# APPENDIX H

# SHEAR WAVE VELOCITY PROFILES

## GEOTECHNICAL DESIGN MANUAL

*January 2022*

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# APPENDIX H

# SHEAR WAVE VELOCITY PROFILES

## H.1 INTRODUCTION

### H.1.1 South Carolina Reference Shear Wave Profiles

The shear wave profiles presented in this Appendix are provided for reference purposes only. Project specific shear and compression wave profiles to depths of at least 100 feet beneath either the existing ground surface or the approximate original ground surface shall be developed from in-situ shear wave measurements as required in Chapter 4. These shear and compression wave profiles shall be extended to the anticipated B-C Boundary as required, for performing a site-specific seismic response analysis, using geologic publications, previous investigations, and the reference shear wave profiles presented on the Geotechnical Design Webpage of the SCDOT Website (see Section H.1.1.4).

A number of seismic studies have been performed in South Carolina and have yielded shear wave profiles for different parts of the state. The majority of the published shear wave profiles are in the Coastal Plain. The shear wave velocity profiles were obtained by one of the following testing methods: Seismic Refraction, Seismic Reflection, Surface Wave (SASW and MASW), Downhole (including Seismic CPT), or Crosshole techniques as described in Chapter 5. When shear wave measurements are not available for soil formations beyond the shear wave testing capabilities, estimates are typically made by using available shear wave data from formations previously tested or by using geologic information. Regardless of the data available all shear wave profiles shall be measured to a depth of at least 100 feet.

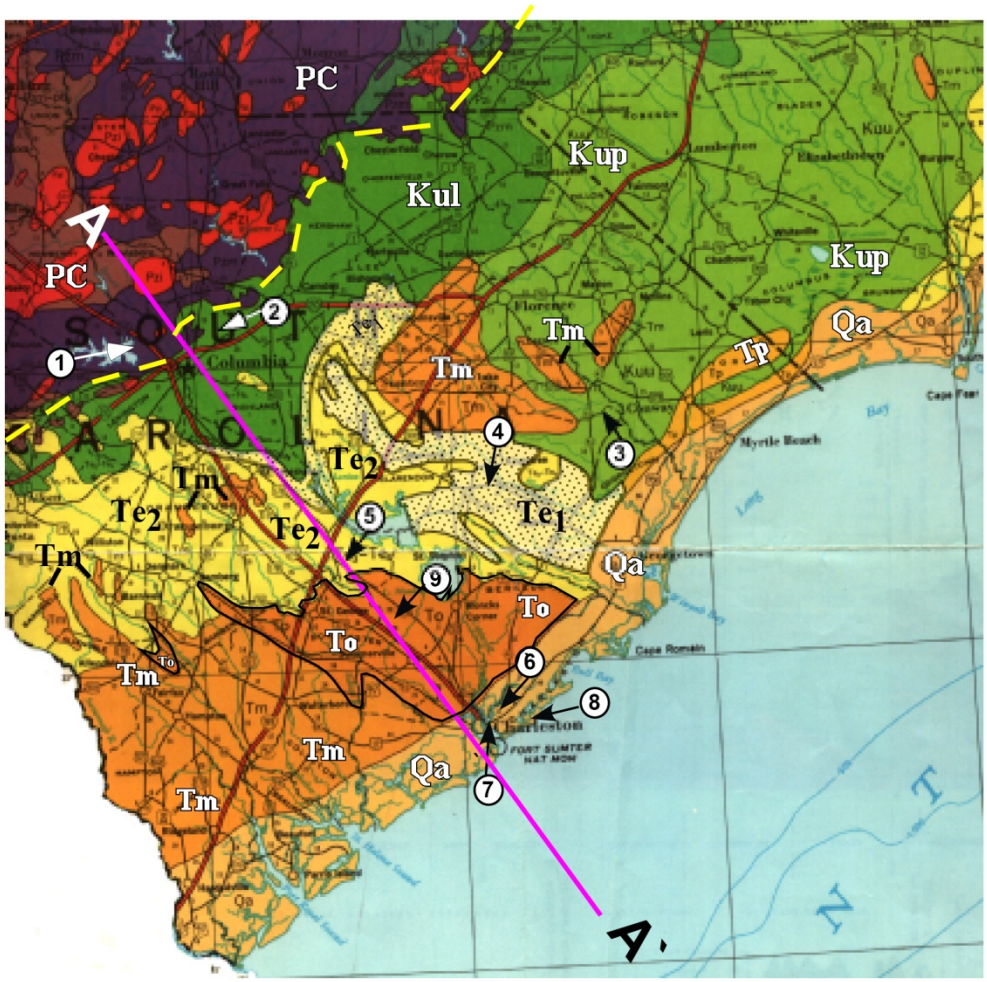
The shear wave velocity profile information contained in this Appendix has been divided into 3 sections: USGS Shear Wave Velocity Data, South Carolina Emergency Management Division (SCEMD) Seismic Risk and Vulnerability Study, and Published / SCDOT Shear Wave Velocity Profiles. A brief review of these reference shear wave velocity profiles is presented in the following Sections.

#### H.1.1.1 USGS Shear Wave Velocity Data

The U.S. Geologic Survey (USGS) has compiled shear wave profiles in South Carolina in a report prepared by Odum, Williams, Stepheson and Worley (2003). Shear wave measurements were obtained by seismic refraction/reflection profiling techniques for nine locations in South Carolina as indicated in Figure H-1 and listed below:

1. Lake Murray Dam Spillway, Columbia, SC: Paleozoic Rocks of the Carolina Slate Group.
2. Fort Jackson Military Base, Columbia, SC: Cretaceous Tuscaloosa Formation (Middendorf Formation)
3. Deep Creek School: Peedee Formation (Upper Cretaceous)
4. Black Mingo: Black Mingo Formation (lower Eocene-Wilcox Group)
5. Santee Limestone: Santee Limestone (Middle Eocene-Clayborne Group)
6. The Citadel, Charleston, SC: Quaternary deposits (barrier sand facies) overlying Upper Tertiary Cooper Group (Ashley and Parkers Ferry Formations) - The Citadel

7. U.S. Highway 17 Overpass next to Ashley River Memorial Bridge: Quaternary deposits overlying Upper Tertiary Cooper Group (Ashley and Parkers Ferry Formations)
8. Isle of Palms, Charleston, SC: Quaternary deposits (beach and barrier-island sand facies) overlying Upper Tertiary Cooper Group (Ashley and Parkers Ferry Formations)
9. U.S. National Seismograph Network (USNSN) installation site: Quaternary deposits overlying Upper Tertiary Cooper Group (Ashley and Parkers Ferry Formations)




Generalized Geologic Units

| | |
|---|---|
| Qa | Surface soils and fill, Pleistocene and Holocene of alluvial and marine origin |
| Tp | Pliocene sandy shell marl |
| Tm | Miocene sandy phosphatic marl, shaley (Hawthorn Group) |
| To | Oligocene massive phosphatic marl (Cooper Group-Ashley Fm.) |
| $Te_2$ | Eocene upper units- calcilutite and limestones (Cooper Gp - Parkers Ferry Fm. ) Santee Ls. |
| $Te_1$ | Eocene lower units-clayey to sandy siltstone and limestone (Wilcox Group, Black Mingo Fm.) |
| Kup | Cretaceous- calcareous clayey sands and limestone (Peedee Fm.) |
| Kul | Cretaceous- predominantly clean to silty sands and pure clay (Tuscaloosa Fm.) |
| Pc | Precambrian- metamorphosed early Paleozoic and older sedimentary and volcanic rocks and granitic intrusions (Carolina Slate Group) |

**Figure H-1, USGS Nine Study Locations**
**(Odum, et al. (2003))**

Shear wave ($V_s$) profiles for the 9 USGS sites are summarized in Table H-1 and shown in Figure H-2.

**Table H-1, USGS Shear Wave Profile Summary**
**(Odum, et al. (2003))**

| Site No. | Site Name | Latitude (degrees) | Longitude (degrees) | Surficial Geology [1] | Highest $V_S$ in Upper 164' (50 m) | | Description [1] |
|---|---|---|---|---|---|---|---|
| | | | | | (m/s) | (ft/sec) | |
| 1 | Lake Murray Spillway | 35.052 | 81.210 | Fill, Pz | 2,674 @ 23 m | 8,770 @ 75 ft | Carolina Slate Group ($P_z$) |
| 2 | Fort Jackson | 34.028 | 90.912 | $K_u$ | 866 @ 27 m | 2,840 @ 89 ft | Tuscaloosa Fm |
| 3 | Deep Creek School | 33.699 | 79.351 | Q?, $K_u$ | 710 @ 22 m | 2,330 @ 72 ft | Q over Peedee Fm |
| 4 | Black Mingo | 33.551 | 79.933 | Q, $T_l$ | 855 @ 9 m | 2,805 @ 30 ft | Q over Eocene Wilcox Group |
| 5 | Santee Ls | 33.235 | 80.433 | $T_l$ | 932 @ 7 m | 3,057 @ 23 ft | Santee Limestone |
| 6 | The Citadel, Charleston | 32.798 | 79.958 | Q, $T_u$ | 795 @ 78 m | 2,608 @ 256 ft | Q over $T_u$ (Cooper Group) |
| 7 | US Hwy. 17, Charleston | 32.785 | 79.955 | Fill, Q | 247 @ 11 m | 810 @ 36 ft | Q over $T_u$ (Cooper Group) |
| 8 | Isle of Palms | 32.795 | 79.775 | $Q_h$, $T_u$ | 497 @ 23 m | 1,630 @ 75 ft | Q over $T_u$ (Cooper Group) |
| 9 | USNSN | 33.106 | 80.178 | Q, $T_u$ | 792 @ 10 m | 2,598 @ 33 ft | Q over $T_u$ (Cooper Group) |

[1] Definitions: Q – Quartenary; $T_u$ – upper Tertiary; $T_l$ – lower Tertiary; $K_u$ – upper Cretaceous; $P_z$ - Paleozoic

