# APPENDIX 1

## LATE QUATERNARY GEOMORPHIC SETTING OF

# ARCHÆOLOGICAL SITE 7K-C-107,

## KENT COUNTY, DELAWARE

By
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1993



This appendix is an abridged version of a thesis submitted by the author in partial fulfillment of requirements for the degree of Master of Science in Geology at the University of Delaware. Additional appendices and illustrations will be found in the original thesis.

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# ABSTRACT

At the request of the Delaware Department of Transportation (DelDot) and Heite Consulting of Camden, Delaware, a geological investigation was conducted in the vicinity of archæological Site 7K-C-107. The site is located approximately three kilometers northwest of the city of Dover, Delaware. The study included sediment sampling at the archæological site and a detailed topographic and subsurface investigation of a bay basin and the floodplain of the St Jones River. Data obtained from these studies combined with a detailed radiocarbon and pollen geochronology allowed a reconstruction of the Late Quaternary geomorphic history of the vicinity of the site.

The Late Quaternary landscape surrounding the site probably consisted of sand dunes with local interdune swales and deflation areas. From approximately 21,000 - 15,000 years B.P., many interdune areas became flooded, probably due to an increase in precipitation. Large scale æolian erosion and deposition was slowed, and sediments deposited in the basin during this time consisted primarily of loess. There is no record of any sediments being deposited within the floodplain sequence during this time. From 15,000 - 10,300 years B.P, thick sand and gravel units were deposited by the St. Jones River, suggesting an increase in the frequency of large storms and runoff. Although there isn't any record of sediments from the basin for this time, the basin is likely to have remained flooded. By 10,300 years B.P., vertically accreted deposits dominated floodplain sedimentation, suggesting a change toward drier climatic conditions. Generally dry conditions continued until approximately 2,800 years B.P. During a brief period occurring at some time during the interval from approximately 8,800 - 5,680 years B.P., an extended period of drought contributed to extensive æolian erosion and deposition on the upland landscape. About 2,800 years B.P., the climate became wetter, and the bay basin was again flooded. The St. Jones River now flowed through swampy wetlands, eroding older deposits and leaving two terraces on either side of the present floodplain.

# ACKNOWLEDGMENTS

I would like to thank my advisor Jim Pizzuto whose enthusiasm for everything that is geology made this thesis possible. I would also like to thank my committee members, Dr. John C. Kraft and Dr. John Wehmiller, for their support and expertise.

Bob "Snake" Owen deserves special thanks for his often unappreciated field assistance.

And, lastly I would like to thank; the Department of Geology for providing field and laboratory equipment; Peter Miller at Environmental Resource Management, Inc. (ERM) for providing the GPR equipment; Dr. Grace S. Brush, for her pollen work; the staff at the Delaware Geological Survey for their expertise and continuous advice; Ned Heite and Kevin Cunningham for their financial support, my friends at Artesian Water for moral support as well as an occasional loan of field equipment... and especially my family for their total support.

# 1. INTRODUCTION

This study of the Late Quaternary geomorphic setting of archæological Site 7K-C-107 was undertaken at the request of the Delaware Department of Transportation (DelDot) and Heite Consulting of Camden, Delaware. The site is located approximately three kilometers northwest of the city of Dover in Kent County, Delaware. Previous work at the site has included reconnaissance work by Custer and Galasso (1983) and Phase I and II investigation by Heite Consulting (1992). Research during Phase II excavations indicated the possibility that buried horizons at the site could date to Paleo-Indian time (greater than 6500 B.C.).

Because of the upland position of the site on the landscape, burial was thought to be the result of æolian, and not colluvial or alluvial origin. Detailed analyses by Soils International, Inc. of several soil profiles at the site and surrounding areas, has supported an æolian origin for both the local geomorphology as well as the buried horizons (Foss et al. 1992).

archæological sites indicating burial by æolian deposition have also been recognized in several other areas of the mid-Atlantic Coastal Plain. Curry (1980) and McNamara (1982) studied æolian deposition at several sites in central Anne Arundel County, Maryland. Investigations at the Abbot Farm site in central New Jersey, including the detailed soils work of Stewart (1983), have also shown evidence of æolian deposition. Custer (1986) and Custer and Watson (1987) studied stratigraphic breaks in soil profiles and the possible influence of æolian deflation at several sites in Delaware and Maryland.

Data from these studies have generally indicated that æolian deflation and deposition have occurred during the interval from 2000 B.C. to 6500 B.C. (Custer and Watson 1987). Many of the sites show evidence of burial during Late Archaic and early Woodland time. This interval generally corresponds with the warm/dry mid-Holocene Xerothermic period (6,500 B.P. to 3,200 B.P.) (Curry 1980; McNamara 1982; Joyce 1988). It is unlikely, however, that æolian deflation and deposition occurred during this entire time interval. In fact, many authors (Blytt 1881; Sears 1942; Deevey and Flint 1957; Wendland and Bryson 1974) have suggested that there is evidence of two dry periods during Holocene time.

Several additional problems are associated with employing paleoclimatic data derived from archæological sites. Through their impact on local vegetation, human activities themselves can have a significant influence over local geomorphological processes which often overshadows the imprint from regional climatic conditions (Joyce 1988). Custer (1986) also noted that æolian processes which cause deflation at a site can contribute to mixing, possibly reducing the quality and usefulness of data. Sufficient carbon for the determination of absolute dates by radiocarbon dating is also not generally present in a position bracketing æolian sediments.

As early as the 1880s, researchers recognized that wind-blown sediments could be deposited in marsh areas and peat bogs (Dana 1883). Detailed stratigraphic records from these environments are likely to identify periods of æolian deposition. Also, because of increased preservation potential of seeds, pollen, and organic matter, these records may provide a more refined paleoclimatic history and a considerably refined absolute chronology as to the dates of change. Several other depositional environments, including many fluvial systems, are also likely to provide a stratigraphic record that reflects changes in environmental conditions along with sufficient organic debris for dating.

In the immediate vicinity of archæological Site 7K-C-107 are the floodplain of the St. Jones River and two small closed depressions, commonly known as "bay basins." Similar features have been shown to contain a sediment record spanning Holocene time. Rasmussen (1958) investigated several basins in Delaware and established that their origin dated to late Pleistocene time. Through pollen analysis he was also able to show that the record of sediments preserved within several basins generally followed the Blytt-Sernander chronology of Holocene environmental episodes. Stolt and Rabenhorst (1987a 1987b) studied both the distribution and origin of basins across the Eastern Shore of Maryland and central Delaware. Webb et al. (1989) and Webb (1990) studied sedimentation rates in several basins in central Delaware to evaluate water-level fluctuations during the Holocene. The Holocene paleogeomorphic history for an archæological site in central Delaware was developed through the investigation of basin sediments by Pizzuto (1992). Results from this study indicated a "package" of sandy sediments bracketed above and below by the more typical fine sand, silt and clay basin fill encountered by various other authors. Palynological results and radiocarbon dating, however, did not refine the time interval during which these sandy sediments were deposited.

The study of the record of paleoenvironmental change as recorded in fluvial sediments has developed from the early work of Davis (1902). In addition to recognizing the influence of changes in base level in his study of the grading of river systems, Davis (1902) postulated that a river will steepen its longitudinal profile by aggradation during a trend toward more arid conditions, and will decrease its profile by entrenchment during more humid conditions. The field evolved with the recognition that the principal factors involved in causing ungraded streams are the characteristics of runoff and sediment yield, both of which are significantly influenced by prevailing climatic conditions (Knox 1983) in addition to tectonic activity and changes in base level.

Most studies employing an alluvial stratigraphic record in the investigation of climate change have been in the mid- and southwest United States. In his study of floodplain deposits in south central Missouri, Brackenridge (1980 1981) was able to reconstruct a detailed Holocene record of periods of aggradation, of stability, and of erosion. McDowell (1982) established an alluvial chronology for a small watershed in western Wisconsin. Through her evaluation of the climatic conditions responsible for changes noted in the alluvial chronology, she was able to reconstruct a Holocene geomorphic history for the watershed. In a somewhat different approach to the relationship between prevailing climatic conditions and fluvial response, Hereford (1984) investigated the twentieth-century record of alluvial stratigraphy along the Little Colorado River in northeastern Arizona. This study was unique in that an abundance of detailed climate (temperature and precipitation) and discharge data was available for this time period.

A few studies in the eastern United States have compared alluvial stratigraphic records to Holocene records of climatic change. Scully and Arnold (1981) investigated alluvial terraces along the Upper Susquehanna River in south central New York. Their research noted a correlation between changes in local palynology and changes from periods of incision to periods aggradation. The alluvial stratigraphic record of a terrace along the Lower Susquehanna River Valley was also investigated by McNamara (1985). McNamara attributes changes in the alluvial stratigraphy to reflect a decrease in river discharge associated with the mid-post-glacial xerothermic.

The objective of this study is to reconstruct the Late Quaternary geomorphic history of archæological Site 7K-C-107 primarily through the interpretation of sediments recovered from one of the bay basins, the St Jones River floodplain and the archæological site itself. Particular interest is placed on recognizing the æolian sediments found at the archæological site, the basin, and the floodplain.

