# HAZARDS ANALYSIS, BUILDING 950, BROOKS AIR FORCE BASE, BEXAR COUNTY, TEXAS

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November 19, 1975

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## Summary of Conclusions

Based on available information, building 950 is a suitable site for storage of lunar samples. The only apparent hazard is the high shrink-swell capacity of the soil. This soil property should be considered in any modifications to the building.

## Introduction

This study was conducted by the Bureau of Economic Geology, The University of Texas at Austin, for the Johnson Space Center of the National Aeronautics and Space Administration. Its purpose is to ascertain any potential hazards to building 950, Brooks Air Force Base, San Antonio, Bexar County, Texas, the proposed site selected for long-term storage of a portion of the lunar sample collection.

The authors express their appreciation to Charles M. Woodruff, Jr., Geologic Consultant, General Land Office (on leave from the Bureau of Economic Geology), for providing information on map units and local geology; to C. R. Gilbert, Water Resources Division, U. S. Geological Survey, for flood-plain and hydrologic information; and to Melroy I. Brandt, Chief of Engineering and Construction, Brooks Air Force Base, for information and assistance in the on-site investigation.

## Regional Geology

Bexar County is located on the northern edge of the Gulf Coastal Plain, which is separated from the Edwards Plateau by the Balcones Escarpment. The topographic and physiographic divisions in Bexar County are largely determined by the geologic structure of underlying formations. Formations underlying the Coastal Plain dip in general to the southeast, and consist of Tertiary and Quaternary clastic sediments. Formations underlying the Edwards Plateau are essentially horizontal and are composed of Cretaceous carbonate rocks. Bexar County includes locally extensive developments of stream terrace deposits. These cut across and cover over older formations, masking surface features that would otherwise characterize the underlying strata.

The major streams in the map area, the San Antonio River and its tributary, Salado Creek, flow to the south or southeast. Both are spring fed and perennial, while all other streams in Bexar County are, at least in part, intermittent.

## Local Geology

Environmental geologic units (plate 1) define and catalog areas where certain kinds and amounts of activity could be carried out without losing acceptable levels of environmental quality. The elements which define environmental geologic units include: (1) geologic substrate and soil, (2) topography and landform morphology, (3) geologic process, (4) biota, and (5) human activity. In some cases, an environmental unit is composed of several elements. For example, the black-soil alluvial plain unit is defined in terms of geologic substrate, soil, and landform morphology. It is an alluvial plain composed of sand and gravel with a thick black or dark-brown clay loam. On the other hand, some units are defined on the basis of a single element, such as the gravel cap unit, which is defined by its composition (Gustavson and Cannon, 1974).

Flood plains (FP) (plate 1) occur as narrow, linear, slightly sloping areas bordering underfit incised streams. The mapped flood plains are subject to high-frequency flooding (table 1). The substrate beneath the flood-prone areas can be any bedrock type occurring along the river course. The major streams usually do not cut into the bedrock, however, but are bedded in alluvial material. Thick loamy or clayey soils develop on the alluvial material of the flood plain; in the channel itself, of course, soil-forming processes do not operate.

Terrace deposits (AT) are composed of gravel, sand, and mud with loamy soils more than 4 feet thick, and are immediately adjacent to active flood plains. These flat areas represent flood plains of older river systems, probably of Pleistocene age, that are being incised by the Modern river systems. They are generally undissected except along their edges. Terraces develop a brown, loamy soil, and may be subject to high-magnitude, low-frequency flood events.

Black-soil alluvial plains (BSAP), the unit on which the proposed facility (and most of the city of San Antonio) is located, are similar to terraces genetically and often physiographically. They are broad, flat surfaces also related to ancient river systems, and cap many of the stream divides in the San Antonio area. These units are older and occur above the terrace deposits of the San Antonio River and its tributaries and are not subject to flooding. Alluvial plains are underlain by calichified gravel with a thick development of black, clayey soil. The clayey soils have high shrink-swell capacity, and may pose some engineering problems at the surface. These will be discussed in the section dealing with soil cover of the area. The alluvium is composed of sandy limestone gravel, and of quartzose sand and chert gravel cemented by caliche. Slopes are generally less than 2 percent, but may be as high as 20 percent on the dissected edges. In areas of 2 percent or less slope and low permeability, there may be standing water after a rainfall.