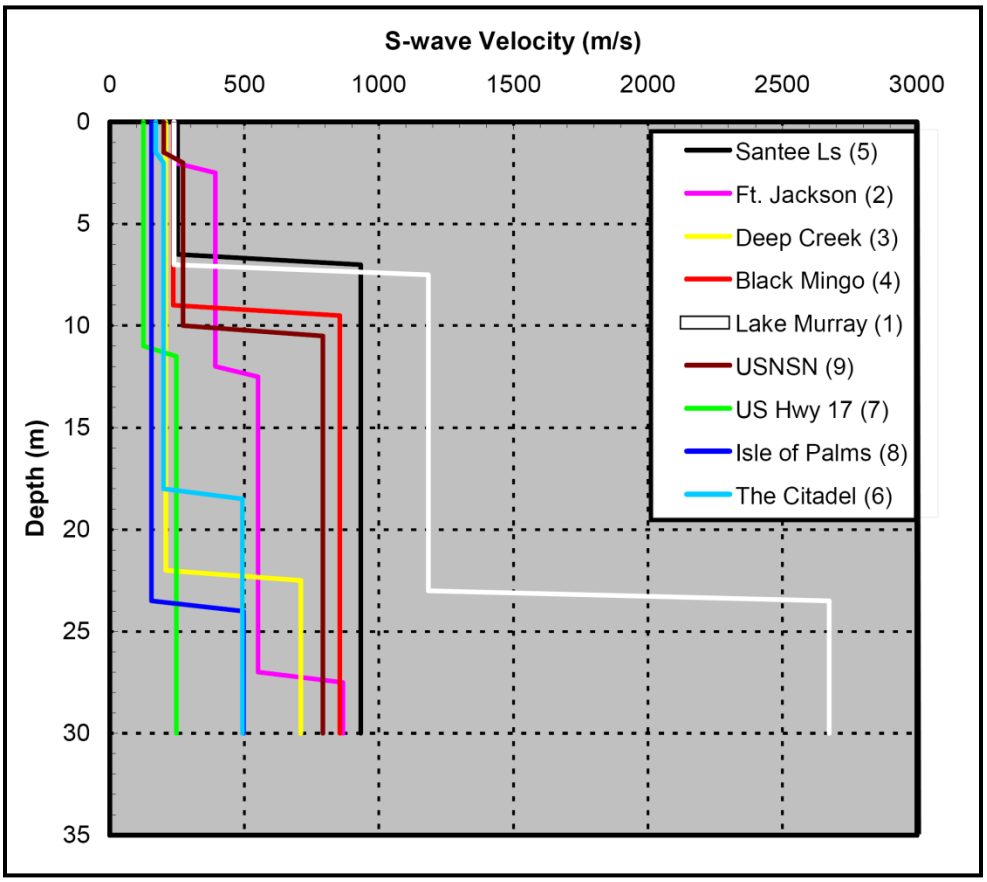



**Figure H-2, USGS Shear Wave *$V_S$* Profile**
**(Odum, et al. (2003))**

The shear wave ($V_s$) and compression wave ($V_p$) profiles developed for the 9 sites are shown in Figures H-3 and H-4. The columns show successively higher velocity layers V1, V2, and V3,

indicated by yellow, blue, and light brown, respectively. For a detailed interpretation of the results shown in these profiles refer to Odum et al. (2003).

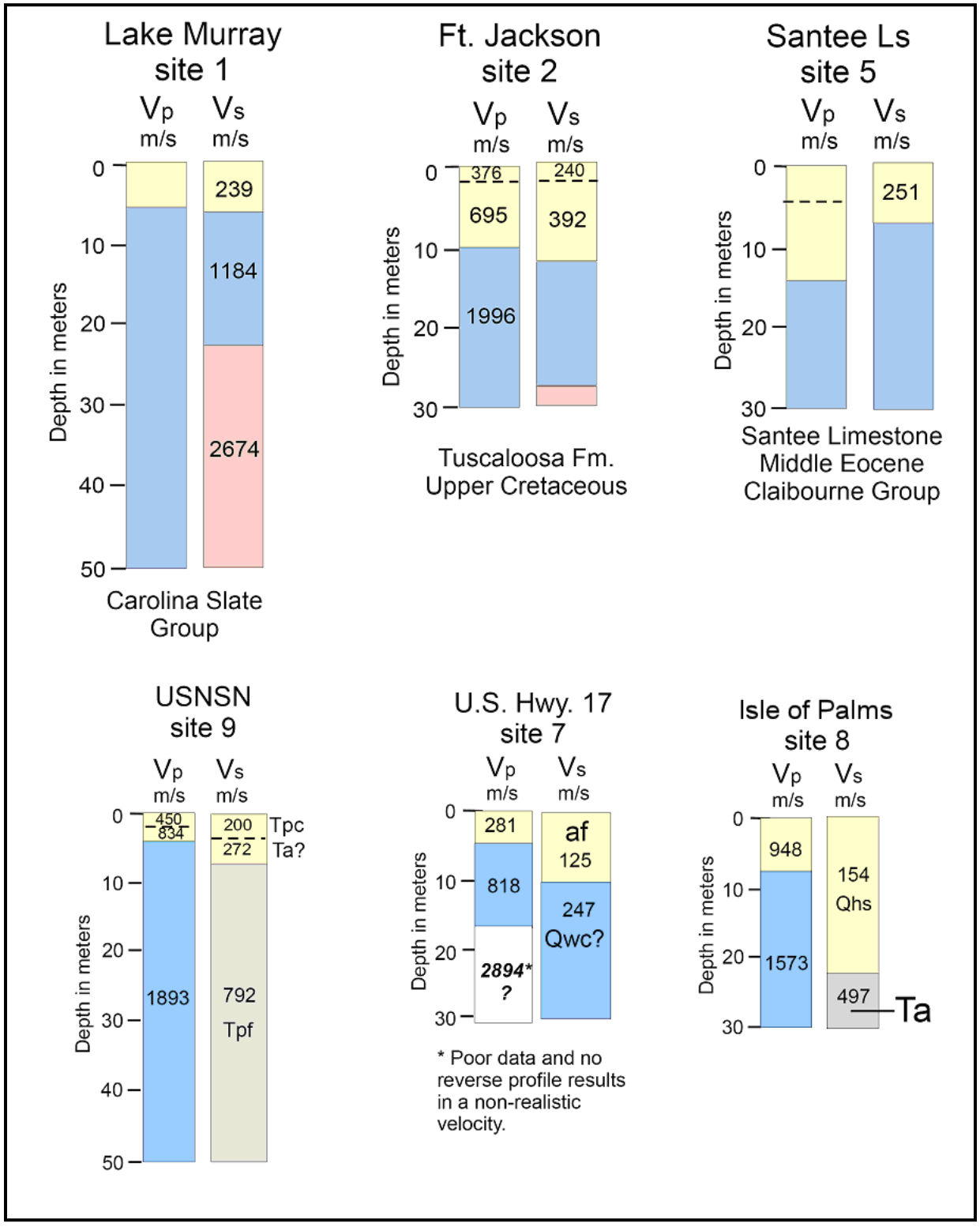



**Figure H-3, USGS Sites 1, 2, 5, 9, 7, and 8 (Odum, et al. (2003))**

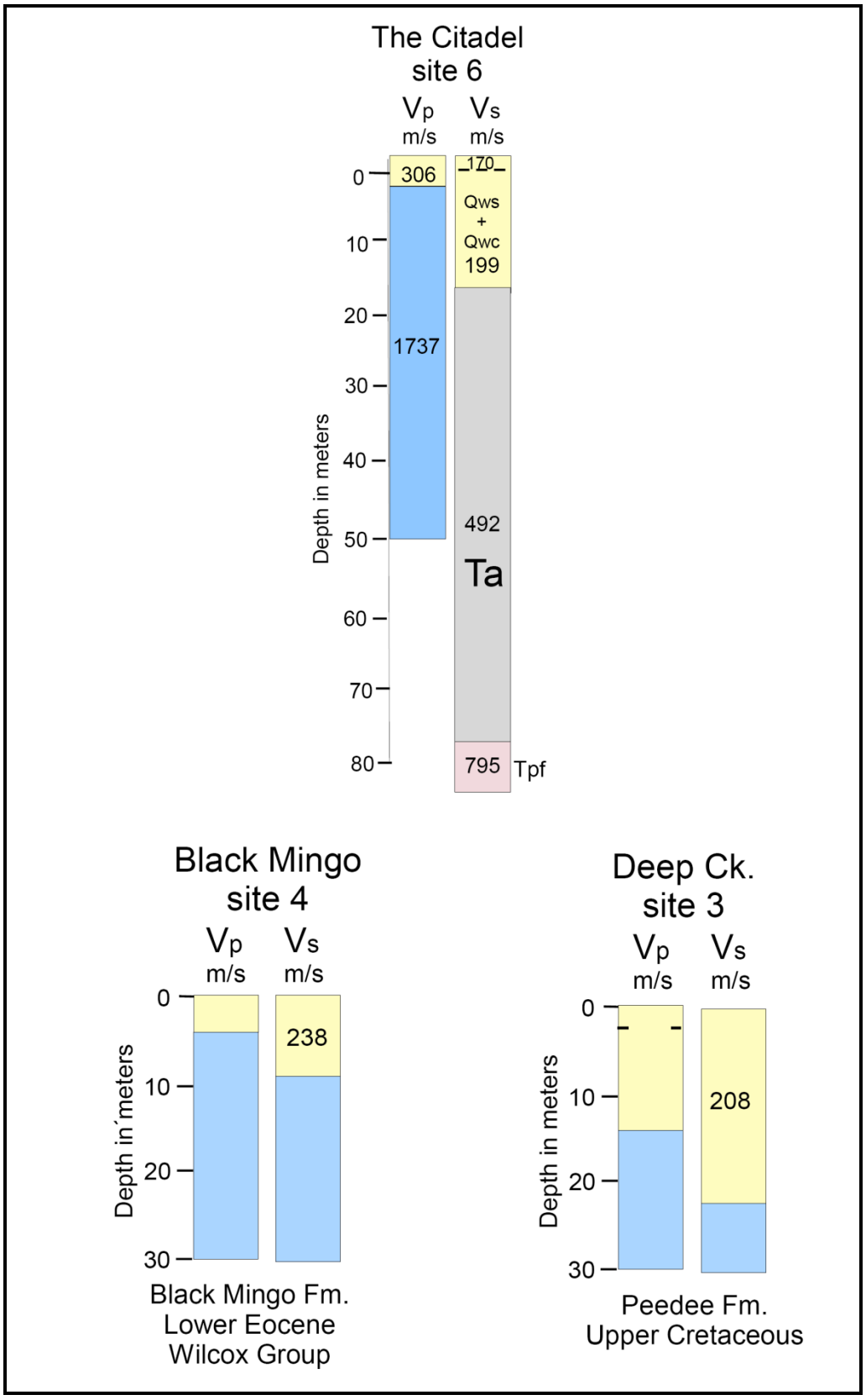



**Figure H-4, USGS Sites 6, 4, 3**
**(Odum, et al. (2003))**

### H.1.1.2 SCEMD Seismic Risk and Vulnerability Study

A study was prepared by URS Corporation (2001) for SCEMD. This study evaluated the potential losses resulting from 4 scenario earthquakes that may occur in South Carolina sometime in the future. South Carolina was divided into 4 site response categories based on physiographic provinces, surficial geology, and trends in subsurface data. The 4 site categories that were selected for this study are: Piedmont, Savannah River, Charleston, and Myrtle Beach. The extent of these site response categories are shown on a South Carolina map in Figure H-5. The shear wave profiles for the Piedmont, Savannah River, Charleston, and Myrtle Beach are shown in Figures H-6, H-7, H-8, and H-9, respectively. For a detailed explanation of the base shear wave profiles used in this study refer to SCEMD report prepared by URS Corporation (2001).