# 2. STUDY AREA

The study area is located in central Delaware approximately three kilometers (1.8 miles) northwest of the city of Dover, Delaware (FIGURE 1). This part of the Atlantic Coastal Plain is of generally low relief and is made up of broad interfluves separated by small perennial streams.

The archæological Site (7K-C-107) is located at an elevation of approximately 12 meters above sea level on a small hill overlooking the confluence of the Fork Branch and Maidstone Branch tributaries of the St. Jones River. The elevation of the tributaries and the adjacent floodplain is approximately 5 meters above sea level. The Fork Branch has a drainage area of approximately 19.5 sq. km (7.5 sq. miles) (Woodruff 1972). The Maidstone Branch drains an area of approximately 45 sq. km (17.3 sq. miles) (FIGURE 2).

The two basins are located on the upland area southwest of the archæological site. The first basin is approximately 90 meters in diameter and is located 30 meters from the site. The second basin is approximately 50 meters in diameter and is located 450 meters southwest of the site. Figure 3(a) shows the relative locations of the basins, the archæological site, and the floodplain in map view. As indicated on this map, the centerline for the proposed highway right-of-way intersects each of the features. The notations (7+00, 8+00, ... 35+00) shown on the map indicate highway department survey stations. These stations are spaced at 30.48 meter (100 foot) intervals along the proposed centerline. Figure-3(b) shows the relative elevations of the features in cross-section.

Surficial sediments in the area are thought to be predominantly of the Pleistocene age Columbia Formation (Jordan 1964). The Columbia Formation is made up of reddish-orange brown to tan, medium to coarse sands and gravels. The Columbia Formation is thought to be of fluvial origin. These sediments are estimated to extend to a depth of approximately 6 m (20 feet) in the study area (Jordan 1974; Pickett and Benson 1983), although erosion has reduced this thickness in many areas.

Soils developed on the upland areas are mapped as the Sassafras-Fallsington Association. Soils in the Sassafras Series are deep well-drained soils which formed in sandy sediments. Fallsington soils are poorly drained soils formed in sandy sediments. Soils on the floodplain are mapped as 'swamp' and Johnston Series. The Johnston Series soils are wet, very poorly drained soils formed in recent accumulations of highly organic sediments. The basin farthest from the site is mapped as the Elkton Series: poorly drained, gray soils in slight depressions and on upland flats (Matthews and Ireland 1971).

# 3. METHODS

In order to reconstruct the Late Quaternary geomorphic history of archæological Site 7K-C-107, a detailed geological investigation was undertaken of one of the bay basins, the St Jones River floodplain, and the archæological site itself. Field work at the basin and floodplain involved the study of both the local relief, as well as the subsurface stratigraphy. Laboratory work involved the collection and comparison of sediment samples from basin cores, floodplain cores, and the archæological site in order to recognize the æolian sediments in the three different environments. Stratigraphic control was also provided by carbon 14 dating and palynological analyses.

The first area investigated was the basin located approximately 400 meters southwest of the archæological site. The basin closest to the archæological site appeared to have been highly disturbed and was not investigated. A transect across the basin was selected along the centerline of the proposed highway right-of-way. Stakes were set every 3.05 meters (10 feet) from the topographic high at highway department station (8+00), southwest of the basin, to station (12+00) on the northeast side of the basin. Elevations at each of the stakes were surveyed-in using a Topcon model AT-F3 Auto-level and rod.

Initial subsurface reconnaissance included taking approximately 20 open barrel gouge-auger cores with both a small diameter (2.5 cm) and large diameter (5.0 cm) core barrel. The sandy sediments encountered during coring prevented penetration of more than one meter at any of the coring locations.

In order to extend the depth of investigation, a hand operated bucket auger (8 cm diameter) was used. Eight locations, spaced at 15.24 meter (50 foot) intervals along the transect (8+00, 8+50, 9+00, ... 12+00), were selected for augering. Five additional locations were also augered. Two of these locations were on the transect line at 9+70 and 10+30. The three other locations selected were to the north and west of the transect line. Augering depths reached a maximum of 5.3 meters. Sediment samples were collected during augering at every 30.5 cm (1 foot) of depth, or at a change in lithology. Plate 1 provides an example of the hand-augering operation. The depth to ground-water was also measured in each of the open hand-auger holes prior to backfilling.

Four piston cores were collected at locations along the transect near the center of the basin (9+50, 9+70, 10+00, and 10+30). Piston cores were collected inside 7.2 cm diameter aluminum coring pipe. Coring procedures followed the vibra-coring technique of Hoyt and Demarest (1981) supplemented with a piston to improve recovery.

Ground-Penetrating-Radar (GPR) was also utilized in the subsurface investigation of the basin. GPR data were collected using a 300 MHz (Megahertz) transmitter (Model 3105 AP) manufactured by Geophysical Survey Systems Inc. A continuous line of GPR data was collected along the same transect (8+00 to 12+00) established for augering and coring locations. Plate 2 illustrates GPR data collection.

The second part of the study area investigated was the floodplain located just to the northeast of the archæological site. As with the basin, a transect was selected along the centerline of the proposed highway right-of-way. A line of stakes was set every 3.05 meters (10 feet) starting at highway department station 21+50, located approximately 30 meters southwest of the archæological site, and finishing on the other side of the floodplain at 30+00. Elevations at each of the stakes were surveyed-in using a Topcon model AT-F3 Auto-level and rod. The floodplain survey also included the archæological Site. Plate 3 provides an example of the surveying across the site.

Twelve piston cores were collected at locations along the transect. Coring locations were selected to maximize subsurface resolution while still providing complete coverage of the entire floodplain. Eight of the cores were spaced at 15.24 meter (50 foot) intervals starting at the southwestern edge of the floodplain (23+00, 23+50, ...26+50). Two cores were collected at the northeastern end of the transect (28+00 and 29+00). Two additional cores were also collected to fill in gaps in the record (23+10 and 28+80). Plate 4 illustrates the piston coring operation on the floodplain.

The third area investigated included the sediments at the archæological site. Five distinct soil zones were delineated by Heite (1992). Zones 2, 3, and 4 were sampled for sedimentological analyses.

**Plate 1**
**Hand-augering southeast of the basin**

**Plate 2**
**GPR data recovery**

All sediment collected in the field was described in detail in accordance with the Unified Soil Classification System (USCS). This classification system includes detailed descriptions of texture, color, inclusions, moisture content, plasticity, and consistency.

Sixteen samples were selected from the piston cores for radiocarbon analysis. Sampling locations were selected to maximize both the possible range of dates, as well as the resolution in the piston core (PC-14) selected for palynological analyses. Samples were analyzed by Beta Analytic Inc. in Miami, Florida.

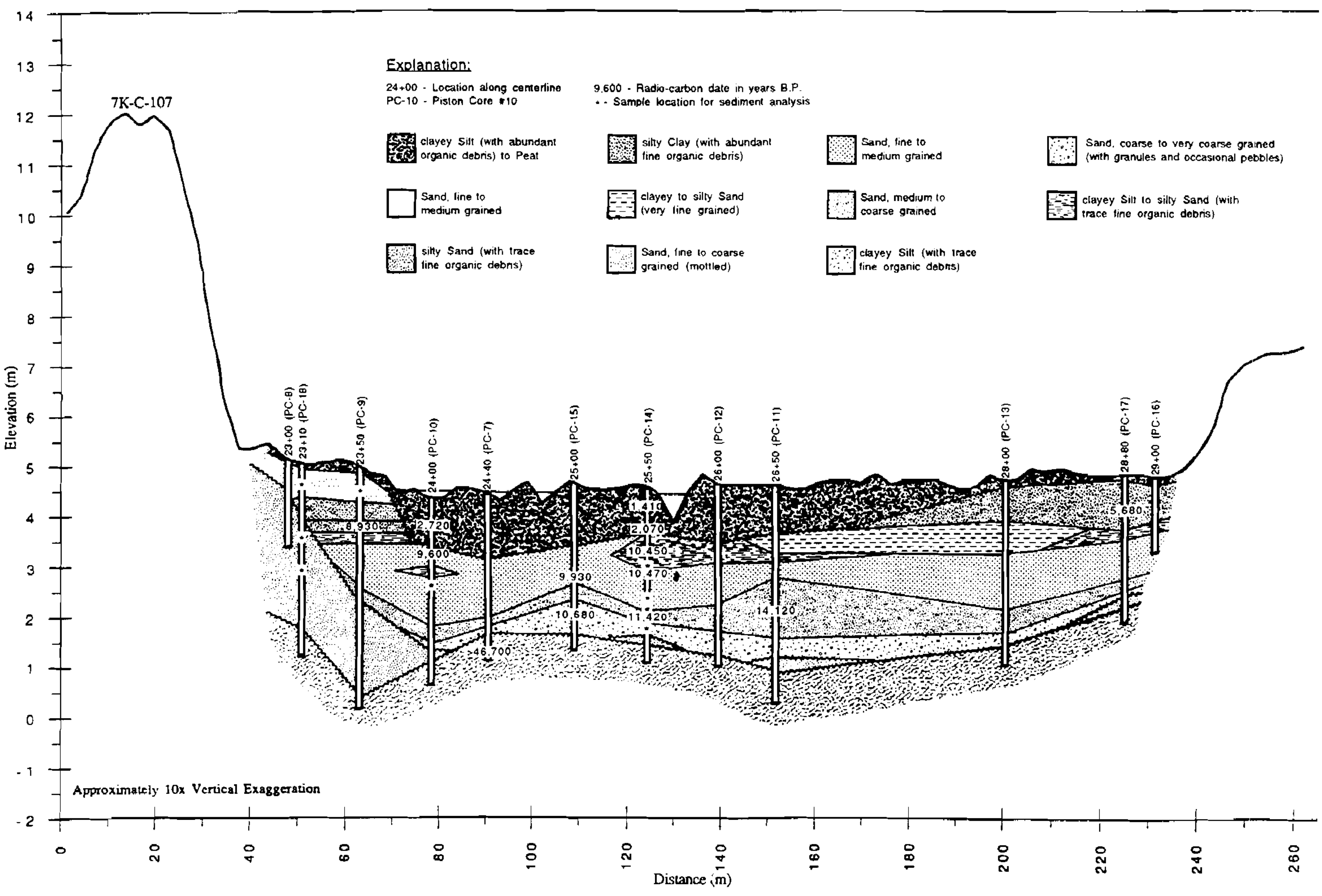
Selected samples from the basin, the floodplain, and the archæological Site were analyzed to determine their grain size distributions. Laboratory procedures followed those outlined by Folk (1980).