Gravel caps (GC-cal) are composed of caliche and chert or limestone gravel. They are essentially dissected black-soil alluvial plains, eroded to the extent that the thick clay soils are no longer present; relict gravelly clay soils may remain. The gravel caps are areas of rapid infiltration, and form stable construction sites. These caps are erosionally resistant and occur above sandy mud substrates. They may be up to 50 feet thick, and flat on top with the eroded edges sloping 15 to 20 percent. The gravels comprising these deposits are highly calichified. Calichification is a pervasive soil process on all terranes in this climate (Woodruff, 1975).

Calcareous mud (CR-CS) areas are marked by a substrate consisting predominantly of calcareous, locally expansive clay muds with slopes of 0 to 15 percent. The soils of this unit are chiefly clay loams. The unit is gullied in areas that contain much silt, and is generally steeper below erosionally resistant gravel caps.

Dissected expansive mud (CMR) consists of sandy to clayey muds that are locally gypsiferous with slopes of 1 to 5 percent. Soils developed on these units have a high shrink-swell capacity and possess severe construction limitations.

Moderately rolling sandy mud (SMR) consists of interbedded sand and mud with slopes greater than 3 percent and sandy clay loam soils.

## Seismology

The Balcones Escarpment is a pronounced south- to southeast-facing faultline scarp that trends southwest to northeast through Central Texas. The faults that produced this feature were active during the Miocene (13 to 25 million years before present). Based on several kinds of stratigraphic evidence, no movement has taken place since that time, and the fault system poses no threat of earthquake hazard to the region (W. R. Muehlberger, V. E. Barnes, C. M. Woodruff, Jr., personal communications). In the immediate area of the lunar sample storage site, Plio-Pleistocene gravel (the black-soil alluvial plain) lies above faults of the Balcones system. These faults are inferred in the clay units (CR-CS) (plate 1), based on previous mapping (Arnow, 1963).

There is no evidence of faulting in the gravels, which indicates that there has been no fault movement since the Pliocene.

## Meteorology

The Balcones Escarpment, the major topographic feature in the region, lies approximately 15 to 20 miles north of the storage site. Orographic uplift of moisture-laden air passing over the escarpment often produces rainfall intensities far exceeding those normally experienced in the vicinity. Two types of high-intensity rainstorms mentioned by Baker (1975) are thunderstorms and storms of tropical origin.

Thunderstorms, the most violent form of atmospheric convection, result when thermal instability occurs in lifting air along a topographic rise or an isobaric convergence. In 1935, precipitation from an intense thunderstorm at D'Hanis, Texas (about 50 miles west of the storage site along the escarpment), resulted in 22 inches of rainfall in 2 hours 45 minutes.

Weather disturbances of tropical origin are responsible for the greatest flood-producing storms that affect Texas. These cyclonic storms (called hurricanes when winds exceed 75 mph) evolve from easterly waves that pick up enormous quantities of moisture from passage over warm tropical seas. Weather conditions in the Caribbean make stable easterly waves most likely to occur in September. If an especially vigorous wave reaches the orographic barrier of the

Balcones Escarpment, long-duration, heavy rains may result. This happened in the largest of all continental U. S. rainstorms, at Thrall, Texas (east of the escarpment between Austin and Temple), on September 9-10, 1921, which produced 38.2 inches of rainfall in 24 hours (Baker, 1975).

The recurrence interval of these high-intensity rainfalls is not known and cannot be predicted, nor can the degree of hazard to building 950 be predicted in the event of such a storm. It is prudent to recognize that storms of these magnitudes can occur.

Mean annual precipitation in the San Antonio area is about 30 inches, and is distributed fairly well throughout the year. Maxima occur in May and September, and result from convective thunderstorm activity and the movement of moisture-laden air along the established tropical Gulf storm track. Minima occur in winter and summer (Baker, 1975).

The location of San Antonio on the edge of the Gulf Coastal Plain results in a modified subtropical climate. Northerly winds prevail during most of the winter, and southeasterly winds from the Gulf of Mexico prevail during the summer and some of the winter.

Relative humidity is close to 80 percent early in the day throughout the year, and drops to around 50 percent in the afternoon.

No tornadoes of any consequence have been experienced in the immediate area (U. S. Department of Agriculture, 1966).