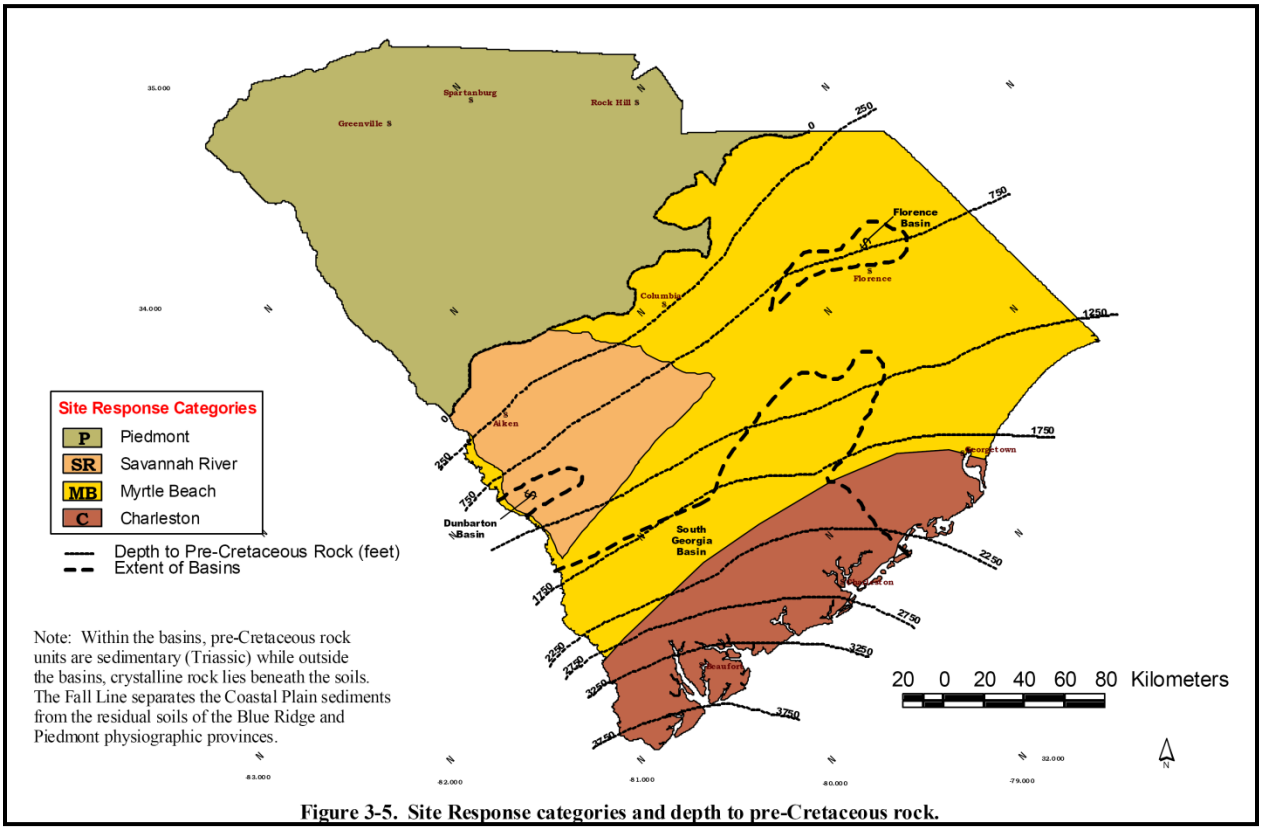



**Figure H-5, Site Response Categories and Depth To Pre-Cretaceous Rock (URS Corporation (2001))**

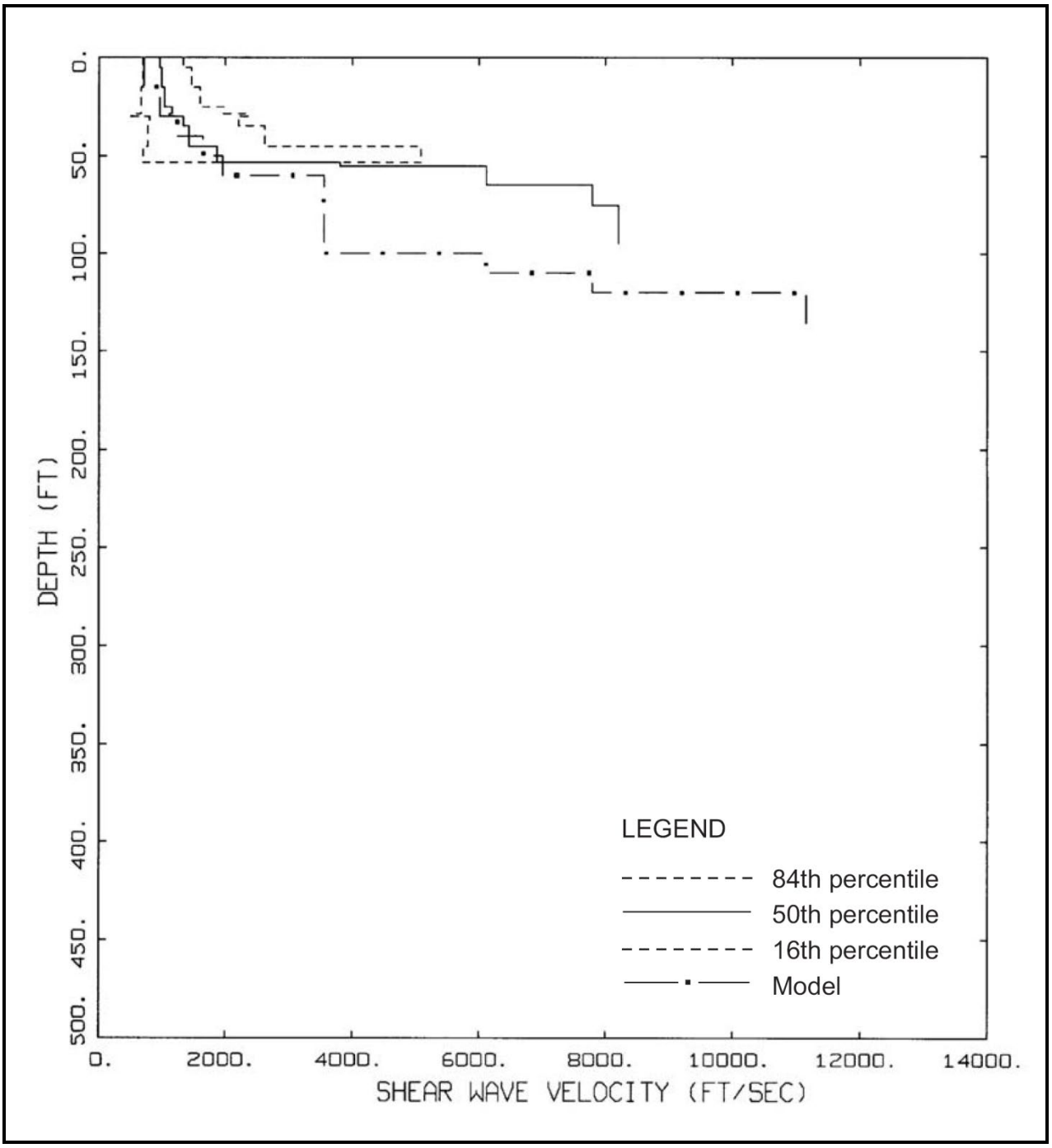



**Figure H-6, Piedmont/Blue Ridge Site Response Category Base Vs Profile (URS Corporation (2001))**

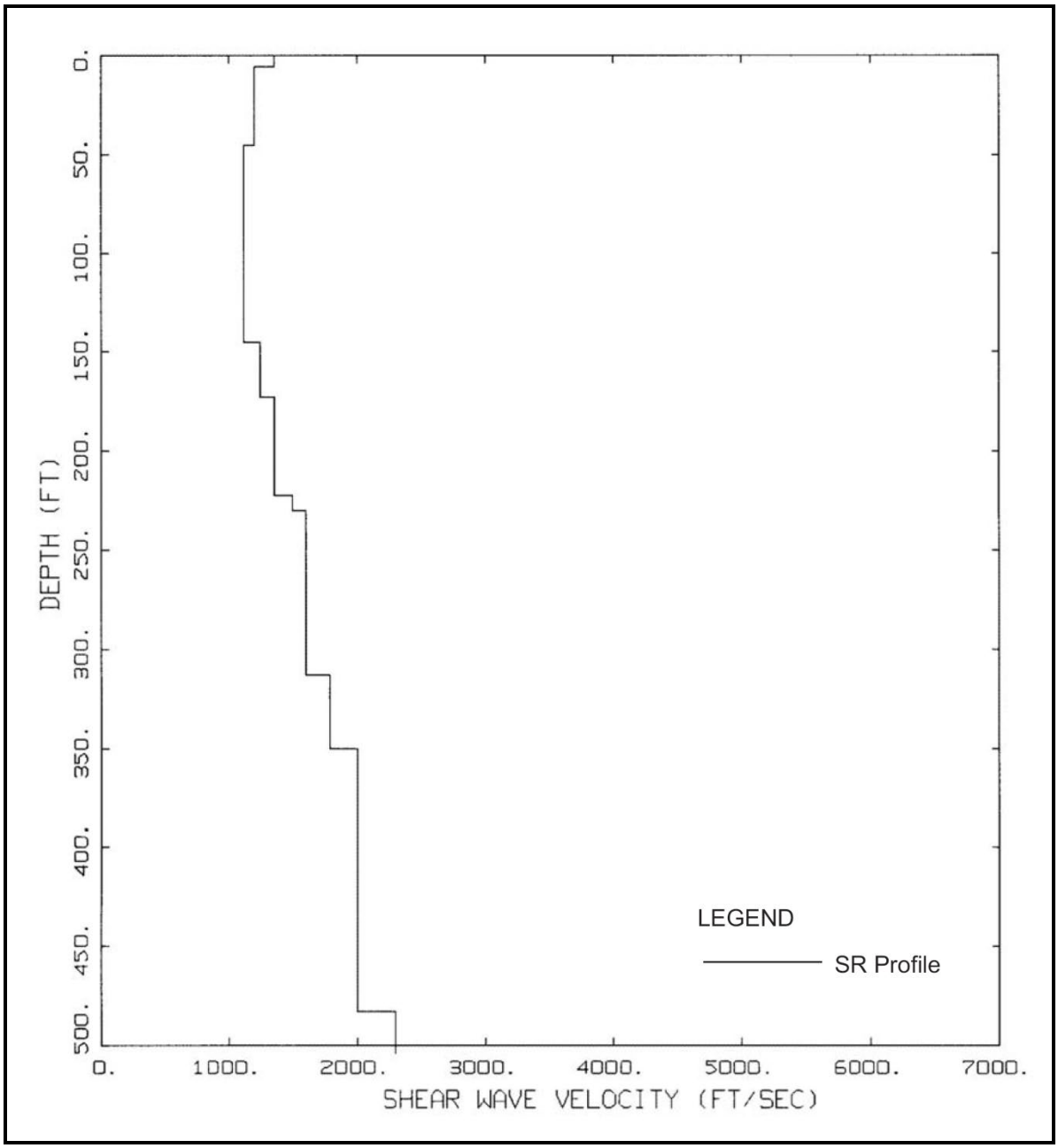



**Figure H-7, Savannah River Site Response Category Base Vs Profile (URS Corporation (2001))**

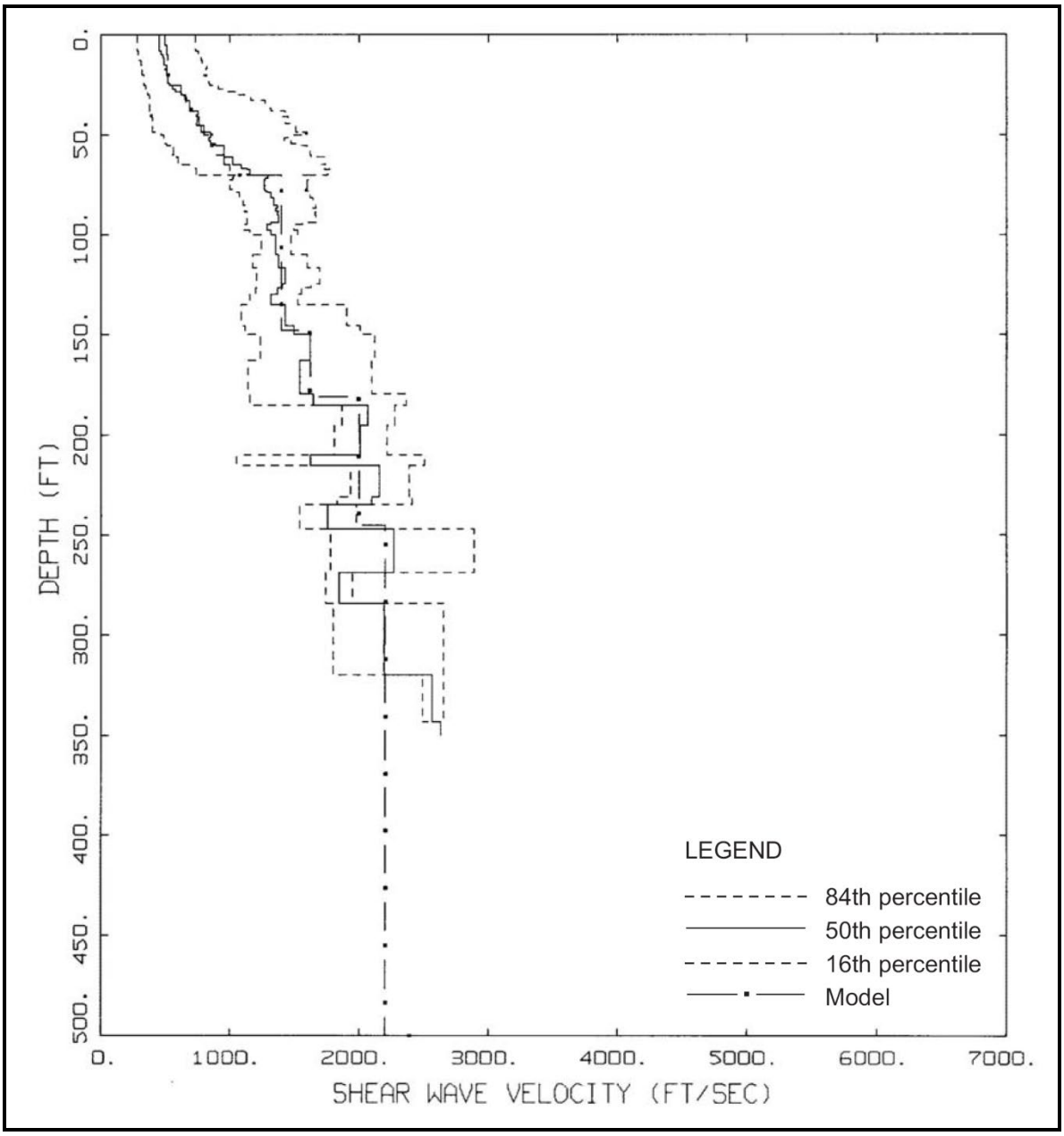



**Figure H-8, Charleston Site Response Category Base Vs Profile (URS Corporation (2001))**

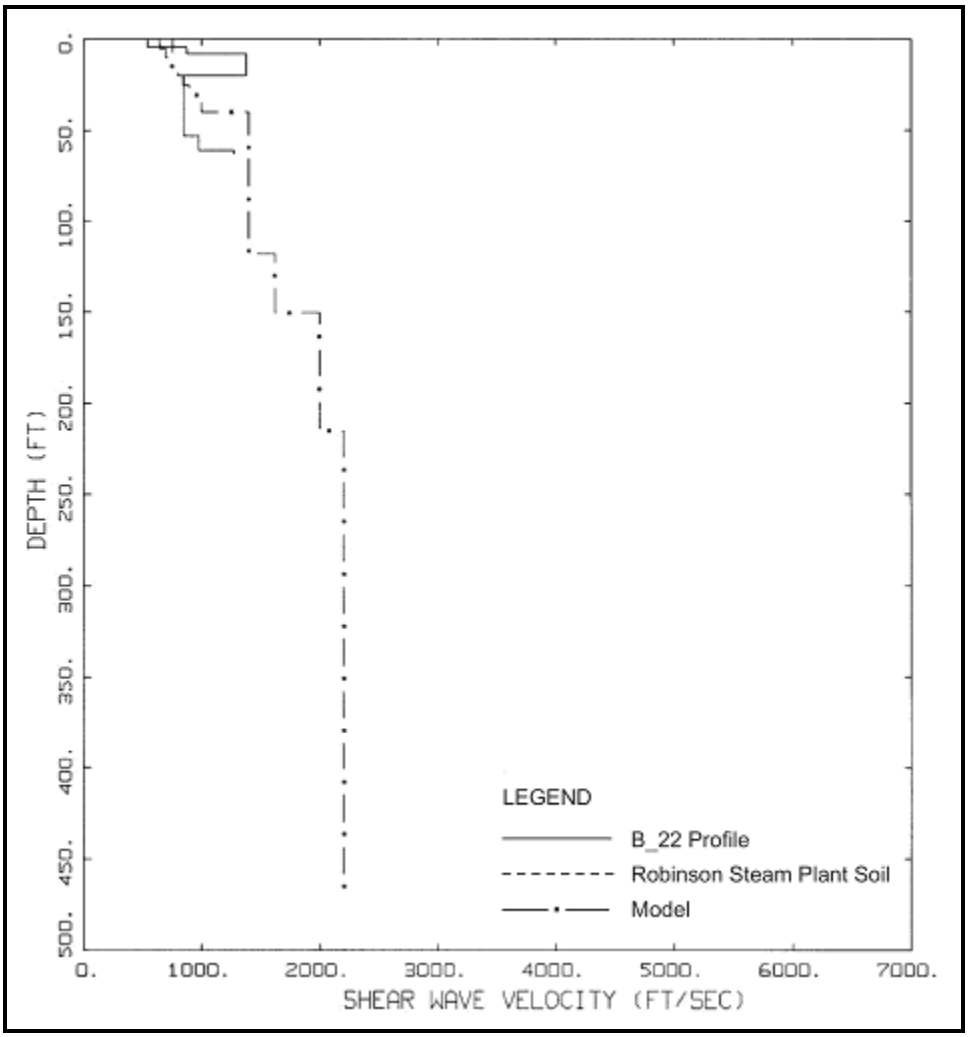



**Figure H-9, Myrtle Beach Site Response Category Base Vs Profile (URS Corporation (2001))**

### H.1.1.3 Published / SCDOT Shear Wave Velocity Profiles

A partial review of published shear wave velocity profiles has been compiled to provide additional reference data for use in characterizing sites in South Carolina. The shear wave profiles are provided as references. For a detailed description of the geologic formation and geotechnical investigation, refer to the source documents. The list of the shear wave profiles compiled is provided below:

1. Seismic CPT and Geophysical shear wave profiles taken in Piedmont soils from the National Geotechnical Experimentation Sites (NGES) located at Opelika, Alabama. The Seismic CPT is shown in Figure H-10 and the geophysical testing is shown in Figure H-11. This site is generally accepted to be representative of Piedmont surface soils.
2. Seismic CPT shear wave profile taken at the Savannah River site in South Carolina is shown in Figure H-12. This shear wave profile is generally representative of the soils at the U.S. Department of Energy Savannah River Site.
3. Seismic CPT shear wave profile taken at the Ravenel Bridge (Cooper River Bridge), located in Charleston, South Carolina, is shown in Figure H-13.