All samples were first pretreated with 30% hydrogen peroxide solution to remove any organic constituents. Following pretreatment, samples were each washed through a 4 phi (63 micron) sieve to separate the sand and coarser fraction from the fine (silt and clay) fraction. The fine fraction was collected, dried, and weighed. The coarser sediments were then dry sieved using a 1/4 phi sieve set.

Dr. Grace Brush from the Geography Department at Johns Hopkins University analyzed one core (PC-14) from the floodplain for pollen content. A single sample was also analyzed from core PC-7 by Dr. Groot from the Delaware Geological Survey.

**Plate 3**
**Surveying at Blueberry Hill site**

**Plate 4**
**Piston coring**




## Figure 4

**General lithologic cross-section for the basin from 8+00 to 12+00**

# 4. RESULTS

Data for this investigation are based on a detailed topographic survey, descriptions of 16 continuous piston cores, descriptions of sediment samples collected from 13 hand-augering locations, detailed textural analyses of selected sediment samples, and stratigraphic control provided by radiocarbon dates and palynology. All sediment samples and continuous cores were described in detail in accordance with the Unified Soil Classification System (USCS).

A generalized lithologic cross-section for the basin is presented in Figure 4. Sediments encountered during hand-augering in areas adjacent to the basin consisted primarily of fine to medium sand, medium to coarse sand, and sandy to clayey silt. In addition to the gross changes noted in lithology, subtle changes were observed in the character and degree of soil development. A thin Ap horizon was observed at all augering locations. The Ap horizon is poorly developed consisting primarily of coarse organic debris and roots. There is little evidence of an A horizon (A2) developed below the Ap horizon suggesting that farming activities may have denuded the local surface.

A weakly developed B horizon, possibly a BC horizon was found at most augering locations. Evidence for buried B horizons, beneath the BC horizon, was also encountered at several locations. This evidence was based primarily on observable changes in color, illuviation of silt and clay, and subtle changes in consistency. Buried A horizons were observed beneath the BC horizon at the northeastern and southwestern edges of the basin.

Sediments encountered beneath the soil sequences were primarily fine to medium sand. Below these sediments, coarser sands were observed as the deepest sediments encountered in the area to the southwest of the basin. To the northeast of the basin the coarse sediments were underlain by a sandy silt. Both the medium to coarse and, and the sandy silt indicated moderate mottling.

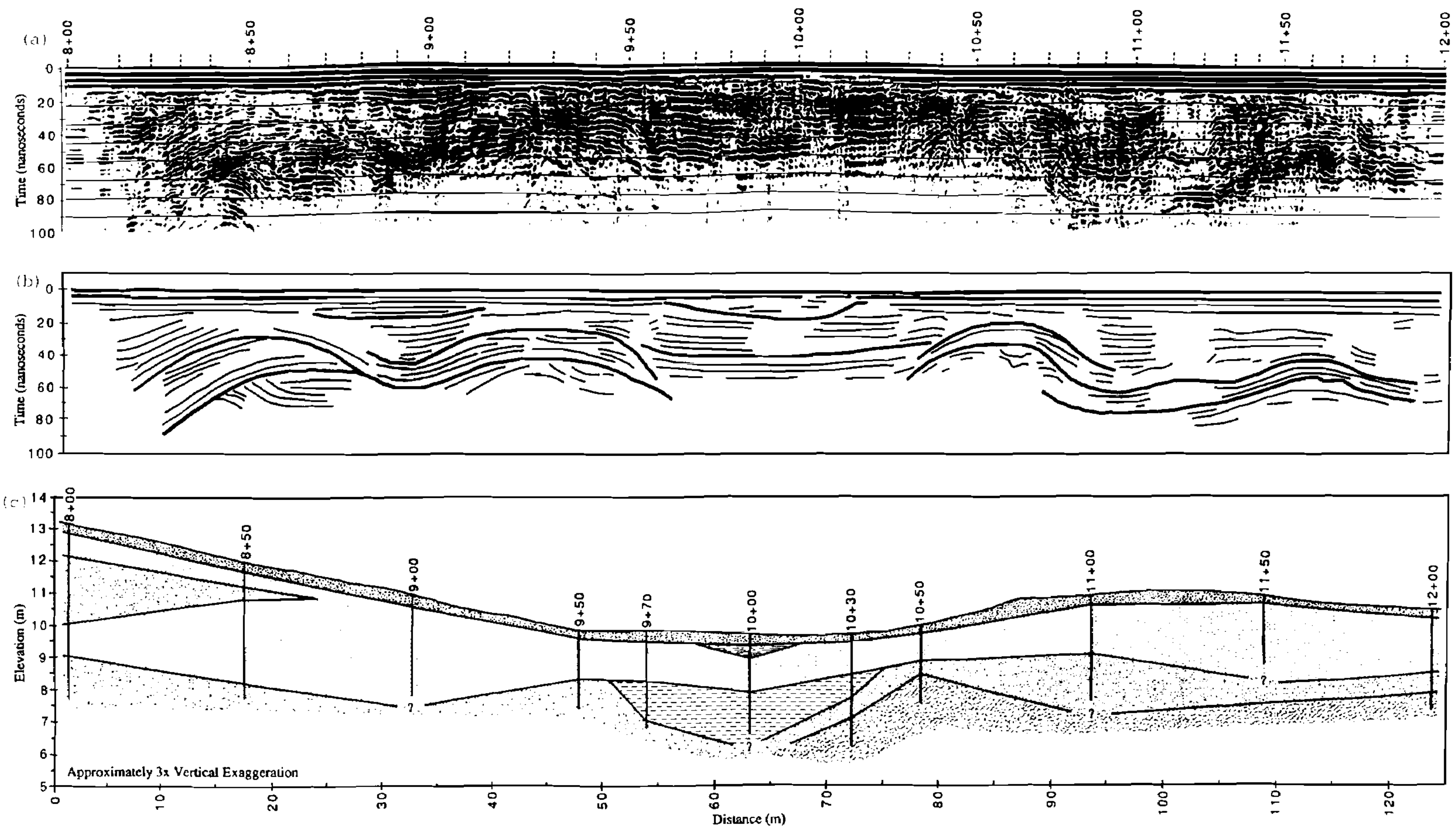
Sediments collected by hand-augering and coring within the basin included fine to coarse sand, clayey silt, silty sand, and sandy silt. The deepest sediments encountered within the basin (basal sediments) were medium to coarse sand. Above this the "basin fill" sediments are predominantly clayey silt. The clayey silts were generally finely laminated. Some of these laminations were of very subtle changes in texture, others included small layers of organic debris, while still others were small drapes of fine to medium sand. A mud crack was also observed within these sediments. However, the mud crack did not appear to be filled with any of the overlying deposits, suggesting that the mud crack had closed before deposition resumed. Clayey silt to silty fine sand was deposited above the mud crack. A moderate degree of mottling was observed in these sediments.

Sediments found above the silty basin fill consisted of fine to medium sand showing a high percentage of silt and clay. The increase in silt and clay may be post-depositional, and may have resulted from illuviation and possibly from fine sediments washing into the feature from adjacent slopes. Moderate to extreme mottling was also observed in these sediments.

Above these sediments is a sandy silt with a high percentage of fine organic debris. This sediment is well represented only in the center of the basin. Surficial sediments within the basin also include an Ap horizon indicating that the feature was plowed at some point in its history. An aerial photo from the 1930s shows that the feature was cleared.

A single continuous line of GPR data was collected along the same transect that was established for the piston core and hand-auger locations (8+00 through 12+00). Figure 5 (a) presents the GPR record, (b) notes the significant interfaces observed on the GPR record, and (c) presents the same lithologic cross-section presented in Figure 4.