## Hydrology (Flood Plain)

Flood plains of both the San Antonio River and Salado Creek occur adjacent to the area of the proposed facility. However, inspection of the base map reveals that both flood plains are well removed areally or topographically from the proposed storage facility. Flooding of Salado Creek or the San Antonio River will not affect building 950.

The San Antonio River is channelized from about Hemisfair Plaza to just south of where Military Drive crosses the stream. At that point, the river is in its natural stream bed, although the entire length remaining of the river down to its junction with the Medina River is controlled and maintained by a Federal Flood Control Project. Locally, two spillover dams are evident on the base map, but their value in controlling a flood would be negligible, as they are filled under normal flow conditions. Olmos Reservoir Dam is the only impounding structure on the San Antonio River, and it is only a flood-retardation outlet and not a flood-control structure, with a maximum capacity of 15,500 acre-feet (C. R. Gilbert, personal communication).

The proposed facility at Brooks Air Force Base is located in an area dominated by fluvial geomorphologic features. The base map for this study was taken from work done by Woodruff for the Bureau of Economic Geology South Texas environmental geologic mapping project. Map units on the Southton quadrangle sheet delineated by Woodruff are defined in the local geology section of this report. Flood-plain units for both the San Antonio River and Salado Creek were mapped by the occurrence of natural geomorphic features present in the field. Boundaries of the flood-plain units represent the greatest extent to which a maximum flood crest might overbank for each river system. Delineation of flood-plain units, it must be emphasized, was not based on statistical or recording-period flood data and therefore is not bound by definitions of flood types developed by the U. S. Army Corps of Engineers and other agencies (see U. S. Army Corps of Engineers, 1969).

Bureau of Economic Geology mapping of flood-prone units was checked by hypothetically superimposing maximum flood height (for recording periods available) on the natural elevation of the stream at a point parallel (latitudinally) with the proposed facility. The proposed facility lies more than 40 feet above the highest recorded flood height of the San Antonio River (fig. 1) and more than 25 feet above that of Salado Creek.

Maximum recorded discharge on the San Antonio River at San Antonio was that of September 10, 1921, when a peak discharge of 15,300 cubic feet per second was estimated (table 1). No peak discharge since then has reached even half that figure. Calculation of recurrence interval may be done by several methods. The authors chose to use the USGS Water Resources Division's Log-Pearson Type III distribution method, because it gives a more representative recurrence interval in light of the peak discharges dealt with for the San Antonio River system. This method is especially good for spring-fed streams such as the San Antonio River (C. R. Gilbert, personal communication).