4. Seismic CPT shear wave profiles taken at Wetland Bridges 1 and 3 on US 17 between US Highway 21 intersection in Gardens Corner and the Combahee River. Two shear wave profiles were developed for Bridges 1 & 2 and Bridges 3 & 4 as shown in Figure H-14. The SCPT B-14 taken at Bridge 1 is shown in Figure H-15 and B-5A taken at Bridge 3 is shown in Figure H-16.
5. Seismic CPT shear wave profiles taken for a new bridge on US 378 over Great Pee Dee River, approximately 18 miles east of Lake City, South Carolina. Representative shear wave profiles from two SCPT SC3 and SC4 are shown in Figure H-17 and H-19, respectively. The corresponding SCPT logs for SC3 and SC4 are shown in Figures H-18 and H-20, respectively.

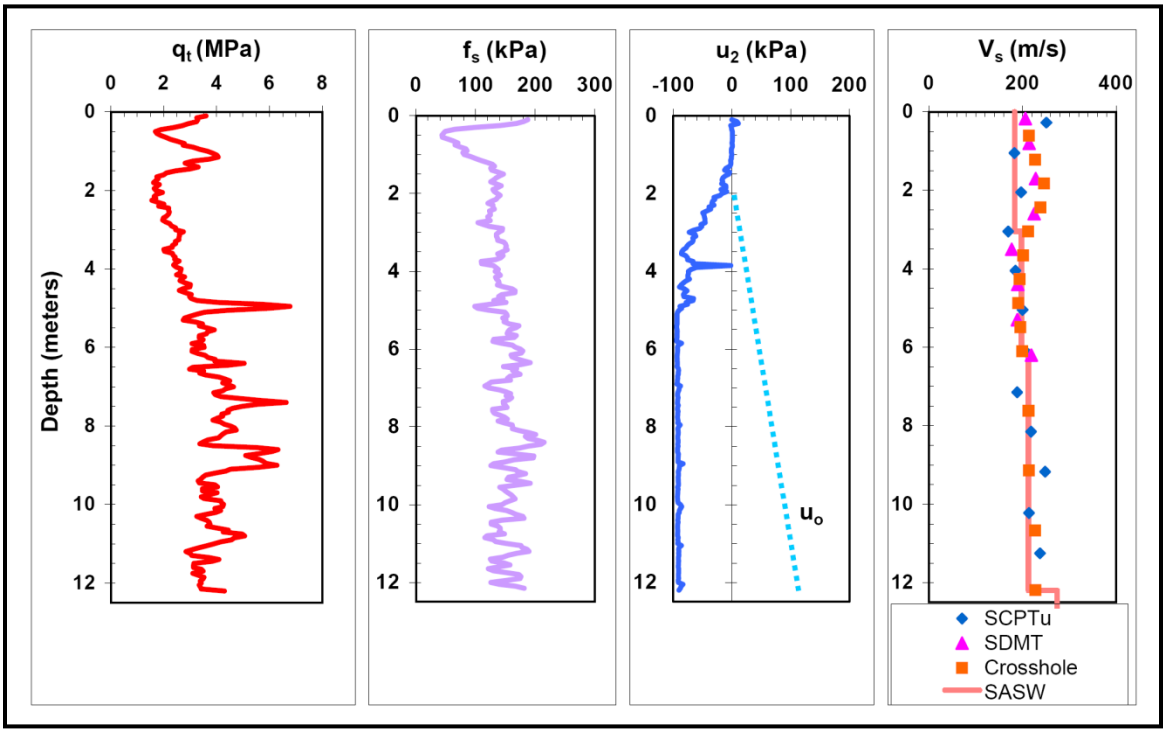



**Figure H-10, SCPT Piedmont Profile - NGES Opelika, Alabama (Mayne, et al. (2000) with permission from ASCE)**

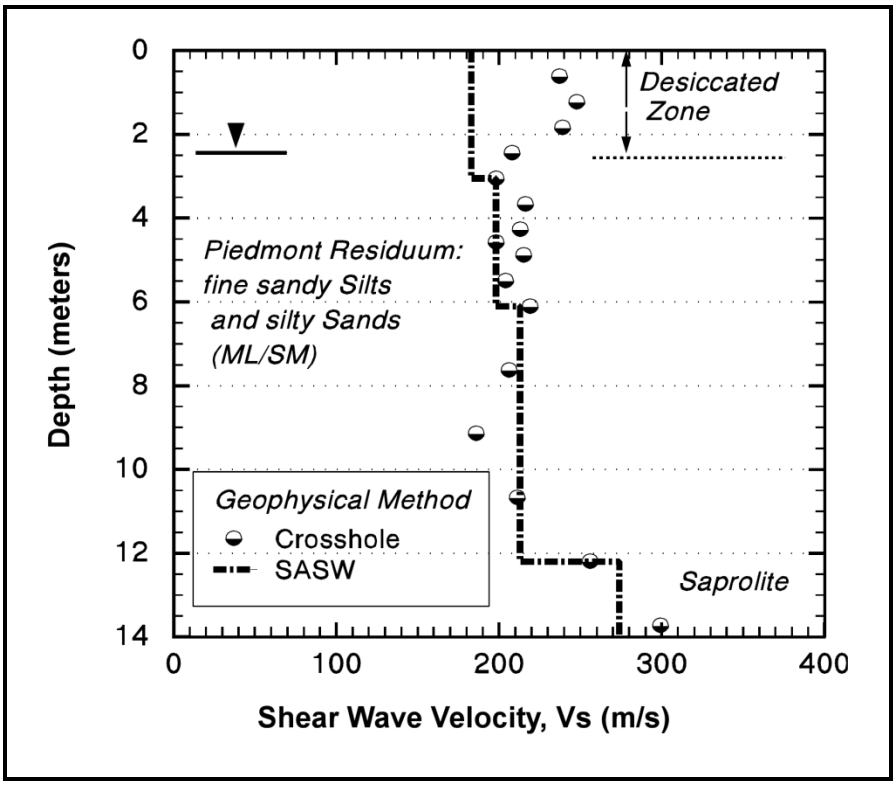



**Figure H-11, Geophysical $V_S$ Piedmont Profile - NGES Opelika, Alabama (Mayne, et al. (2000) with permission from ASCE)**