# Figure 5
# Ground penetrating radar record




(a) Ground penetrating radar (GPR) record for the basin from 8+00 to 12+00, (b) Interpretation of the significant interfaces on the GPR record, (c) Lithologic cross-section for the basin

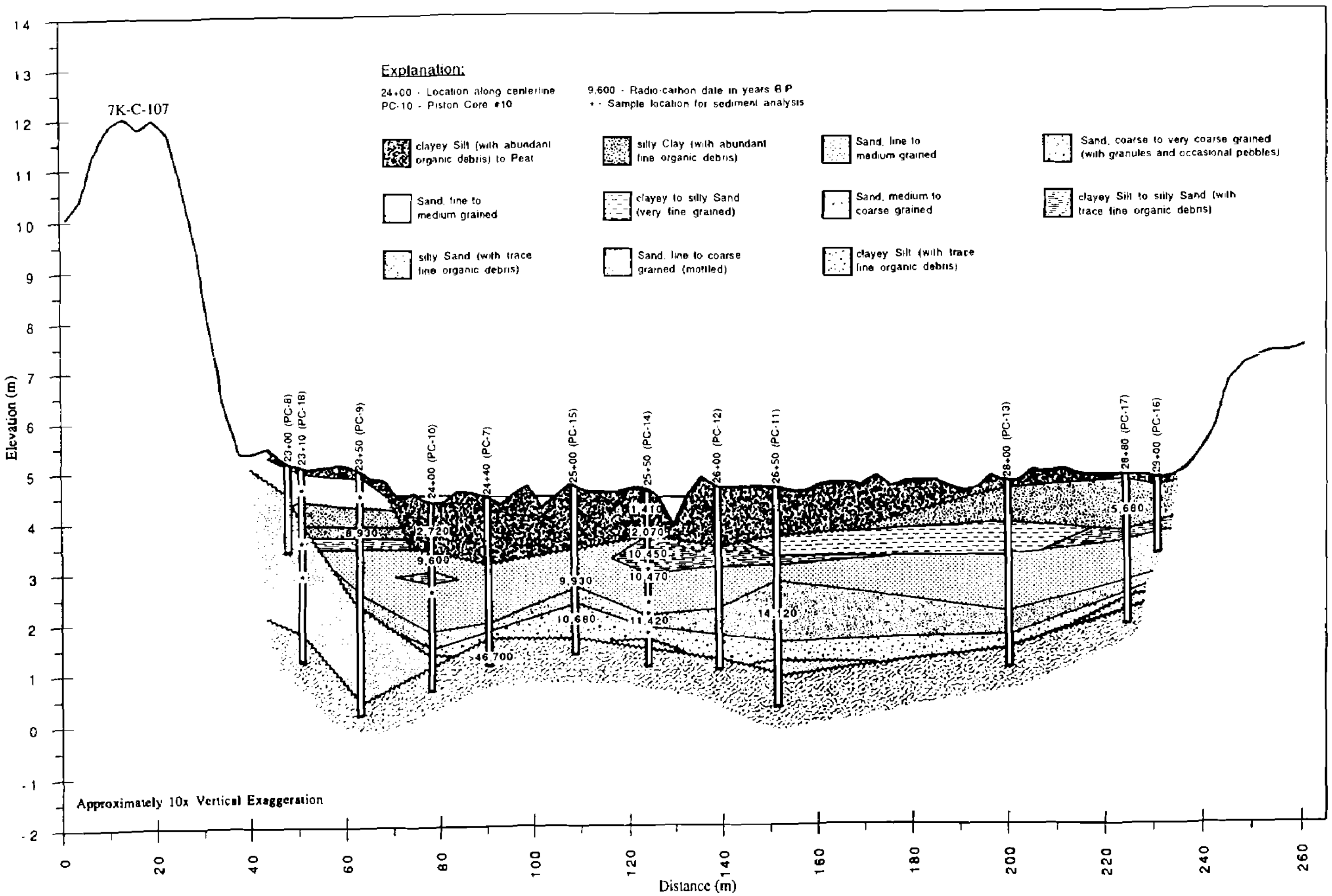



**Figure 6**

**General lithological cross-section for the floodplain**

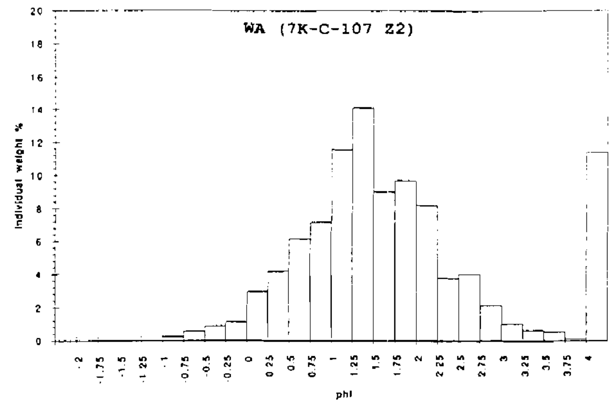



**Figure 7**

**Histogram for sediment sample WA from zone 2 at the archæological site**

The general swale-like stratigraphy and location of the basin fill sediments seen in the lithologic cross-section is also seen in the GPR record. However, many of the interfaces observed on the record are likely to be a result of the subtle changes observed in soil development that are not illustrated on the lithologic cross-section.

Water was encountered in all open hand auger holes and limited the maximum possible augering depth. The depth to water was measured in all open auger holes including several within the basin. The water table outside the basin appeared to be essentially flat. On the date of measurement the water table outside the basin was found at an elevation of approximately 8.5 meters. Water levels in open holes within the basin sediments were found at an elevation of approximately 9.5 meters. Evidence that water levels fluctuate both inside and outside of the basin was seen in the moderate to extreme mottling observed in the sediments.

A generalized lithologic cross-section for the floodplain is presented in Figure 6. Sediments encountered in the floodplain subsurface consisted of clayey silt, pebbles, granules, coarse to very coarse sand, medium to coarse sand, fine to medium sand, silty sand, silty peat, peat, and silty clay. The deepest sediments encountered during coring were clayey silt. The clayey silts were very dense and caused refusal in all cores that penetrated to sufficient depth.

