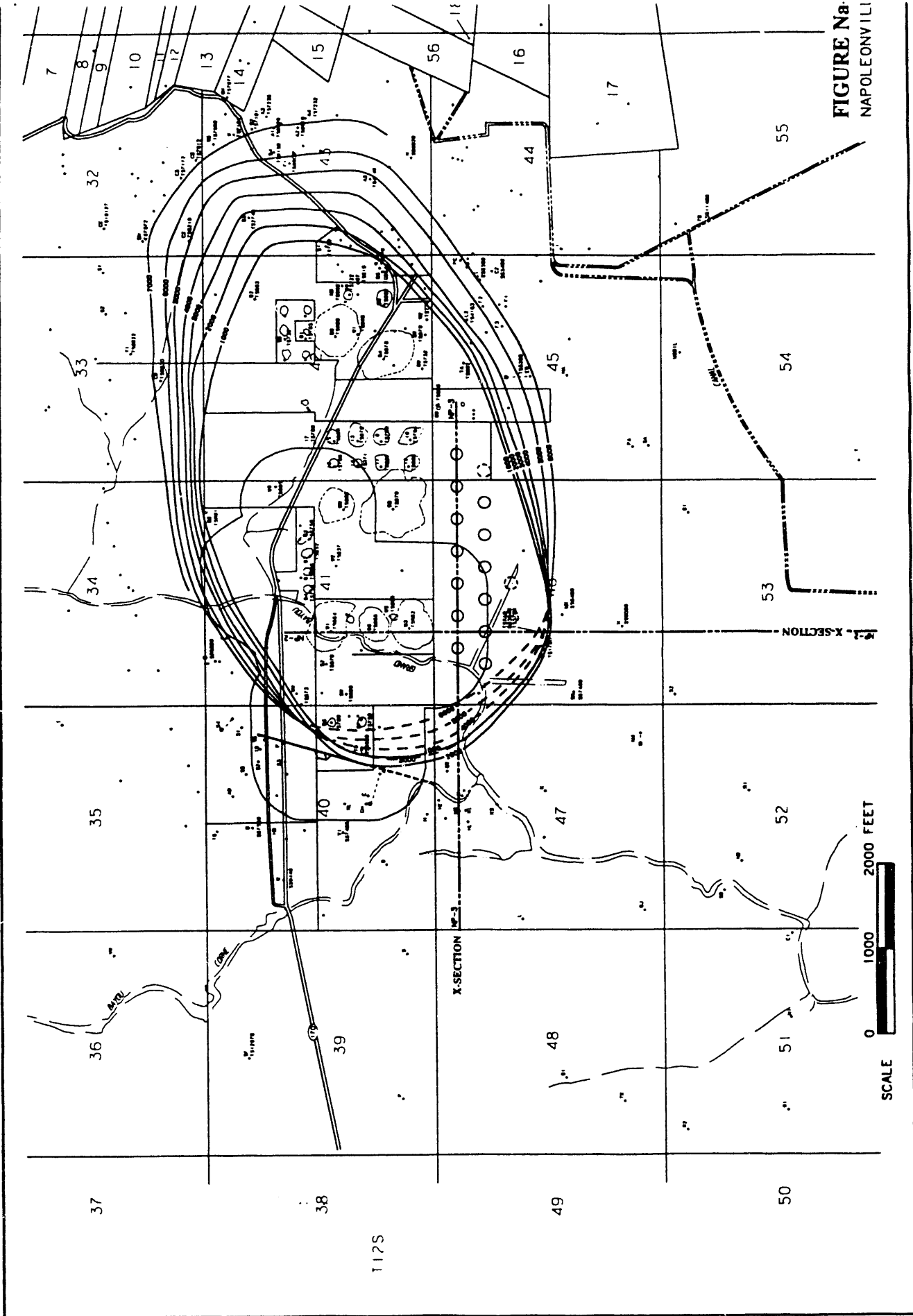


FIGURE No. 1
NAPOLEONVILLE

1125

TEXOMA / SEAWAY DISTRIBUTION GROUPS (TEXAS)

Big Hill (Fig. BH-1) is virtually assured of space for 125 MMB in leached caverns, by extending the current grid of 14 SPR caverns. The site appears to be free of major impediments, unlike most of the other candidate sites. Geotechnical uncertainty remains regarding the northwest overhang, and an apparent north-south trending shear zone. There is no evidence that this shear zone has affected the existing SPR cavern field, but it appears prudent to be knowledgeable of its location and properties, and probably to position new caverns away from it.