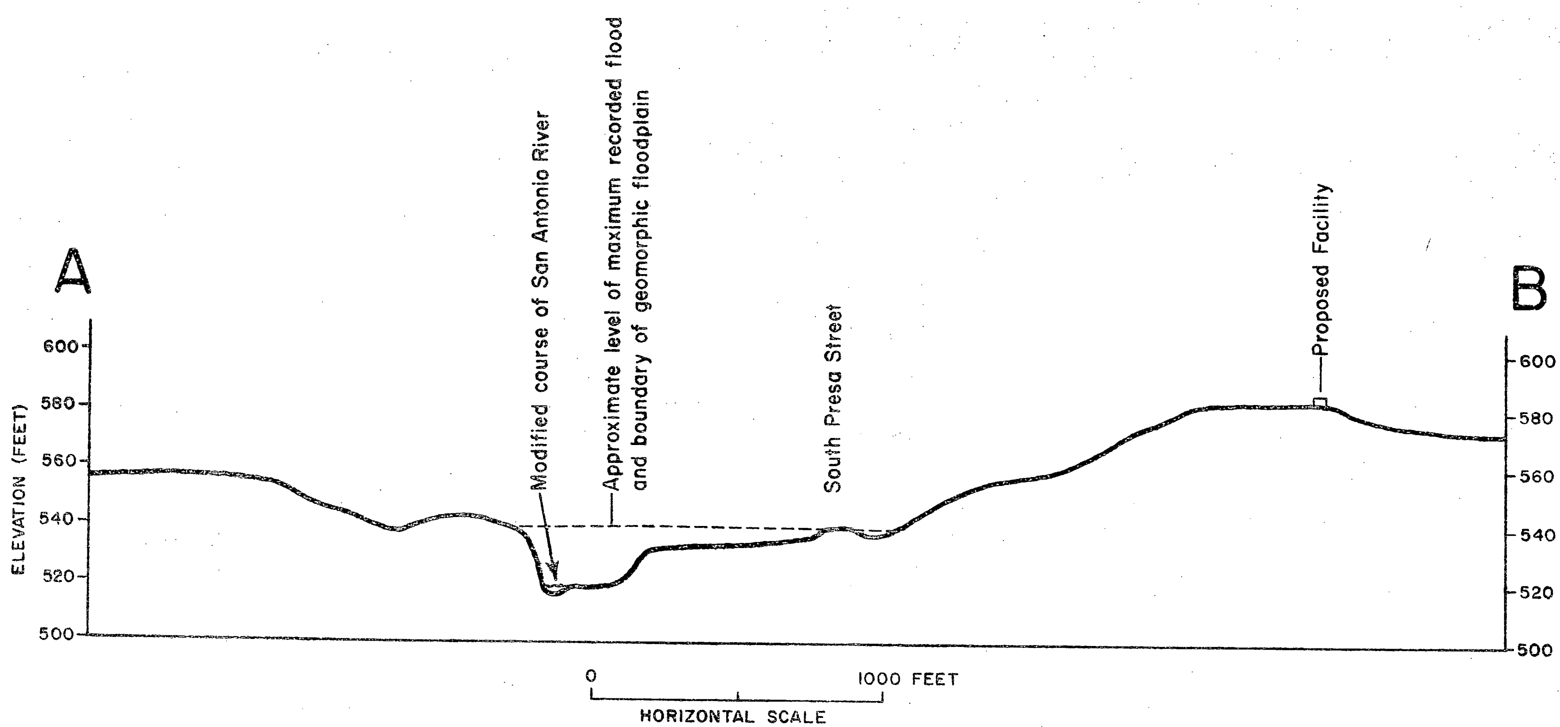


Figure 1. Schematic cross section showing the proposed facility in relation to the San Antonio River.

Table 1. Discharge data for San Antonio River at San Antonio. Gage datum 605.26 ft. (Data courtesy of U.S.G.S. Water Resources Division)

| | Water Year | Annual Peak Discharge (cfs) | Date |
|---|---|---|---|
| * | 1915 | 4600 | 10-23-14 |
| * | 1916 | 2650 | 09-25-16 |
| * | 1917 | 147 | 03-24-17 |
| * | 1918 | | 05-05-18 |
| * | 1919 | 2380 | 09-15-19 |
| * | 1920 | 2430 | 10-16-19 |
| * | 1921 | 15300 | 09-10-21 |
| * | 1923 | 390 | 07-21-23 |
| * | 1924 | 648 | 05-26-24 |
| * | 1925 | 641 | 05-10-25 |
| | 1926 | 1940 | 04-20-26 |
| | 1927 | 845 | 06-14-27 |
| | 1928 | 755 | 06-02-28 |
| | 1929 | 588 | 05-24-29 |
| | 1940 | 1040 | 06-29-40 |
| | 1941 | 1470 | 04-28-41 |
| | 1942 | 1680 | 09-04-42 |
| | 1943 | 2350 | 10-04-42 |
| | 1944 | 1260 | 09-06-44 |
| | 1945 | 1820 | 12-04-44 |
| | 1946 | 5740 | 09-27-46 |
| | 1947 | 984 | 11-10-46 |
| | 1948 | 2840 | 08-26-48 |
| | 1949 | 1640 | 06-25-49 |
| | 1950 | 1390 | 10-22-49 |
| | 1951 | 1800 | 06-03-51 |
| | 1952 | 363 | 09-18-52 |
| | 1953 | 1610 | 09-04-53 |
| | 1954 | 758 | 06-26-54 |
| | 1955 | 810 | 02-04-55 |
| | 1956 | 1230 | 05-15-56 |
| | 1957 | 1850 | 05-27-57 |
| | 1958 | 1210 | 06-22-58 |
| | 1959 | 772 | 05-16-59 |
| | 1960 | 2360 | 08-15-60 |
| | 1961 | 3410 | 07-22-61 |
| | 1962 | 1140 | 09-06-62 |
| | 1963 | 1500 | 09-12-63 |
| | 1964 | 1870 | 03-18-64 |
| | 1965 | 4510 | 05-18-65 |
| | 1966 | 1190 | 04-25-66 |
| | 1967 | 2240 | 09-15-67 |
| | 1968 | 5730 | 01-18-68 |
| | 1969 | 5360 | 09-23-69 |
| | 1970 | 5970 | 05-26-70 |
| | 1971 | 2610 | 06-21-71 |
| | 1972 | 3860 | 05-07-72 |
| | 1973 | 6090 | 09-27-73 |
| | 1974 | 3520 | 08-08-74 |