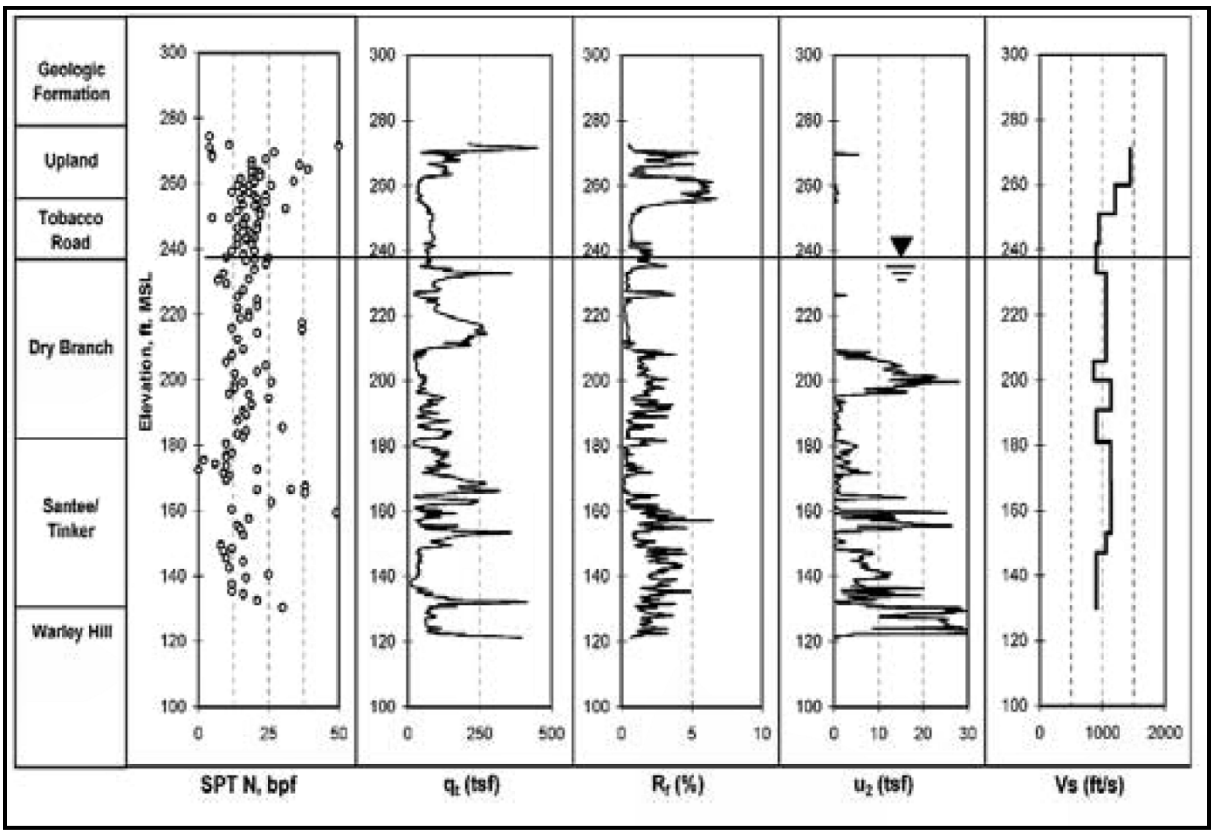



**Figure H-12, SCPT Profile Savannah River, South Carolina (Lewis, et al. (2004))**

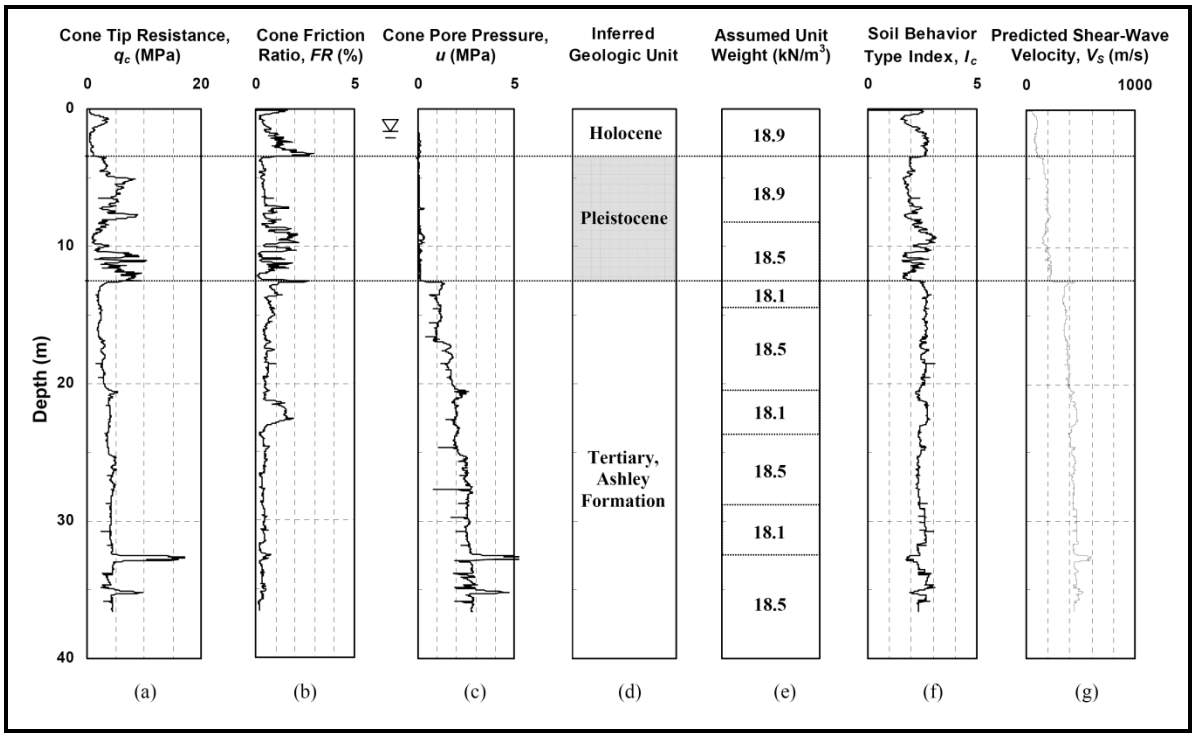



**Figure H-13, SCPT Profile (DS-1) Cooper River Bridge, Charleston, SC (S&ME (2000))**

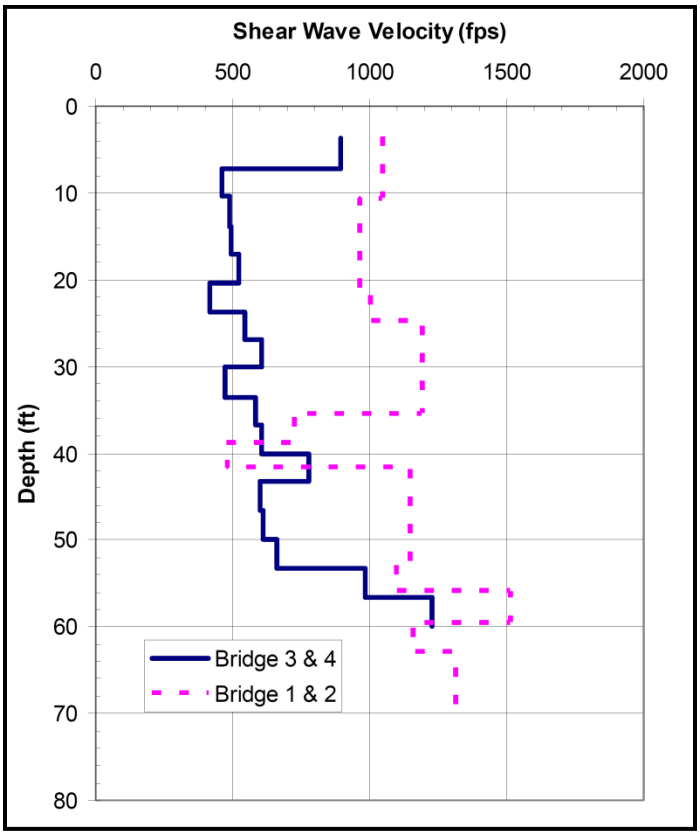



**Figure H-14, Shear Wave Profile US 17, Beaufort County, South Carolina (S&ME (2007))**

Geologic profiles provided in Figures H-15 and H-16

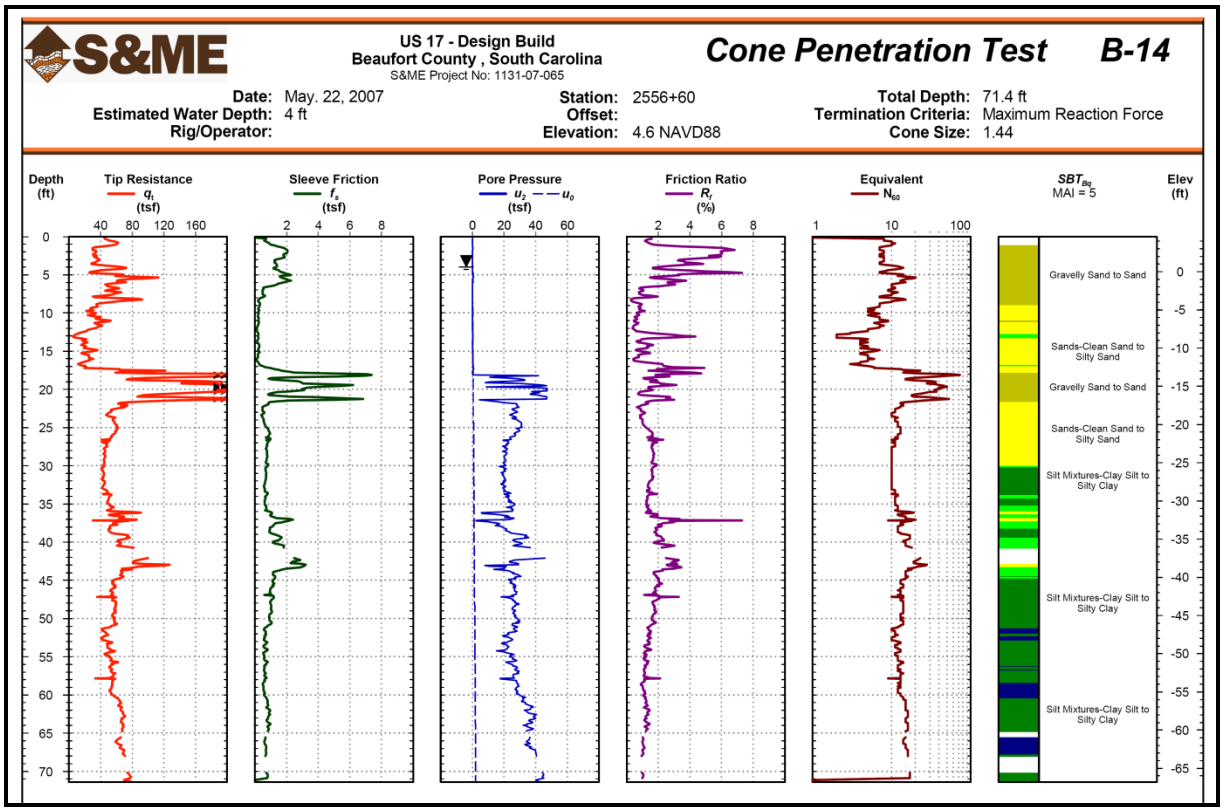



**Figure H-15, SCPT (B-14) US 17 Bridge 1, Beaufort County, South Carolina (S&ME (2007))**

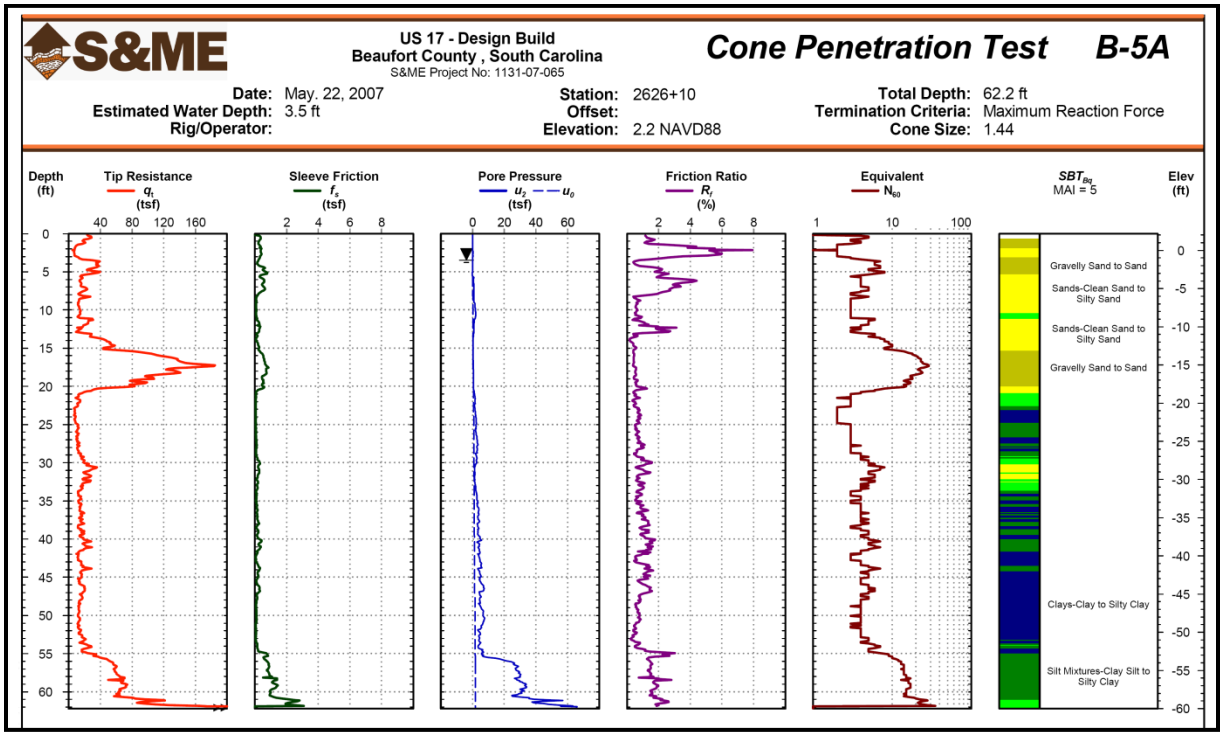
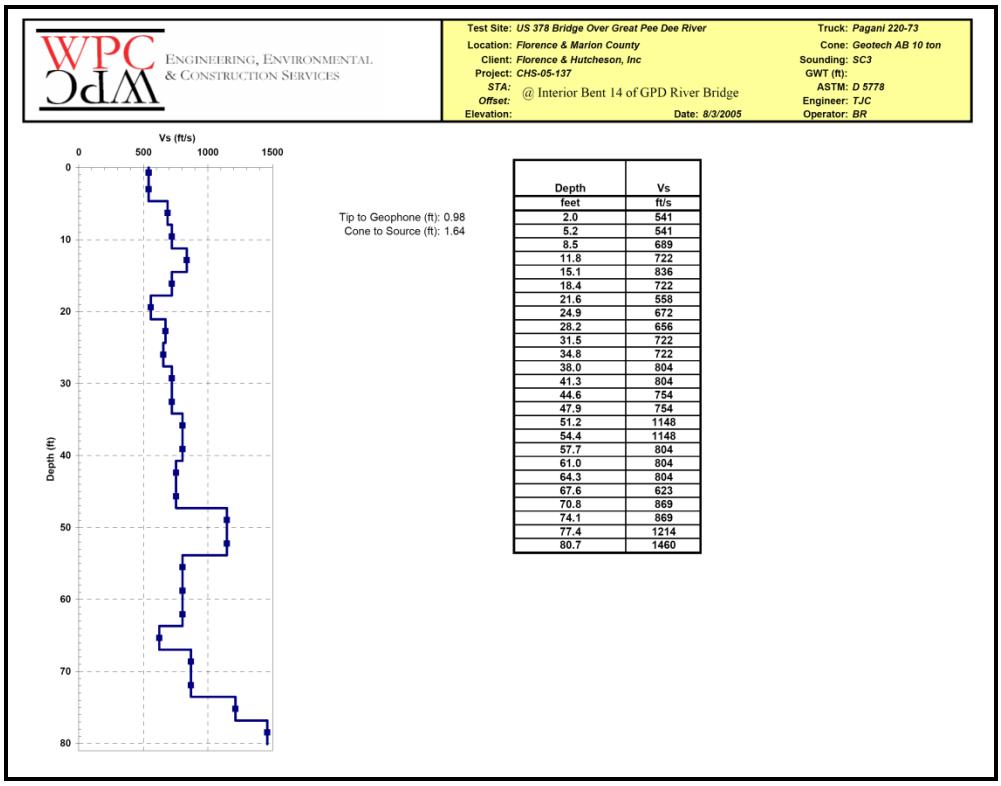



**Figure H-16, SCPT (B-5A) US 17 Bridge 3, Beaufort County, South Carolina (S&ME (2007))**




| Depth | Vs |
|---|---|
| feet | ft/s |
| 2.0 | 541 |
| 5.2 | 541 |
| 8.5 | 689 |
| 11.8 | 722 |
| 15.1 | 836 |
| 18.4 | 722 |
| 21.6 | 558 |
| 24.9 | 672 |
| 28.2 | 656 |
| 31.5 | 722 |