Boling (Fig. Bo-1) has several square miles that potentially could contain 150+ MMB in leached caverns. But the location may be more costly for brine disposal and distribution. The limited amount of former sulphur mining is probably not a concern on the west side of the dome, and adequate separation from current commercial gas storage could be achieved.

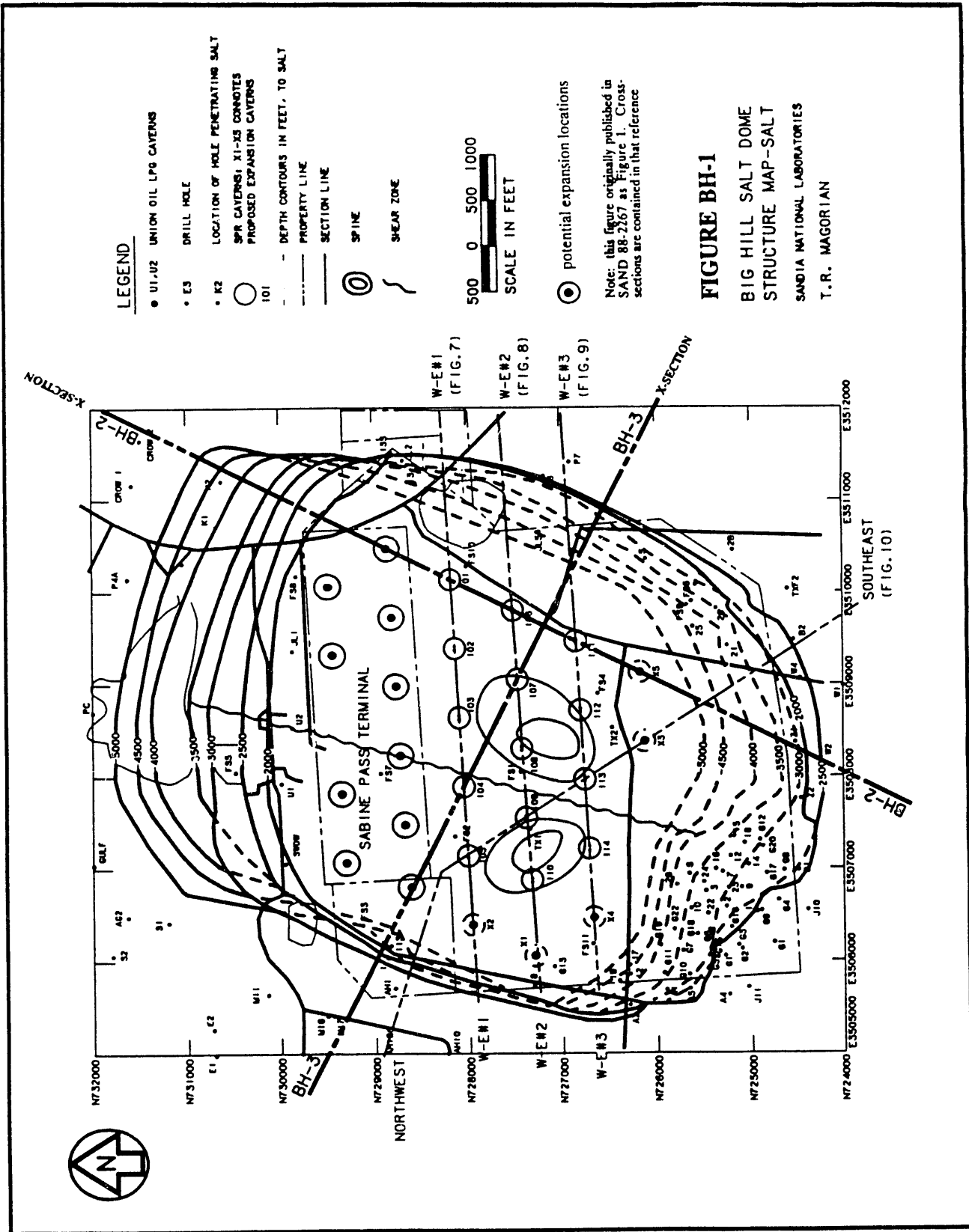
Clemens (Fig. Cl-1), upon reanalysis, has only about 50 acres that are potentially available for SPR caverns, possibly allowing room for 3 or 4 caverns. This is a markedly different conclusion from that stated in the 1989 DOE Report to Congress, which was based on limited data. In addition, sulphur had been mined formerly, and the potential area is adjacent to Phillips' 19-cavern LPG storage facility.

Hawkinsville (Fig. Ha-1) possibly has space for ~100 MMB in leached caverns and no current or former use by oil or mining. However, geophysical verification is needed to define the postulated overhang. Its location, 19 mi west of Bryan Mound, would facilitate distribution through current connections; brine disposal via 12 mi brineline to the Gulf would be advantageous.