Peaks marked with * not passed to Log-Pearson Program

| Exceedance Probability | Recurrence Interval (years) | Magnitudes (cfs) |
|---|---|---|
| 0.9900 | 1.01 | 327.069 |
| 0.9500 | 1.05 | 578.350 |
| 0.9000 | 1.11 | 735.149 |
| 0.8000 | 1.25 | 987.354 |
| 0.5000 | 2.00 | 1759.955 |
| 0.2000 | 5.00 | 3194.571 |
| 0.1000 | 10.00 | 4394.809 |
| 0.0400 | 25.00 | 6209.949 |
| 0.0200 | 50.00 | 7787.934 |
| 0.0100 | 100.00 | 9567.023 *** R.I.> 2N |
| 0.0050 | 200.00 | 11569.137 *** R.I.> 2N |
| 0.0020 | 500.00 | 14597.477 *** R.I.> 2N |
| 1926-74 | No. of items = 39 | Station 8-1780.0 |

**Calculated Averages for San Antonio River at San Antonio Water Year October 1973 to September 1974**

| | | |
|---|---|---|
| Net discharge for 12-month period | = | 40,034.6 cfs |
| Average discharge/month for 12-month period | = | 3336.22 cfs/mo |
| Average discharge/day for 365-day period | = | 109.68 cfs/day |
| Maximum discharge during a month in 12-month period | = | 7566 cfs (Oct., 1973) |
| Maximum discharge during a day in 12-month (365-day) period | = | 954 cfs (Sept. 3, 1974) |

The recurrence interval for the 1921 flood would fall in the 500-year-plus range, making it a very rare-magnitude and low-frequency flood. It must be emphasized, however, that given the right weather conditions, a flood of the 1921 magnitude might occur during any one year in the river system (see meteorology section of this report).

## Soil Cover

The proposed facility is situated on a soil series delineated as the Lewisville silty clay (1 to 3 percent slope) by the U. S. Department of Agriculture (1966). Lewisville series soils are part of the Great Soil Group Grumusols, which also includes the Austin, Crawford, Houston, Houston Black, Krum, and Patrick soils within Bexar County. The Lewisville series is a member of the fine-silty, mixed, thermic family of Typic Calciustolls. It is characteristically composed of very dark-brown to black, calcareous, silty clay soils. Depth to the underlying material ranges from 36 inches to 60 inches, with gravel often occurring near the base of the soil zone. The underlying material for the proposed facility is the black-soil alluvial plain (BSAP) unit designated by the Bureau of Economic Geology (Gustavson and Cannon, 1974). Map units are described in the local geology section of this report.

Characteristics of the Lewisville silty clay soil (1 to 3 percent slope) are as follows (U. S. Department of Agriculture, 1966).

1. Solum thickness range is from 30 to 70 inches.

2. Surface layers commonly contain 32 to 55 percent clay.

3. Surface runoff is slow to medium; internal drainage is medium.

4. Permeability is slow to moderate.

5. Water-holding capacity is good.

6. Hardness of soil is less than 1 on the Mohs scale, while pebbles in the underlying gravel beds have greater than 2.5 hardness on the Mohs scale.

7. Hazard of water erosion is serious on more sloping areas but only slight on nearly level areas; if soils are left unprotected, they are more susceptible to water erosion.