| 34.8 | 722 |
| 38.0 | 804 |
| 41.3 | 804 |
| 44.6 | 754 |
| 47.9 | 754 |
| 51.2 | 1148 |
| 54.4 | 1148 |
| 57.7 | 804 |
| 61.0 | 804 |
| 64.3 | 804 |
| 67.6 | 623 |
| 70.8 | 869 |
| 74.1 | 869 |
| 77.4 | 1214 |
| 80.7 | 1460 |

**Figure H-17, Shear Wave Profile (SC3) - US 378, Lake City, South Carolina (Florence & Hutcheson (2006))**

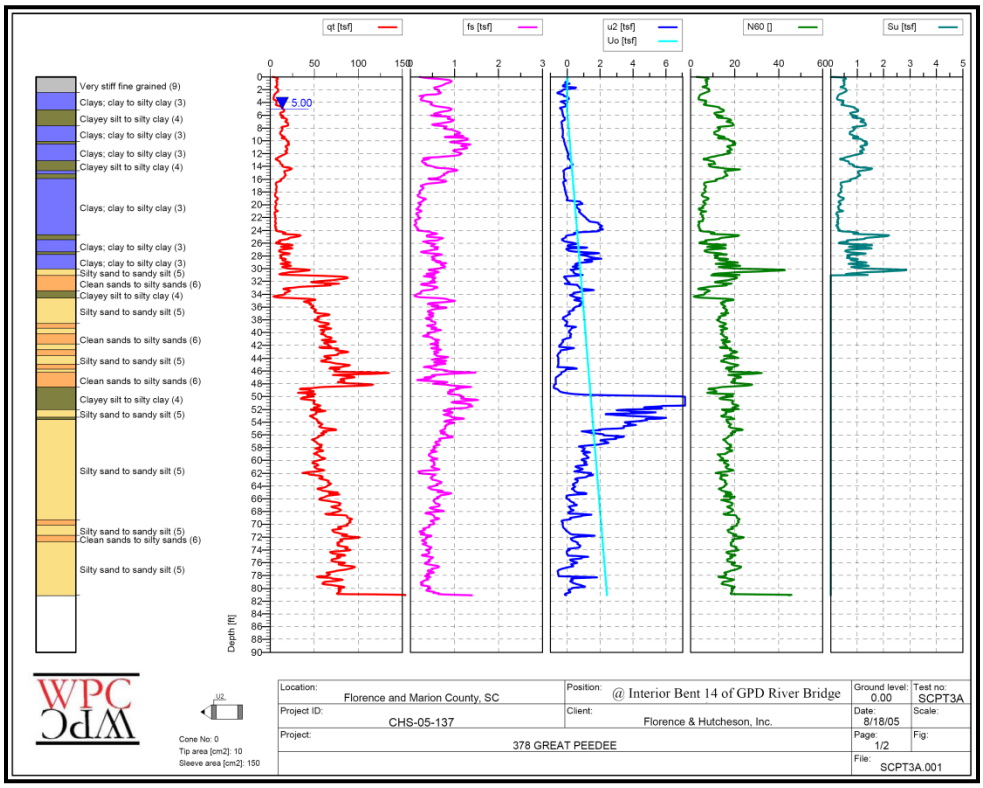
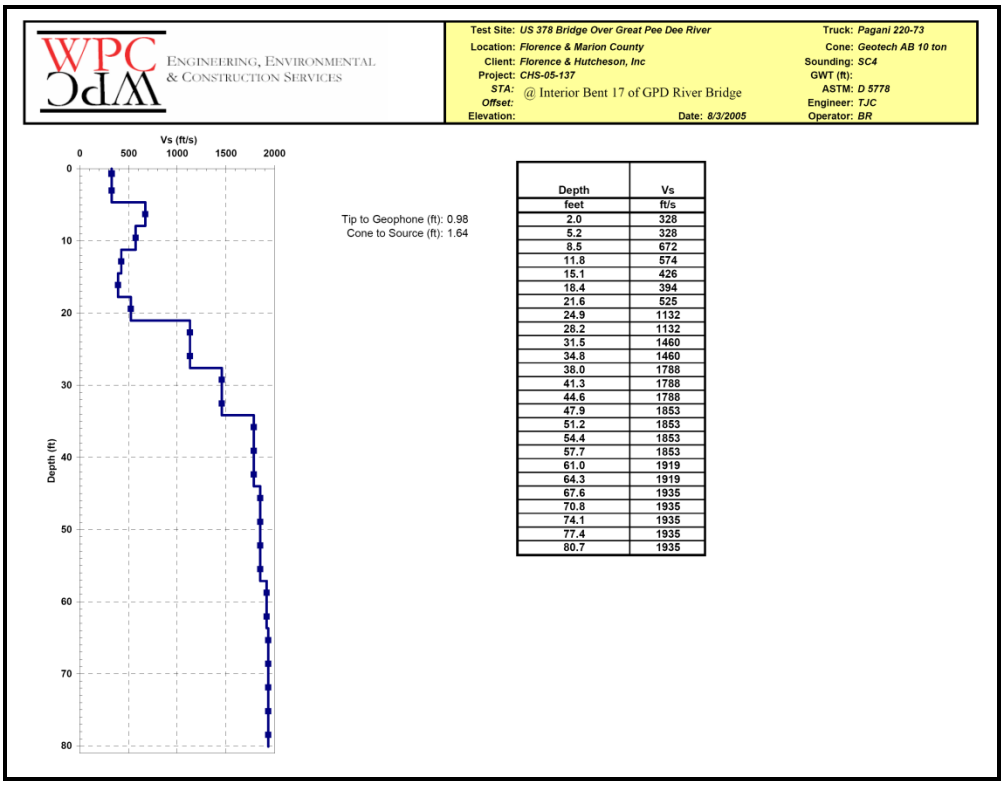



**Figure H-18, SCPT (SC3) - US 378, Lake City, South Carolina (Florence & Hutcheson (2006))**




| Depth feet | Vs ft/s |
|---|---|
| 2.0 | 328 |
| 5.2 | 328 |
| 8.5 | 672 |
| 11.8 | 574 |
| 15.1 | 426 |
| 18.4 | 394 |
| 21.6 | 525 |
| 24.9 | 1132 |
| 28.2 | 1132 |
| 31.5 | 1460 |
| 34.8 | 1460 |
| 38.0 | 1788 |
| 41.3 | 1788 |
| 44.6 | 1788 |
| 47.9 | 1853 |
| 51.2 | 1853 |
| 54.4 | 1853 |
| 57.7 | 1853 |
| 61.0 | 1919 |
| 64.3 | 1919 |
| 67.6 | 1935 |
| 70.8 | 1935 |
| 74.1 | 1935 |
| 77.4 | 1935 |
| 80.7 | 1935 |