Stratton Ridge (Fig. SR-1) has space for ~150 MMB in leached caverns and is well situated with respect to distribution and brine disposal systems. Co-use with 57 commercial caverns and a potential for environmental effects of subsidence would have to be reconciled. A major active fault with vertical offset of some 2000 ft transects the eastern one-third of the dome and effectively must be treated as the dome edge.

CORPUS CHRISTI GROUP (TEXAS)

Gyp Hill (Fig. GH-1) may have space for ~100 MMB, but requires substantial geophysical studies to confirm this volume. The site did not receive detailed study because of its remote location away from major distribution centers.



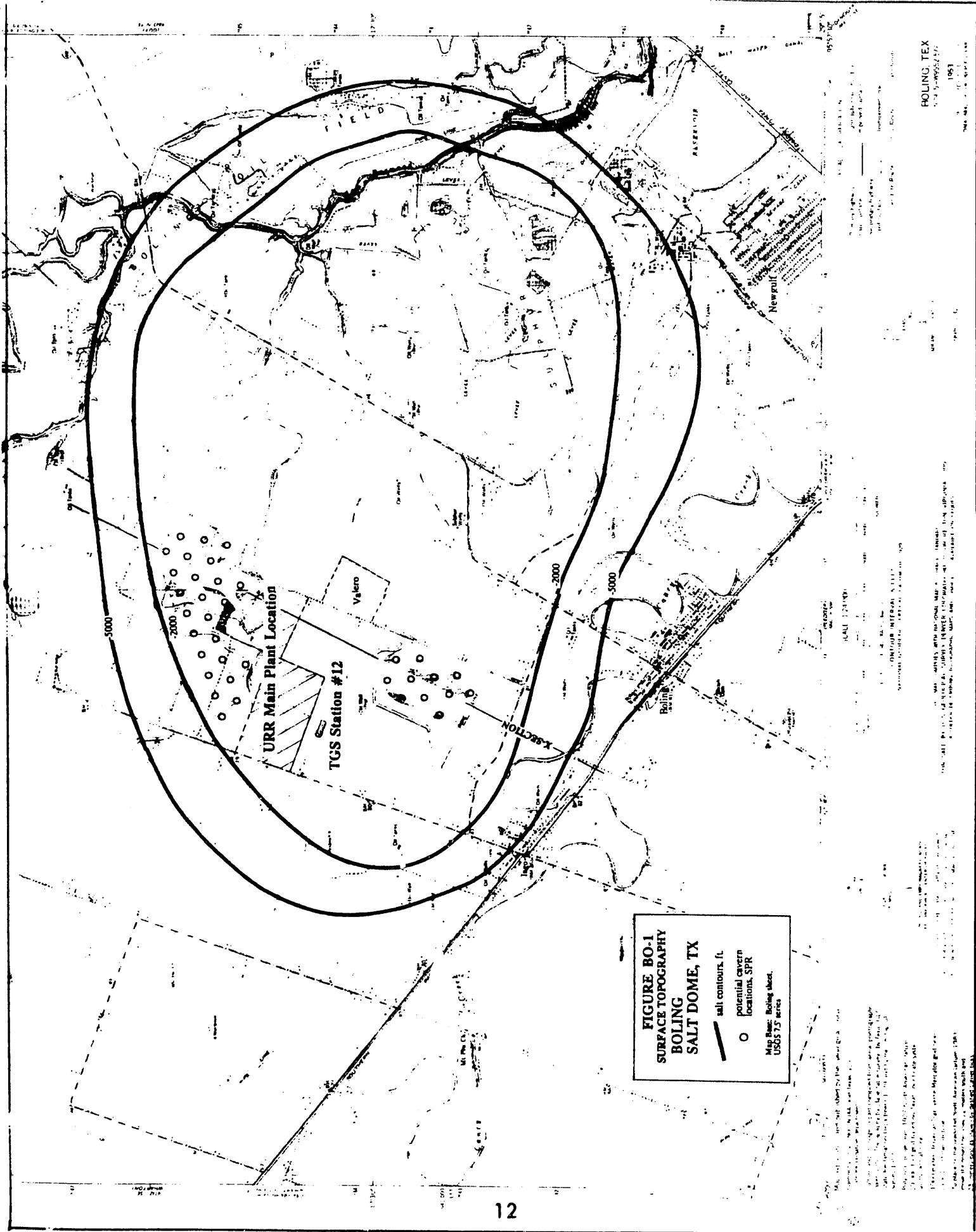


FIGURE BO-1
SURFACE TOPOGRAPHY
BOLING
SALT DOME, TX

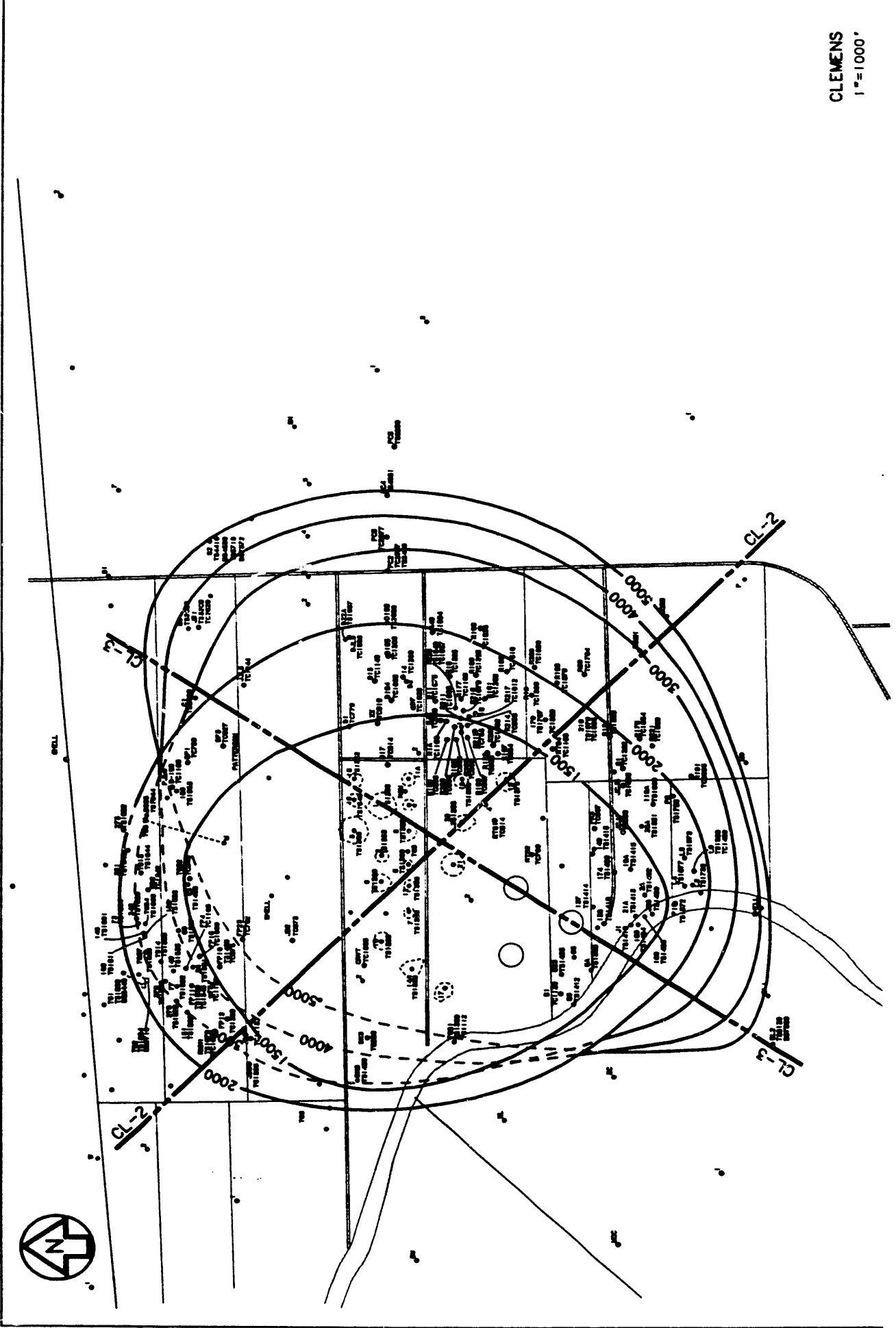
— salt contours, ft.
 O potential cavern locations, SPR