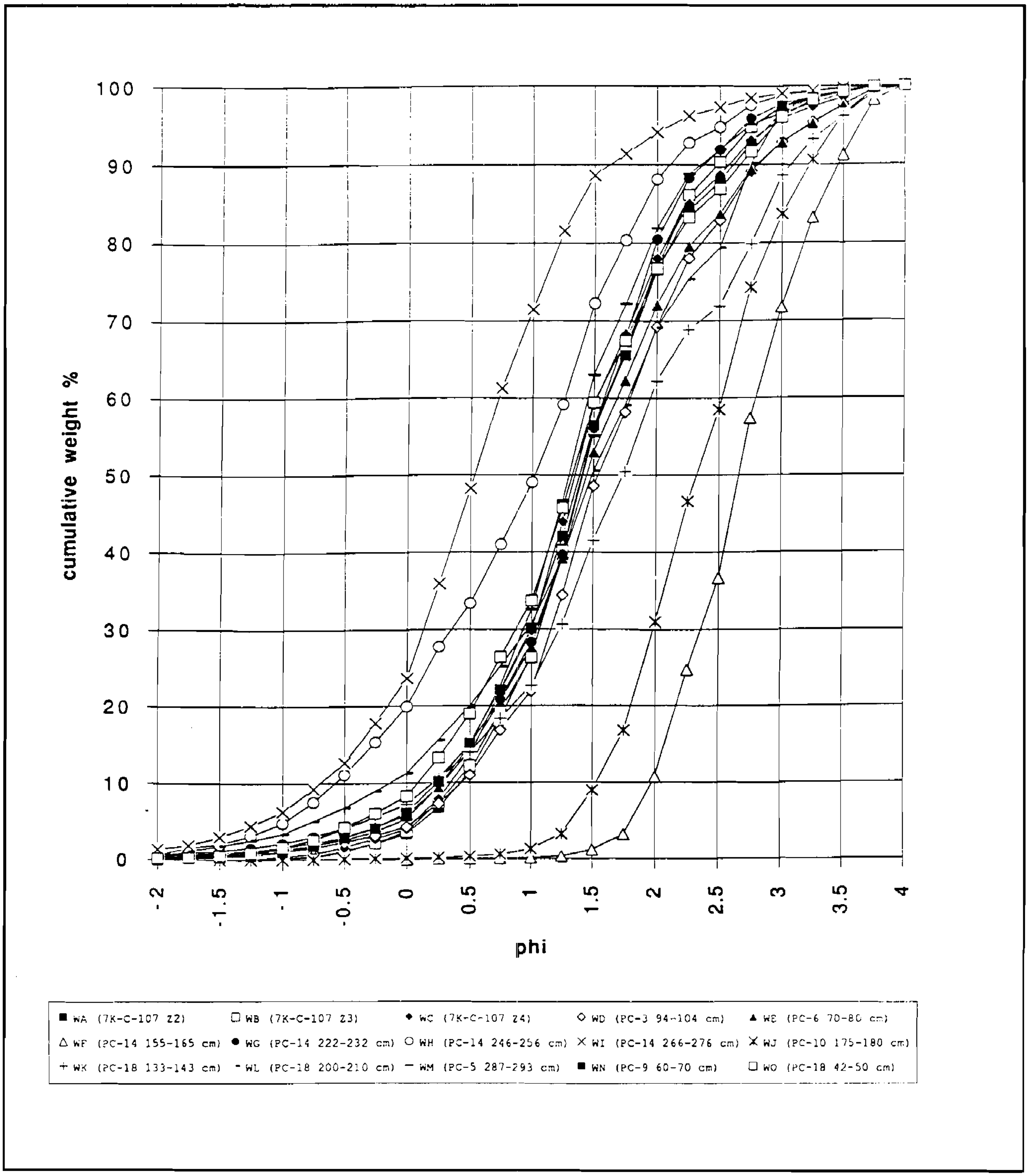



**Figure 8**
**Plot of the cumulative weight percent versus the phi size for the 15 sediment samples.**

Along the southwestern margin of the floodplain, the sediments unconformably overlying the clayey silt were found to be mottled fine to coarse sand. These sediments showed evidence of soil development. Small pockets of these sediments were also found as a thin veneer on top of the clayey silt in a few other parts of the floodplain. The sediment that unconformably mantled the clayey silt over the rest of the floodplain, and in some area the buried soils, was generally a layer of pebbles and granules. The pebbles and granules appeared to be channel deposits that may have been deposited during a lowered base level while valley incision was occurring. There was also evidence of rip-up clasts of the clayey silt incorporated into some of these sediments.

The thin layer of pebbles and granules grade upward into coarse to very coarse sand. There were often several small (10-20 cm) sections of very coarse sand, fining upwards into coarse and medium to coarse sand. Several locations also incorporated layers of medium to coarse sand and fine to medium sand. Occasional layers of woody organic debris were also encountered in these sediments. The thickness of the medium to coarse sand varied considerably across the floodplain.

The medium to coarse sand graded upward into fine to medium sand. The fine to medium sand was generally continuous across the floodplain. Most of this sediment occurred as many small (10-30 cm) fining upward sequences. One of the cores (PC-13) had five small sequences. Some of these small sequences included layers of organic debris. Occasional layers of sandy silt, that appeared to have settled from suspension, were also found within the fine to medium sand.

On the southwestern edge of the floodplain and across the northeastern half of the floodplain, the fine to medium sand was overlain by a clayey silt to clayey to silty sand which appeared to contain a high percentage of organic debris. These sediments also showed fine laminations. Stratigraphically above, but also adjacent to, the clayey silt was a similarly textured very fine grained clayey to silty sand. These sediments, however, were very "blocky," had little organic debris, no laminations, and a lighter color.

Above the clayey silt and above the very fine grained clayey to silty sand, where present, was a silty clay with a high percentage of very fine organic debris. Along the southwestern side of the floodplain these sediments were overlain by a poorly sorted silty sand also containing a trace amount of organic debris. These sediments graded upward into a cleaner, blocky, fine to medium sand. Sediments unconformably overlying the silty clay, and the fine to medium sand, where present, were clayey silt to peat. In several areas, these sediments are highly organic. These sediments were found directly above the deeper fine to medium sand found in the center of the floodplain.

Fifteen sediment samples were analyzed to determine their grain size distributions. Three samples were selected from the archæological Site, 3 from the basin cores, and 9 from the floodplain cores for analyses. Samples from the archæological Site were selected from Zones 2, 3, and 4 of the 5 zones delineated by Heite (1992). The 3 samples selected from the basin included two from the sandy sediments within the basin fill sediments, and one from the sand encountered below the basin fill sediments. Sampling locations are shown on Figure 4. The 9 samples from the floodplain cores were selected to represent the different sands that were encountered. The sampling locations are shown on Figure 6.

Following the mechanical analysis of the sand size fraction of the samples, weights for each phi size were converted to a weight percentage and a set of histograms of 'weight percent' vs 'phi size' were prepared to graphically present the data. The histogram for the sample collected from zone 2 at the archæological Site (WA) is shown in Figure 7. The histogram plots the weight percentage for each phi size in the sample.

Although this graphical presentation of the data shows the general distribution of sediment sizes for each sample, it is difficult to compare the samples to one another. A second method of graphically displaying the data is the cumulative curve. This curve plots the 'cumulative weight percent' vs 'phi size'.

Table 1
Statistical parameters for sediment samples from the archaeological site, the basin, and the floodplain

| Sample location | ID label | Mean | Dispersion | Skewness | Kurtosis | %<4 phi |
|---|---|---|---|---|---|---|
| 7K-C-107 Z-2 | WA | 1.43 | 0.78 | 0.48 | 1.07 | 11.42 |
| 7K-C-107 Z-3 | WB | 1.41 | 0.79 | 0.47 | 1.10 | 7.36 |
| 7K-C-107 Z-~~4~~5 | WC | 1.38 | 0.85 | 0.49 | 1.08 | 24.51 |
| PC-3 94-104 cm | WD | 1.60 | 0.93 | 0.50 | 1.16 | 26.33 |
| PC-6 70-80 cm | WE | 1.52 | 0.98 | 0.46 | 1.13 | 31.51 |
| PC-14 155-165 cm | WF | 2.67 | 0.57 | 1.18 | 0.91 | 19.98 |
| PC-14 222-232 cm | WG | 1.37 | 0.84 | 0.34 | 1.21 | 1.75 |
| PC-14 246-256 cm | WH | 0.89 | 1.04 | 0.08 | 0.99 | 1.04 |
| PC-14 266-276 cm | WI | 0.50 | 0.91 | 0.11 | 1.25 | 1.48 |
| PC-10 175-180 cm | WJ | 2.36 | 0.63 | 0.98 | 0.98 | 4.12 |
| PC-18 133-143 cm | WK | 1.74 | 1.11 | 0.34 | 0.98 | 14.42 |
| PC-18 200-210 cm | WL | 1.46 | 1.14 | 0.19 | 1.02 | 4.58 |
| PC-5 287-293 cm | WM | 1.30 | 0.80 | 0.46 | 1.13 | 4.20 |
| PC-9 60-70 cm | WN | 1.39 | 0.86 | 0.43 | 1.08 | 0.41 |
| PC-18 42-50 cm | WO | 1.33 | 0.97 | 0.34 | 1.11 | 0.84 |

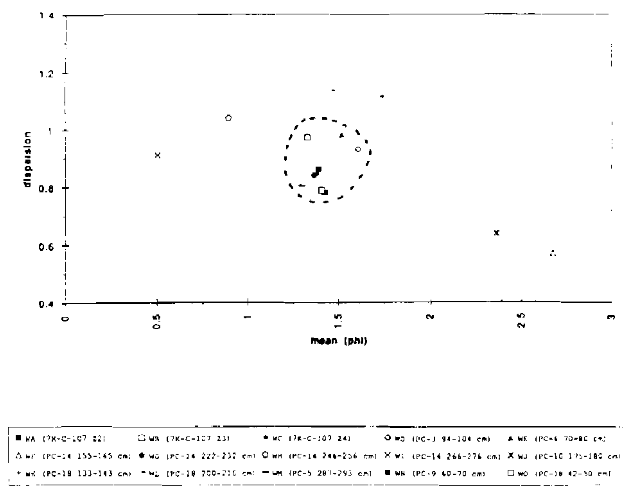



**Figure 9**
**Plot of the dispersion versus the mean for each of the sediment samples**

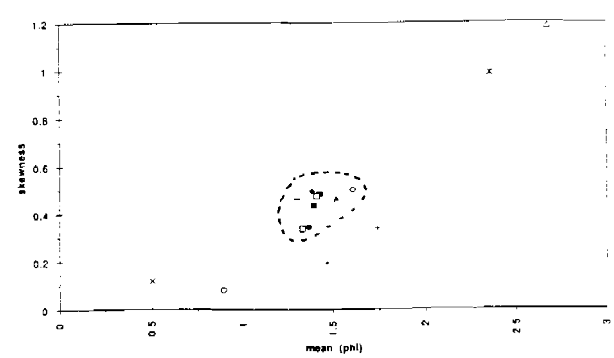



**Figure 10**
**Plot of the skewness versus the mean for each of the sediment samples**

Figure 8 is a single plot of the cumulative curve for each of the 15 samples. The cumulative percent curves also allow for the derivation of statistical grain size parameters (Folk 1980). Four parameters were derived for each of the samples: graphic mean, dispersion (standard deviation), skewness, and kurtosis. These parameters allow many samples to be easily compared.