**Figure H-19, Shear Wave Profile (SC4) - US 378, Lake City, South (Florence & Hutcheson (2006))**

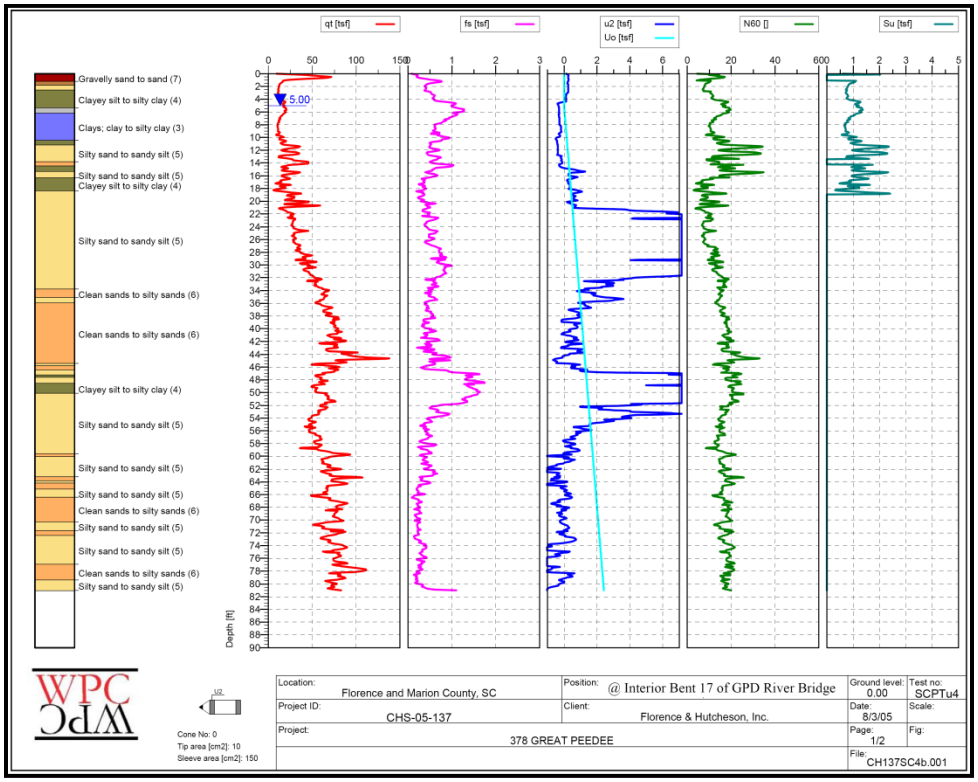



**Figure H-20, SCPT (SC4) - US 378, Lake City, South Carolina (Florence & Hutcheson (2006))**

### H.1.1.4 SCDOT Deep Shear Wave Velocity Profiles

SCDOT has over the past several years collected shear wave velocities from beneath the surficial soil materials. These shear wave velocities have been obtained with the purpose of attempting to identify the B-C boundary at the locations shown in Figure H-21. Provided below is a link to the Geotechnical Design Webpage:

https://www.scdot.org/business/geotech.aspx

Look for the button “GIS Map” in the Section Labeled “Consultant Seismic Information Request Form”. Once the map is accessed, select the balloon that is closest to the project site and select “More Info” for access to the spreadsheets containing the site data and the soils information for that specific site.

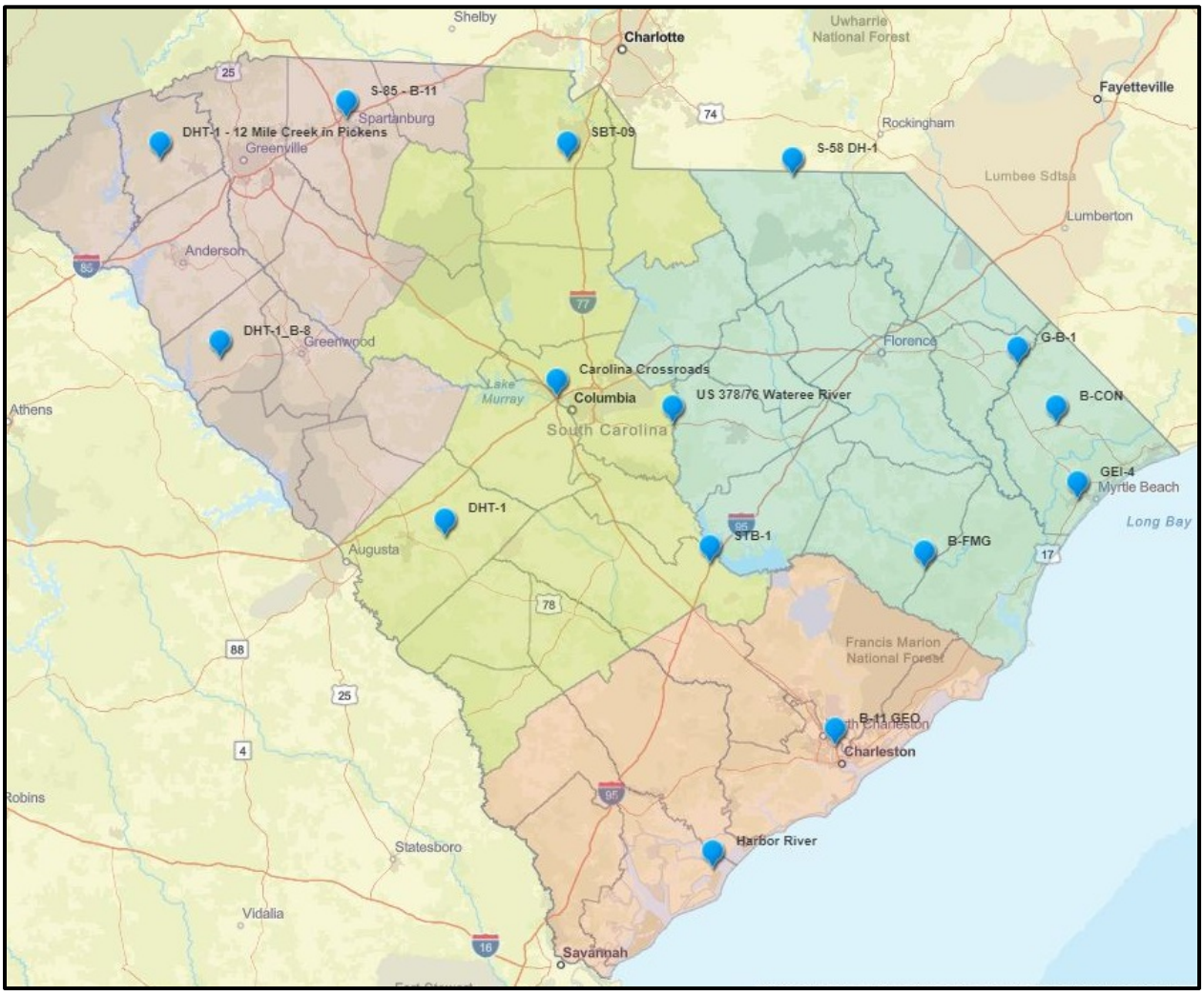



**Figure H-21, Deep Hole Location Map**
**(SCDOT Website (2021))**

- DHT-1 is located in Aiken County, SC along S-1304 over Shaw’s Creek and is an extension of soil test boring B-6. This site is considered to be located in the Upper Coastal Plain Physiographic Province.

- Carolina Crossroads consists of six shear wave velocity profiles taken along the I-26, I-20 and I-126 corridor in the Columbia metropolitan area. These sites are located in the Piedmont Physiographic Province.
- DH-1 (B-2) is located in Chesterfield County, SC just south of the border with North Carolina on S-58 over Thompson Creek. This site appears to lie just west of the interface between the Piedmont and Coastal Plain Physiographic Provinces.
- STB-1 is located in Orangeburg County, SC at the intersection of US 301 and I-95. This site is located in the Middle Coastal Plain Physiographic Province.
- G-B-1 is located in Horry County, SC along the proposed alignment for I-73 at the location of where S-917 crosses the Little Pee Dee River. This site is located in the Middle Coastal Plain Physiographic Province.
- SB-1 (Harbor River) is located in Beaufort County, SC along US 21 over Harbor River. This site is located in the Lower Coastal Plain Physiographic Province.
- B-11 GEO is located in Charleston County, SC along the proposed Port Access Road. This site is located in the Lower Coastal Plain Physiographic Province.
- GEI-4 is located in Horry County, SC at the intersection of US Highway 17 – Bypass, S-707 and Farrow Parkway (Backgate Interchange). This site is located in the Lower Coastal Plain Physiographic Province.
- B-Con is located near the proposed intersection of future I-73 and the SC 22. This site is located in the Lower Coastal Plain Physiographic Province.
- B-FMR is located in Georgetown County near the future Andrews Bypass. This site is located in the Lower Coastal Plain Physiographic Province.
- SB-09 is located in York County, S-655 (Auten Road) over Fishing Creek. This site is located in the Piedmont Physiographic Province.
- SC-85 is located in Spartanburg, SC over Norfolk-Southern Railway, S-995 and S-2. This site is located in the Piedmont Physiographic Province.
- DHT-1 is located along 12 Mile Creek in Pickens County and is located in the Piedmont Physiographic Province.
- DHT-1 is located on S-32 in Abbeville County over Little River. This site is located in the Piedmont Physiographic Province.

The results for B-CON and B-FMR are from a research report (SPR 731) that was prepared by the Inthuorn Sasanakul, University of South Carolina. SPR 731 is also available on the Geotechnical Design Webpage.

## H.2 REFERENCES

Florence & Hutcheson (2008), “Site-Specific Seismic Response Study US 378 Bridge Replacements over the Great Pee Dee River and the CSX Railroad, Florence and Marion Counties, South Carolina”, SCDOT File No. 21.182B.1 (PIN 30597), Columbia, SC.

Lewis, M. R., McHood, M. D., and Arango, I., (2004), “Liquefaction Evaluation at the Savannah River Site – A Case History”, Proceedings*: Fifth International Conference on Case Histories in Geotechnical Engineering*, New York, NY, April 13-17, 2004, Paper No. 3.21.

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