Map Base: Boling sheet, USGS 7.5 series

BOLING, TEX.
 1951



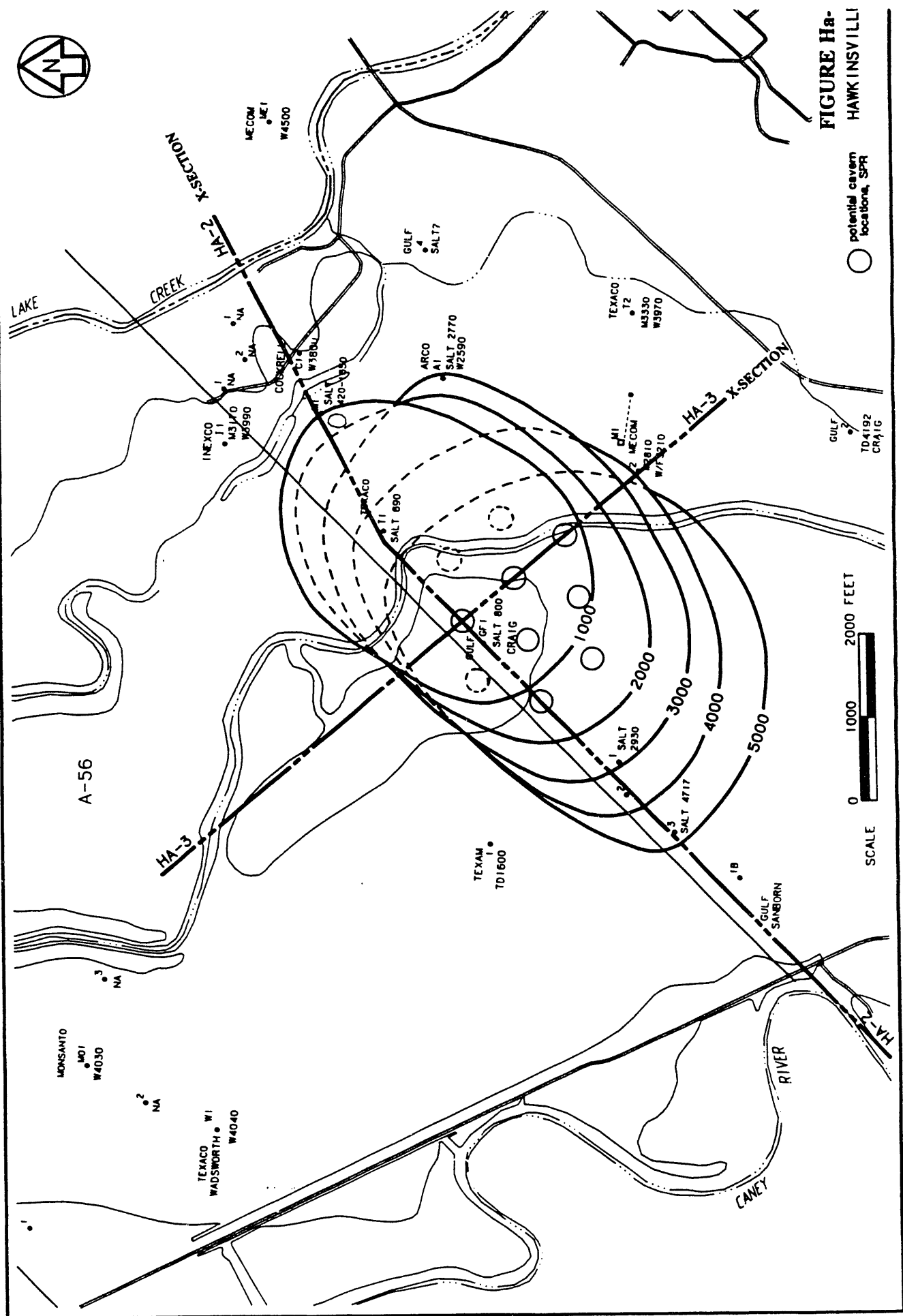
NO 8/2/81 FILE: 080001
DIR: P078412 BLDG: 080018



CLEMENS
1" = 1000'