Two methods exist to determine these parameters from the cumulative curves, the graphical method and the method of moments (Friedman 1979; Folk 1980). Folk argues that the graphical method is easier to use and that the method of moments does not necessarily provide more accurate data. The graphical method was utilized for this research. This method derives the statistical parameters by reading directly from the curve the diameter for specific percentages. The graphic mean ($M_z$) is determined by reading the diameters for the percentages $\phi16$, $\phi50$, $\phi80$, and is calculated by the equation:

$$M_Z = (\phi16+\phi50+\phi80)/3$$

The dispersion, or inclusive graphic standard deviation, ($\rho_I$) is calculated by the equation:

$$\rho_I = ((\phi84-\phi16)/4) + ((\phi95-\phi5)/6.6),$$

and is an indication of the degree of sorting of the sample. The inclusive graphic skewness ($Sk_I$) is a measure of the asymmetry of the distribution, primarily influenced by the excess of either coarse sediments or fine sediments on either side of the mean. Skewness is calculated by the equation:

$$Sk_I = ((\phi16+\phi84-2\phi50)/2(\phi84-\phi16))+((\phi5+\phi95-2\phi50)/2(\phi95-\phi5))$$

Kurtosis ($K_G$) is a measure of the peakedness of the distribution and is calculated by the equation:

$$K_G = (\phi95-\phi5)2.44(\phi75-\phi25)$$

Table 1 presents the statistical parameters calculated for each of the 15 sediment samples. An additional column of data including the weight percent of the less than 4 phi size fraction (silt and clay) is also presented on the table. Following procedures outlined in Friedman (1979), 7 "bivariate" plots were prepared to compare the statistical parameters with one another. Figures 9 through 12 are plots of the parameters dispersion, skewness, kurtosis, and %<4 phi versus the mean for each sample. The three additional plots seen in Figures 13 through 15 compare skewness vs dispersion, kurtosis vs skewness, and %<4 phi vs skewness.

As is clearly indicated by these plots, the sediments from the archæological site, the "basin fill" sands, the sample from beneath the "basin fill" sediments, and a very distinct set of sands from the floodplain, generally cluster closely together on each of the different plots. The clusters are outlined on each of the plots with dashed lines. Because the grain-size distribution of each sediment sample is primarily related to 1) the availability of different sizes of particles, and 2) the flow processes transporting and depositing the sediment (Friedman 1979; Folk 1980; Visher 1969), sediments with a similar source, transport, and depositional history will have a similar grain-size distribution and thus similar statistical parameters.

On the plot of %<4 phi vs mean two distinct clusters of data are observed. The difference seen in these sediment groups appears to be related to the degree of post-depositional soil development.

Sixteen sediment samples were selected from the piston cores for radiocarbon analysis. The sampling locations and the results for the 3 sediment samples selected from the basin are shown on Figure 4. The 13 sampling locations and the results for the floodplain cores are shown on Figure 6. The results of the radiocarbon analyses are also compiled in Table 2. The results for sediments from the basin cores showed an age range from 2,020 (± 100) years before present (B.P.) to 20,960 (± 390) B.P.. Dates for sediments from the floodplain cores ranged from 1,410 (± 70) B.P. to older than 46,700 B.P..

A single core (PC-14) from the floodplain was analyzed for pollen content by Dr. Grace Brush at the Geography Department of The Johns Hopkins University.