8. Corrosion potential is high.

9. Suitability for low buildings is poor on Lewisville expansive clays characterized by high shrink-swell capacity.

10. Compressibility is moderate.

11. Excavation potential is high.

Perhaps the most important soil characteristic is the shrink-swell index or potential volumetric change (PVC) of the soil in question. PVC is the pressure exerted by a given soil against a restraining force when the soil expands as a result of an increase in moisture content (see U. S. Department of Agriculture, 1966, for PVC criticality ranges). PVC for the expansive clays of the Lewisville series underlying and adjacent to building 950 is greatest from the ground surface to about 5 feet, and warrants serious consideration in any present and future plans and modifications for the proposed facility. Expansive clays shrink and crack extensively when dry. When wetted moderately to thoroughly, the cracks fill with water and the clays begin to swell. In so doing, they exert pressure on materials which surround them. Thus, concrete foundation strength and architectural-engineering modifications should be designed to accommodate the high swell index of these expansive clays. In addition, any cables, pipelines, or metal beams sunk or buried in the clay soil should be adequately protected from the high corrosion potential of the Lewisville series soils.

## Site Drainage

Site drainage at the proposed facility is adequate to handle runoff from average local precipitation. Building 950 is equipped with storm gutters to handle water runoff from the roof of the building. At the time of our visit (October 16, 1975) it appeared that the roof had recently been renovated. However, ponding problems may arise on the roof because of its flat surface. Grounds adjacent to the building are well vegetated, aiding in the prevention of water erosion of the expansive clay soils. Drainage ditches are well located and should be adequate to contain surface runoff from normal precipitation. Moreover, the natural slope of the topography would carry water away from the proposed facility in all directions, except possibly to the east, where slope is very slight and there are no drainage ditches.

## Man-Made Hazards

Surface traffic in the area adjacent to the proposed facility is light. Most of the surface traffic in the immediate area involves traffic going to the building nearest 950, building 913, and use of the MOGAS facility (plate 1) as a fueling depot for the Brooks vehicle fleet.

Building 950 is located at the end of a dead-end road, so that the only traffic near the building would be those vehicles going to the building itself.

Based on available information, aircraft traffic over the base is minimal for federal aviation and minimal to absent for commercial aviation (primarily from Stinson Airfield). Occasional helicopter landings are the only air traffic on the base itself. The flying facilities of the base have been shut down since 1962 (Melroy Brandt, personal communication).

Nearby hazardous activities are minimal in the immediate area of the proposed facility. MOGAS, an above-ground fuel-storage facility, appears to be the nearest potential hazard in the event that there is an explosion and/or fire at that facility. It contains a total of 25,000 gallons of high-octane and unleaded gasoline in two 10,000-gallon tanks and one 5,000-gallon tank (Melroy Brandt, personal communication). Its proximity (0.3 mile) to building 950 makes it a potential hazard from the standpoint of fire and noxious emanations from a fire. These hazards, however, would require proper wind conditions and lack of control by fire-prevention personnel to affect the storage site to any extent. A second fuel storage facility, #2 fuel storage (plate 1), is located underground about 0.6 mile from the lunar sample storage site, and contains auxiliary fuel oil for a boiler plant. It poses no perceivable hazard to building 950.

Building 950 appears fairly safe from air pollution, in that it has no windows, very few doors, and very few outlets. Further, according to Melroy Brandt, "There are no intense air pollution problems or noxious emissions on or near Brooks AFB."

Current and future use of the air base is exclusively as a medical research and training facility, primarily for the Department of the Air Force (Melroy Brandt, personal communication).

## Conclusions

The proposed facility (building 950, Brooks Air Force Base), based on all available information to date, appears to be well removed from most predictable hazards. Seismic hazard is remote in that the last activity associated with the Balcones fault system occurred over 1 million years ago. Flooding is of no immediate danger, since the proposed facility is located well above the maximum height of any recorded flood for both the San Antonio River and Salado Creek. Site drainage at the proposed facility is adequate to contain average local precipitation and resultant runoff. Surface and air traffic are minimal and pose no hazard. MOGAS is the only potential man-made hazard from the standpoint of fire damage in the event of an explosion. Noxious emanations and air pollution are absent in the immediate area of building 950. The high shrink-swell capacity of the expansive clay substrate is a major potential hazard and should be seriously considered in any architectural-engineering modifications to the proposed facility.

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Plate 1. Base Map, USGS 7-1/2-minute topographic sheet, Southton quadrangle; environmental geologic units mapped by C. M. Woodruff, Jr.

EXPLANATION

AT – Terrace

BSAP – Black-Soil Alluvial Plain

CMR – Dissected Expansive Mud

CR-CS – Calcareous Mud

FP – Flood Plain

GC-cal – Gravel Cap, Calichified

SMR – Moderately Rolling Sandy Mud

D / U Inferred Fault Line