FIGURE Ha-
HAWKINSVILLE



○ potential cavern locations, SPR

SCALE
0 1000 2000 FEET

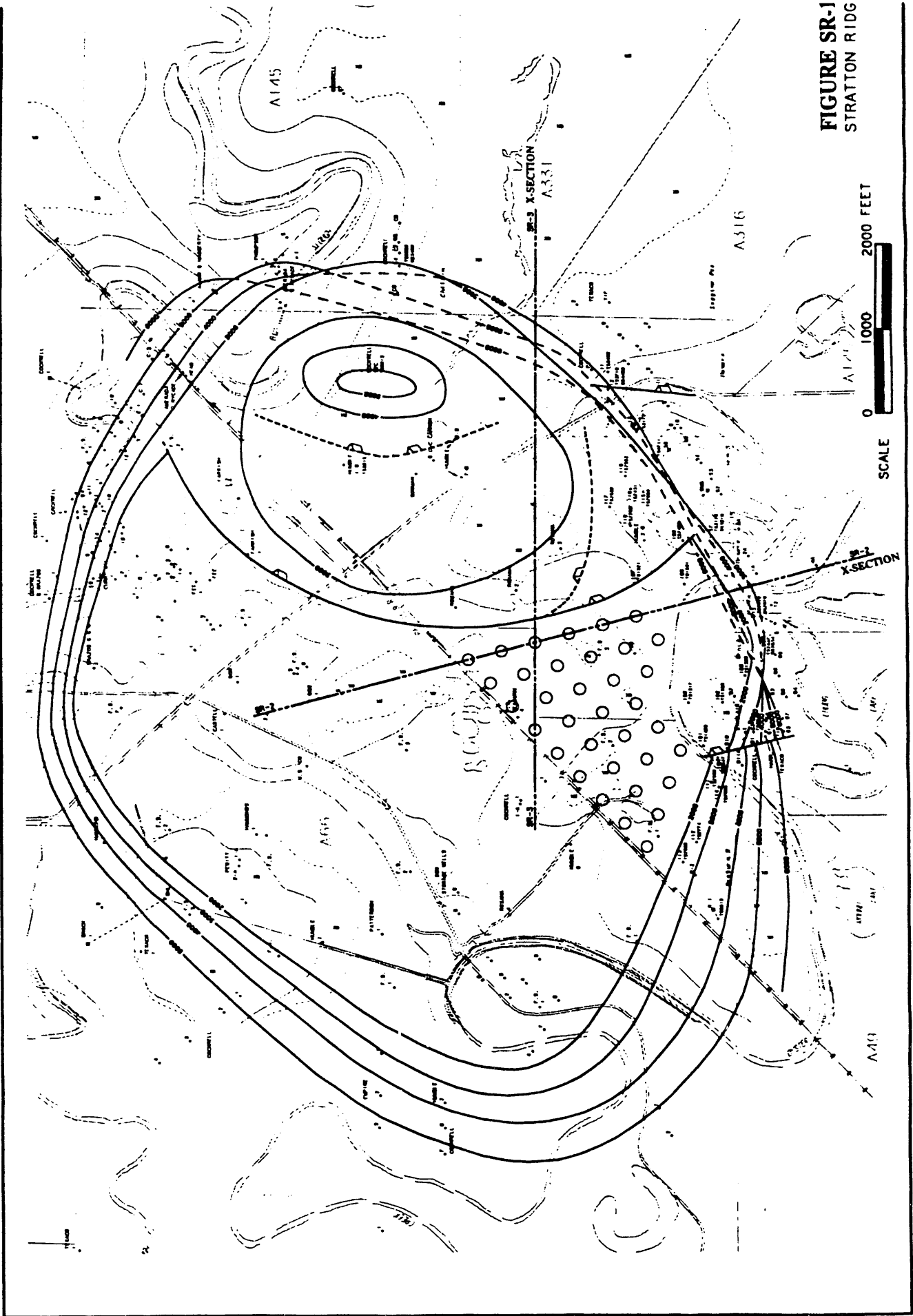
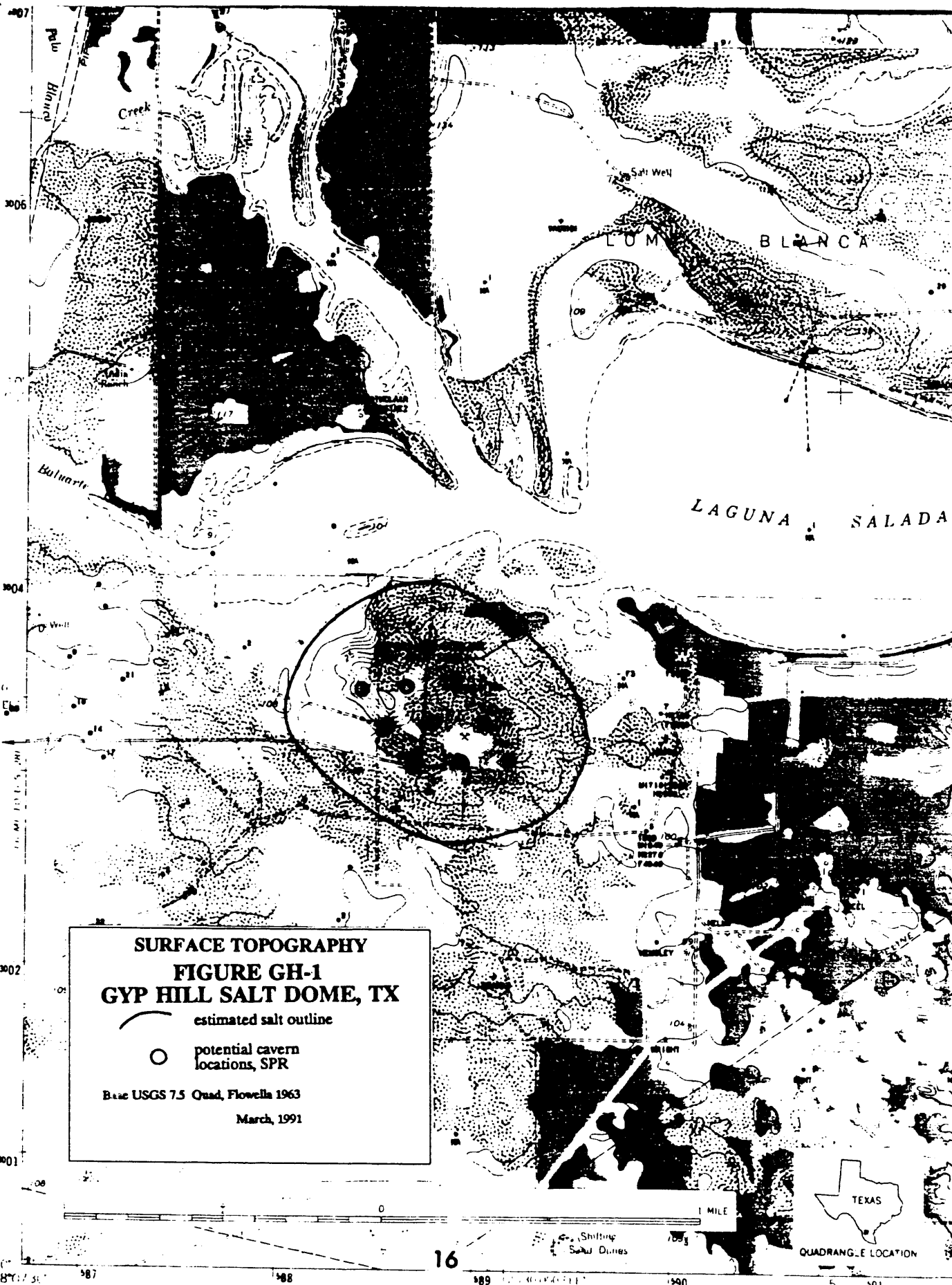