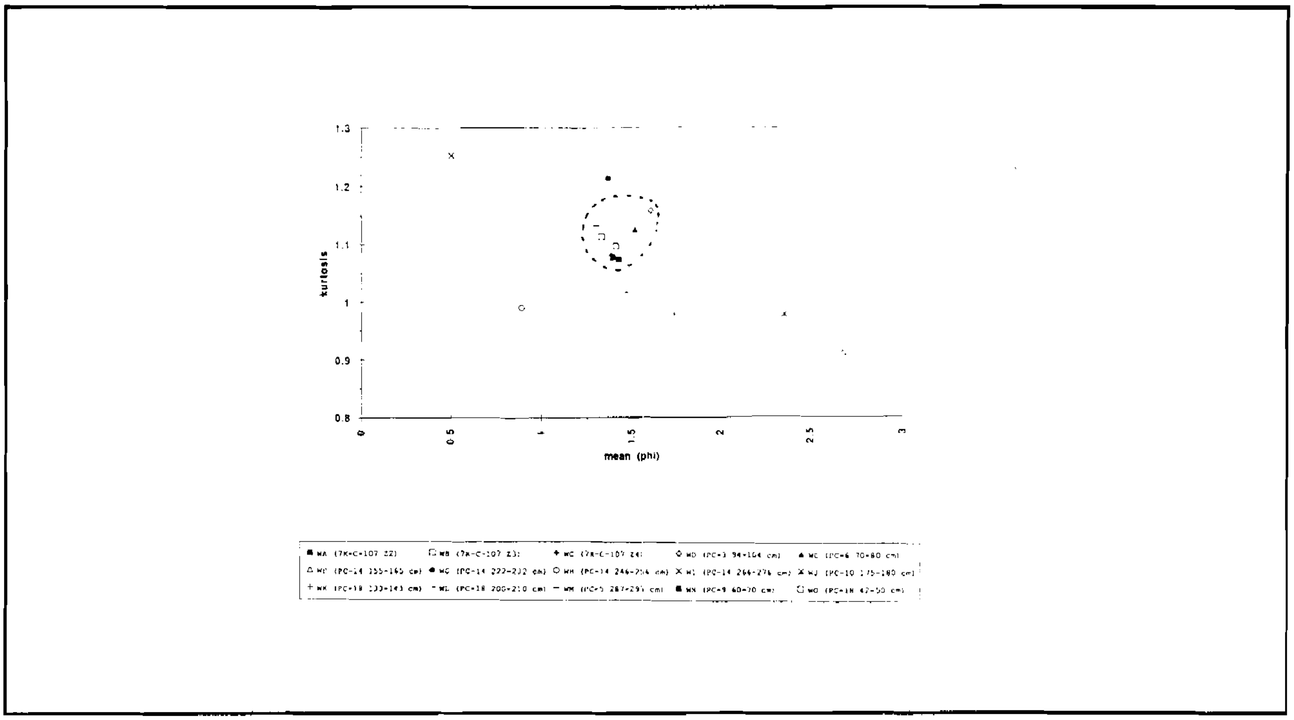



**Figure 11**
**Plot of kurtosis versus the mean for each of the sediment samples**

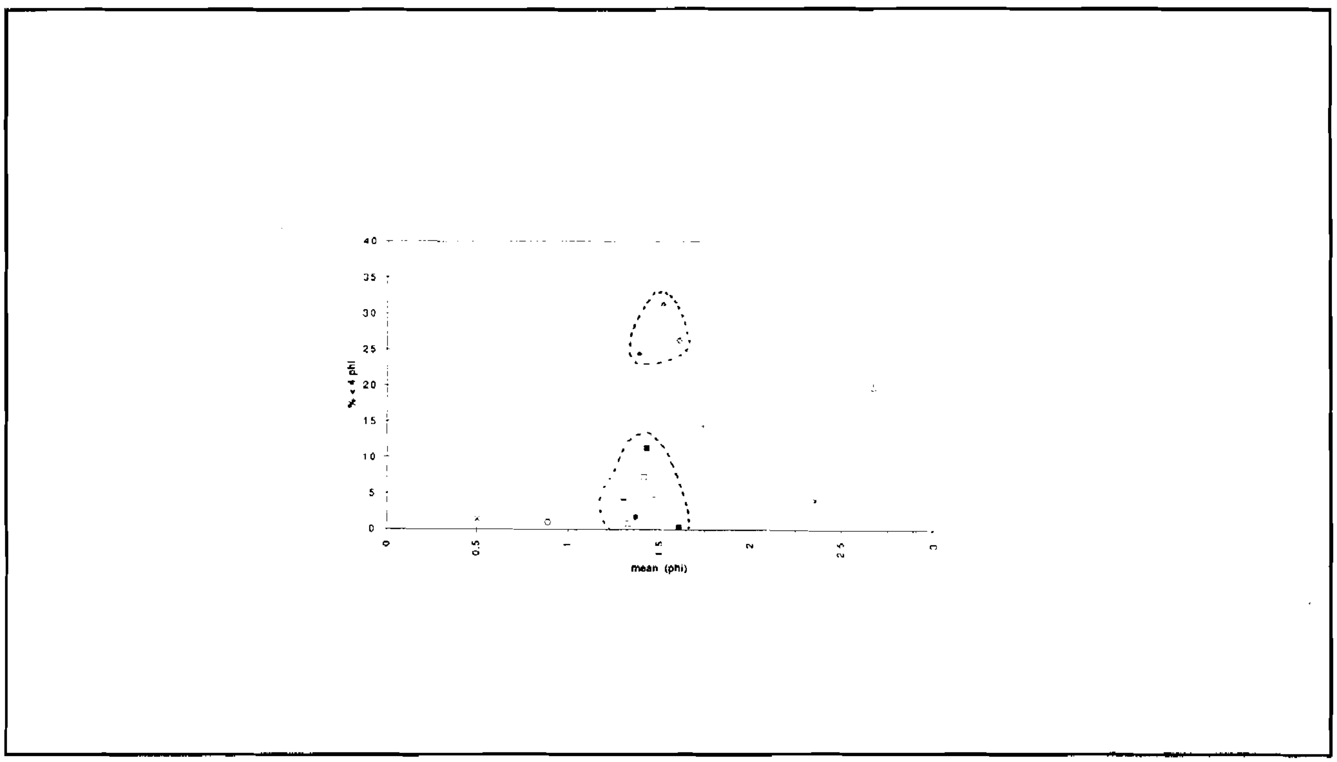



**Figure 12**

**Plot of the %<4 phi versus the mean for each of the sediment samples**

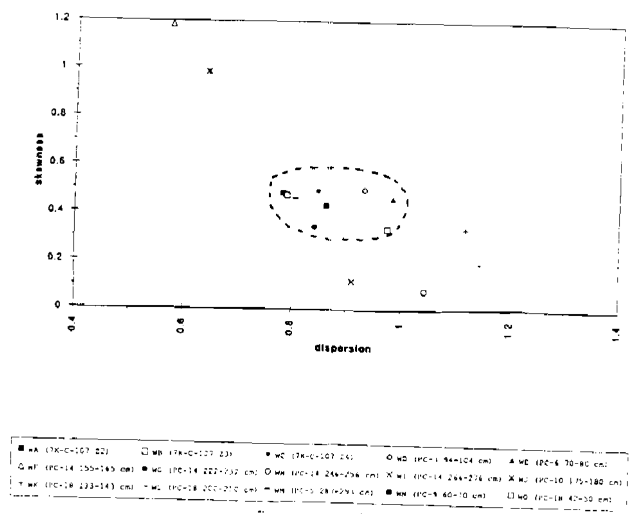



**Figure 13**
**Plot of skewness versus the dispersion for each of the sediment samples**

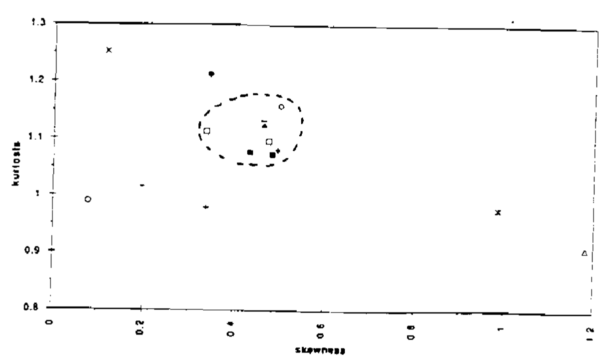



**Figure 14**

**Plot of kurtosis versus the skewness for each of the sediment samples**

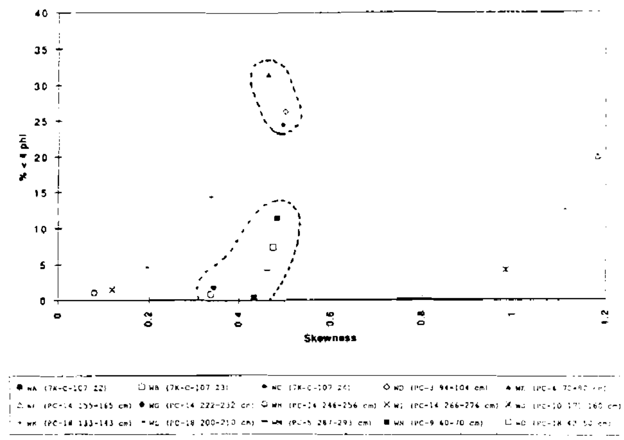



**Figure 15**

**Plot of the %< phi versus skewness for each of the sediment samples**

The pollen record for this core spans the age range from approximately 11,500 B.P. to present, however, the record from approximately 10,300 to 2,800 B.P. appears to be missing, and the clayey silt at the bottom of the core is likely to be older than 46,700 B.P.

The pollen record for sediments from 11,500 to 10,300 years B.P. indicates a period starting with cool wet conditions and changing to cool and generally dry conditions. Pollen from sediments younger than 2,800 years B.P. suggest wet and generally warm climatic conditions. A significant increase in Ambrosia (ragweed) pollen marked European settlement in the top 14 cm of the core. Dr. Groot's analysis indicates that the pollen record for the >46,000 year old clayey silt represents a Miocene flora, typical of the Calvert Formation.

| Sample location | Identification # | C-14 age (years B.P.) | Deviation (years) |
|---|---|---|---|
| PC-3 (45 - 55cm) | Beta 53518 | 2,020 | +/- 100 |
| PC-3 (142 - 162cm) | Beta 53941 | 16,060 | +/- 260 |
| PC-3 (313 - 343cm) | Beta 54093 | 20,960 | +/- 390 |
| PC-7 (314 - 324cm) | Beta 53521 | >46,700 | |
| PC-9 (123 - 129cm) | Beta 56920 | 8,930 | +/- 50 |
| PC-10 (54 - 64cm) | Beta 54094 | 2,720 | +/- 60 |
| PC-10 (94 - 100cm) | Beta 54095 | 9,600 | +/- 90 |
| PC-11 (245 - 251cm) | Beta 54096 | 14,120 | +/- 190 |
| PC-14 (40 - 50cm) | Beta 54097 | 1,410 | +/- 70 |
| PC-14 (81 - 91cm) | Beta 54098 | 2,070 | +/- 60 |
| PC-14 (120 - 130cm) | Beta 54099 | 10,450 | +/- 100 |
| PC-14 (169 - 177cm) | Beta 54100 | 10,470 | +/- 90 |
| PC-14 (257 - 262cm) | Beta 54101 | 11,420 | +/- 350 |
| PC-15 (199 - 205cm) | Beta 54102 | 9,930 | +/- 80 |
| PC-15 (258 - 263cm) | Beta 54103 | 10,680 | +/- 140 |
| PC-17 (70 - 75cm) | Beta 56807 | 5,680 | +/- 80 |

**Table 2**

**Radiocarbon dates for samples from the basin and floodplain**

# 5. Discussion

The geochronology and stratigraphy of the basin, the floodplain, and the archæological site indicate that several discrete periods in the history of the area can be defined. Figure 16 presents a chronostratigraphic interpretation of the basin and the floodplain, subdividing the history of the area into 8 periods. Figure 17 is a composite summary depicting the chronostratigraphic interpretation of the floodplain, basin, and archæological site, the dates of significant discontinuities, and the inferred climate for each of the periods. These periods are discussed in detail in the following sections.

## Prior to Approximately 21,000 BP

The stratigraphic cross-section and GPR record from the basin indicate that the topography of the area during this time consisted of a generally rolling ridge and swale surface suggesting an æolian origin. The oldest "basin fill" sediments recovered from the basin were dated at 20,960 B.P. indicating that the basin formed prior to this time. Several factors suggest that the prevailing direction of æolian transport was from the southwest toward the northeast. The morphology of the area adjacent to basin suggests a dune-like feature. Blowout features and swales tend to form in the lee of dunes. Also, since the northeast face of Blueberry Hill, on which the archæological site is located, is very steep (30 degrees) and it is unlikely that the sediment source which formed the hill could be from the east or northeast.

Fine to medium sand was encountered both outside the basin as well as below the basin. Grain size analyses of sediments selected from below the "basin fill" sediments demonstrate that the grain sizes deposited are appropriate for æolian erosion, transport, and deposition. Grain size characteristics also plot in the same general field as the windblown sediments found later in the basin, at the archæological site, and the windblown sediments found within the floodplain sequence (Figures 4-11 through 4-17).

The oldest sediments encountered during the investigation of the floodplain were dated to be older than 46,700 years B.P. This clayey silt is likely to have been deposited in a quiet open water environment, possibly an estuarine environment. Pollen from these sediments indicate generally cool climatic conditions.

Sediments found above the clayey silt along the southwestern edge of the floodplain and in scattered pockets across the floodplain are poorly sorted fine to coarse sand. These sediments are mottled and have evidence of soil formation indicating an extended period of aerial exposure. Although the date of these sediments is not unequivocally known, it is likely that they formed prior to 21,000 B.P. Although these sediments appear to have formed during the same time period as the æolian sediments found on the adjacent upland areas, their grain size parameters do not plot within the same fields as the other sediments (Figures 9 through 15). The location of these sediments at the foot of Blueberry Hill suggests a colluvial origin.

Other than the possibly colluvial sediments found in the lee of Blueberry Hill along the southwestern side of the floodplain, there is very little evidence of fluvially deposited sediments from this time period.

Although base flow is likely to have been low during this time, as is suggested by the lack of lacustrine sediments in the basin, the lower base level caused by lower sea level toward the close of the period probably contributed to valley incision making the preservation of floodplain sequences less likely.

Other than the possibility that æolian sands were being deposited during this time period, there is essentially no record from the archæological site.

In order to allow for the extensive æolian erosion, transport, and deposition needed to create the ridge and swale topography observed at the basin, and also to form Blueberry Hill, vegetative cover must have been significantly reduced over extensive upland areas. The landscape is likely to be the result of a "local" reworking of older Pleistocene age sands from the Columbia Formation. Periodic storms combined with reduced vegetative cover may also have contributed to colluvial sediments washing down the northeast face of Blueberry Hill and onto the floodplain.

These ideas are consistent with previous interpretations of the Late Pleistocene History of the Delmarva Peninsula, and also with previous interpretations of global Late Wisconsinan climates. Denny et al. (1979) investigated sand dunes in southern Delaware and dated their origin at 30,000 to 13,000 years B.P. The prevalence of local cold and dry conditions required for æolian deposition is also supported by abundant pollen data (Sears 1935; Deevey 1957; Wright 1976; Sirkin et al. 1977; Denny et al. 1979). Incision by the St. Jones River due to a lowered base level during this period is consistent with data on local-relative sea level (Kraft et al. 1976; Hoyt et al. 1990).