FIGURE SR-1
STRATTON RIDGE

SCALE
0 1000 2000 FEET



SURFACE TOPOGRAPHY
FIGURE GH-1
GYP HILL SALT DOME, TX

— estimated salt outline

○ potential cavern locations, SPR

Base USGS 7.5 Quad, Flowella 1963
 March, 1991



**POTENTIAL GEOTECHNICAL SITING CONCERNS
APPLICABLE TO MULTIPLE SITES**

Identification of Concerns

Major system issues in the siting of SPR facilities generally focus on *safety, security, environment, and cost*. Rarely are they mutually exclusive, and one issue may often affect another -- most often cost. Geotechnical siting concerns were discussed in a generic sense in the appendices listed below, and applied to individual sites (Table 2).

Summary of Appendices to Site Reports (not included here)

Appendix A examines expansion potential of existing SPR sites and concludes that locations for additional cavern space exist off of DOE property at Bayou Choctaw, Bryan Mound, and West Hackberry; space for 20-50 MMB or more possibly remains at each dome. Because storage at these sites would tend to "shoehorn" caverns unfavorably toward the dome edges, there are no plans to seriously consider this option.

Appendix B addresses the possibility of using the room and pillar salt mine at Cote Blanche for oil storage. Although the present volume is nearly equal to that presently at the Weeks Island SPR facility (~75 MMB), and will increase by ~12 MMB in another five years, there are several geotechnical factors that would probably be unfavorable for SPR oil storage.

Appendix C reviews the current state-of-the-art for brine disposal in injection wells, which may be a viable alternative to disposal in the Gulf of Mexico for sites with brine pipelines that are ~40 mi or more in length. Improved methods, larger casing, preferred injection horizons, and rate optimization could yield 50,000 BPD/well or greater. Deliberate, protracted leaching schedules can make this a practical and economical solution for brine disposal. Thus, a 25-well field could accommodate a one million BPD leach schedule. Lessons learned from existing SPR disposal wells suggest it can be made more effective than that achieved earlier in the project.

Appendix D reviews the land loss problem in Louisiana's coastal marshlands and shows that Chacahoula, Cote Blanche, Weeks

TABLE 2

USE OF APPENDICES IN SITE REPORTS

APPENDIX	SITE									
	CHACAHOULA	COTE BLANCHE	NAPOLEONVILLE	WEEKS ISLAND	BIG HILL	BOLING	CLEMENS	GYP HILL	HAWKINSVILLE	STRATTON RIDGE
A - Existing Site Expansion (Bayou Choctaw, West Hackberry, and Bryan Mound- Weeks Island and Big Hill are addressed separately)										
B - Cote Blanche Mine Status		●								
C - Brine Injection Wells	●	●	●	●		●				
D - Coastal Marshland Loss	●	●		●						
E - Co-Use Considerations	●	●	●	●	●	●	●			●
F - Cavern Design Criteria			●				●		●	
G - Subsidence Prediction	●	●	●	●			●		●	●
H - Seismicity	●	●	●	●						
I - Flooding Potential	●	●	●	●			●		●	●

CONTRIBUTORS [Appendix]

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- Thomas R. Magorian, Consultant, Amherst, NY - [A]; [C]
- James T. Neal, Sandia National Laboratories - [A]; [D]; [E]; [G]; [H]; [I]
- James L. Todd, Sandia National Laboratories - [F]
- Therese M. Short, Acres International Corporation - [C]
- David C. Steuernagel, Acres International Corporation - [C]

Island, and West Hackberry are vulnerable for the years beyond 2020 unless mitigation is undertaken. Texas coastal sites have different geological conditions and are not a problem.

Appendix E considers possible safety and environmental constraints at domes with multiple operations. Ideally, domes dedicated entirely to SPR would be preferred, but in practice few such domes exist. Nonetheless, fewer competing purposes may be the preferred condition.

Appendix F considers minor alterations in the SPR Phase III Criteria, which might be invoked where slightly deeper or more closely-spaced caverns could be emplaced. Such deviations would not affect cavern integrity, nor would they have a significant cost impact, but they could enable some marginal sites or situations to qualify for a minimum amount of storage volume.

Appendix G considers subsidence prediction at SPR sites, which is expected in solution mining. Subsidence invariably will be a factor to consider, especially at sites which have elevations of 10 ft or less (includes Chacahoula, Napoleonville, Bayou Choctaw, West Hackberry, Stratton Ridge, Clemens, Hawkinsville, and Bryan Mound). Creep closure and associated subsidence are also of concern at the higher elevations of Weeks Island (and would be at Cote Blanche Mine), but their greatest impact is in conjunction with coastal storms and associated flooding of the lowland areas.

Appendix H addresses Gulf Coast seismicity, as numerous questions recur in this regard. However, seismicity is not a siting issue in any sense; at existing and proposed sites the mean horizontal accelerations with a 90% probability of non-exceedance in 250 years are only 3-4% of gravity, a very small force.

Appendix I considers flooding at the lower-elevation sites, and in conjunction with coastal storm surges. Bayou Choctaw, Napoleonville, Chacahoula, and West Hackberry are impacted just because of their low elevation, but sites nearer the coast (Bryan Mound, Stratton Ridge, Hawkinsville, and Clemens) are vulnerable to overland surge. The near-coastal locations at Weeks Island, Cote Blanche, and Big Hill, although flood-dry during hurricanes, could be temporarily inaccessible because of overland surge covering the coastal marshlands.

CONCLUSIONS

No final sites have been identified as of this writing, but it is clear that the Weeks Island and Cote Blanche domes in Louisiana, and Big Hill and Stratton Ridge domes in Texas offer cost and distribution advantages. The selection of sites will be part of the NEPA process and subject to further Congressional action. The SPR Plan to be issued in September 1992 will indicate possible options regarding sites, schedules and cost.

References

- [1] U. S. Department of Energy, Strategic Petroleum Reserve Project Management Office, New Orleans, Expansion of the Strategic Petroleum Reserve to One Billion Barrels: Site Identification, Screening and Selection, February 1989.
- [2] U. S. Department of Energy, Office of Strategic Petroleum Reserve, Report to the Congress on Expansion of the Strategic Petroleum Reserve to One Billion Barrels, Report No. DE/FE-0126, April 1989.
- [3] Magorian, T. R., and J. T. Neal, Sandia National Laboratories, SAND89-2894, Petroleum Storage Potential of Chacahoula Salt Dome, Louisiana, January 1990.
- [4] U. S. Department of Energy, Strategic Petroleum Reserve Project Management Office, New Orleans, Site Geological Characterization for Strategic Petroleum Reserve (SPR) Expansion Candidate Sites, Vol. II, Mar. 15, 1991.
- [5] U. S. Department of Energy, Office of Strategic Petroleum Reserve, Wash. D. C., Report to the Congress on Candidate Sites for Expansion of the Strategic Petroleum Reserve to One Billion Barrels, Report No. DOE/FE-0221P, March 1991.

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