21,000 TO 15,000 YEARS BP

Hand-augering, coring, and the GPR record provided data to develop the general configuration of the basin and "basin fill" sediments. The oldest "basin fill" sediments recovered from the basin were dated at 20,960 B.P. These clayey silts are finely laminated and appear to have been deposited in a shallow lacustrine environment. Some of the thin laminations consist of organic debris and occasionally charcoal. Thin drapes of fine to medium sand also occur. Mud cracks were observed in one of the basin cores indicating at least brief periods during which the basin dried out. A second date of 16,060 B.P. within the clayey silts 1.5 meters above the older date provided a sedimentation rate of approximately 25 cm to 30 cm/1000 years.

Evidence of buried A horizons were found beneath the present margins of the basin. This soil may have been the edge of the basin during this time period.

There is no record of any sediments being deposited within the floodplain sequence during this time. Soil development may have continued on older areally exposed sediments. Some of these sediments may also have been eroded due to valley incision during this time.

A well developed buried B horizon was observed at the archæological site suggesting that soil development may have been occurring during this time.

A slight increase in precipitation during this time period is necessary to raise the local water table on the upland areas and to flood the basin allowing for the deposition of the lacustrine clayey silt. This is likely to have occurred shortly before 20,090 B.P., based on the oldest sediments recovered from the "basin fill" sediments.

The catchment area for the basin is insufficient to provide the observed volume of clayey silt by overland flow and through-flow. Thus, the source for the "basin fill" sediments is likely to have been æolian loess. A continued cold climate may have contributed to a low rate of evapotranspiration such that water tables remained high and the basin remained flooded even with only the slight increase in precipitation. Winter, spring, and fall months may have been slightly wetter, though dry summers may have been necessary to allow for the formation of loess. The sand drapes may have been the result of periodic large storms. Slow loess deposition may also have increased the epipedon at the archæological site and adjacent upland areas increasing the silt and clay available for illuviation to the B horizon.

Several researchers have suggested that these basins formed as interdune swales (Sirkin 1977; Boggs 1987; Stoldt et al. 1987). Other researchers have shown evidence that these features are related to the surrounding water tables (Rasmussen 1958; Phillips 1990; Webb et al. 1989; Webb 1990). Basins in Central Delaware are estimated to have formed 15,000 to 20,000 years ago based on radiocarbon dates of 20,840 and 16,280 for buried soil horizons beneath basin rims (Stolt et al. 1987).

Similar features are presently forming in interdune swales in Australia (Pye 1990).

Stolt et al. (1987) have also suggested that basin sediments are the result of loess deposition. Johnson (1993) has argued that there is a constant flux of loess available for deposition in similar features in Virginia. Webb (1990) studied sedimentation in a swamp in southern Delaware and concluded that Late Pleistocene sedimentation rates were approximately 25 cm/1000 years.

The increase in water table elevations is likely to have increased the base flow to the St. Jones River. This coupled with periodic storms and the continued lowered base level may have contributed to valley floor incision.

Foss et al. (1992) discuss the æolian origin of the buried B horizon at the archæological site. They also argue that prior to burial, the degree of soil development indicates a weathering period of at least 7,000 to 8,000 years.

15,000 TO 10,300 YEARS BP

There is no record of sediments from the basin for this time period.

Extensive aggradation was occurring during this time period. The sediment that unconformably mantles the older clayey silt, and in some areas the buried soils, consists of pebbles and granules. These sediments gradually grade upward into fine to medium sand. Many of the cores indicate several small (10-30 cm thick) fining upward sequences. The sediments comprising the fine to medium sand are the most continuous across the width of the floodplain. These sediments did not provide sufficient pollen for pollen analyses.

Although small sequences (less than 10 cm thick) of vertically accreted sediments are recognized within the fine to medium sand, above the fine to medium sand is a thick sequence (80-100 cm) of vertically accreted sediments, primarily very fine sand and sandy silt. Pollen analyses of these sediments suggest generally cool and dry climatic conditions.

There is essentially no record of change at the archæological site for this time period, other than the well developed buried B horizon possibly indicating continued soil development.

In order to allow for the increase in sediment concentrations necessary for the extensive deposition and aggradation observed during the beginning of this interval, a significant increase in the frequency of large storms is likely to have been coupled with a general increase in precipitation. This change, coupled with the still reduced vegetation due to a continued cool climate, may have increased the degree of overland flow contributing to erosion and possibly a reshaping the upland topography. The increased erosion and resulting increase in sediment concentrations allowed deposition and aggradation even with a continued lowered base level.

The bulk of this period is characterized by a predominance of facies typical of lateral accretion. The deepest sediments are coarse sands, granules, and pebbles deposited as channel lag. These sediments grade upward through medium to coarse sands into fine to medium sands. These sediments are typical of point bar deposits. Occasional sequences of finely laminated fine to medium sand and organic debris possibly indicating bar top or levee deposits are also recognized. Small sequences of vertically accreted clayey silt to silty sand, may be sediments that filled point bar swales. The thick (80-100 cm) sequence of vertically accreted sediments are likely to be overbank deposits.

Although this vertical sequence of facies is typical of a meandering stream system (Boggs 1987), it is possible that the gradual change toward finer sediments also reflected a decrease in the magnitude and frequency of large flood events toward the end of this period. This change may be a reflection of a decrease in precipitation coupled with a decrease in surface runoff from the upland areas due to increased vegetation. The preservation of vertically accreted overbank deposits and the development of a floodplain surface may also be related to vegetation stabilizing the surface of the floodplain. Although there is a significant decrease in deposition by lateral migration toward the end of this time period, radiocarbon dates within the fine to medium point bar and channel deposits indicate that a small amount of deposition was still occurring toward the southwestern side of the floodplain.

Within the sequence of overbank deposits are a light colored very fine grained silty sand. These sediments are very similar in texture to the adjacent overbank deposits, but they are very blocky, and in contrast to the adjacent sediments, appear to have an extremely low percentage of organic debris. These sediments may have formed through rapid sedimentation in a small area of ponded water, or they may have originated as loess. The latter hypothesis is consistent with the interpretation that drier conditions prevailed toward the end of this time period.

The generally wet climatic conditions also affected the sedimentation within the basin. Water table elevations remained high and the basin continued to be flooded during this interval. The increased precipitation, however, is likely to have reduced the loess source for sedimentation in the basin such that only organic debris could have been deposited.

Several researchers support the hypothesis that conditions were generally wet at the close of the Late Pleistocene. Webb (1990) investigated several basins in central Delaware and concluded that water levels dropped at 11,000 years B.P. indicating a sudden decrease in precipitation. Sirkin et al. (1977) evaluated pollen data from peat layers in southern Delaware and concluded that the pollen assemblage represented cool, wet conditions at approximately 13,000 years B.P. Knox (1980) supports a general decrease in the severity of storms during the Late Pleistocene and Early Holocene.

Several researchers have recognized a brief dry period at the beginning of the Holocene. Foss et al. (1978) investigated loess deposition along the Eastern Shore of Maryland. Their investigation of buried soil horizons has suggested that loess deposition occurred shortly after 10,500 years B.P. The thickness of loess in Delaware was investigated by Rebertus et al. (1989). Simonson (1982) investigated soils developed in loess in Virginia, Maryland, and Delaware. Both of these studies, however, did not specifically make any evaluation as to the date of loess deposition.

### 10,300 TO 2,800 YEARS BP

Approximately one meter of fine to medium sand was deposited in the basin during this time period. Grain size analyses of these sediments are appropriate for æolian erosion, transport, and deposition. A weakly developed A horizon may be present above the fine to medium sand.

The rate of vertical accretion has been significantly reduced during this time period. While the rate of accretion during the previous period averaged approximately 50 cm/1000 years, the rate during this period is less than 10 cm/1000 years. Sediments deposited on the floodplain surface during this interval are primarily highly organic silty clay. These sediments also have a high percentage of charcoal. Pollen analysis was not available for these sediments. A radiocarbon date in the middle of this sequence of sediments for a core near the northeastern side of the floodplain provided a date of 5,680 years B.P.

In the middle of the sequence of sediments deposited during this interval is a sequence of silty sand and fine to medium sand. These sediments were only deposited along the southwestern margin of the floodplain (PC-8, PC-9, and PC-18). The silty sand is poorly sorted and incorporates a significant percentage of organic debris. The fine to medium sand overlying the silty sand is well sorted and contains a small percentage of silt and clay. Grain size analyses of these sediments are appropriate for æolian erosion, transport, and deposition. Radiocarbon analysis of a sample from approximately 5 cm below the silty sand provided a date of 8,930 years B.P.

Taking into account the low sedimentation rate of the clayey silt from which the date of 8,930 years B.P. was determined, it is likely that the beginning of the æolian sedimentation occurred around 8,800 years B.P. The end of æolian sedimentation may also be estimated by the stratigraphic position of the 5,680 year B.P. sample located on the northeastern side of the floodplain.

Since this area appears to represent continuous sedimentation of clayey silt across the interval during which the æolian sands were deposited along the southwestern side of the floodplain, and since the dated material was located stratigraphically above the contact between the clayey silt and the æolian sand, the æolian deposition is likely to have ended by 5,680 years B.P.

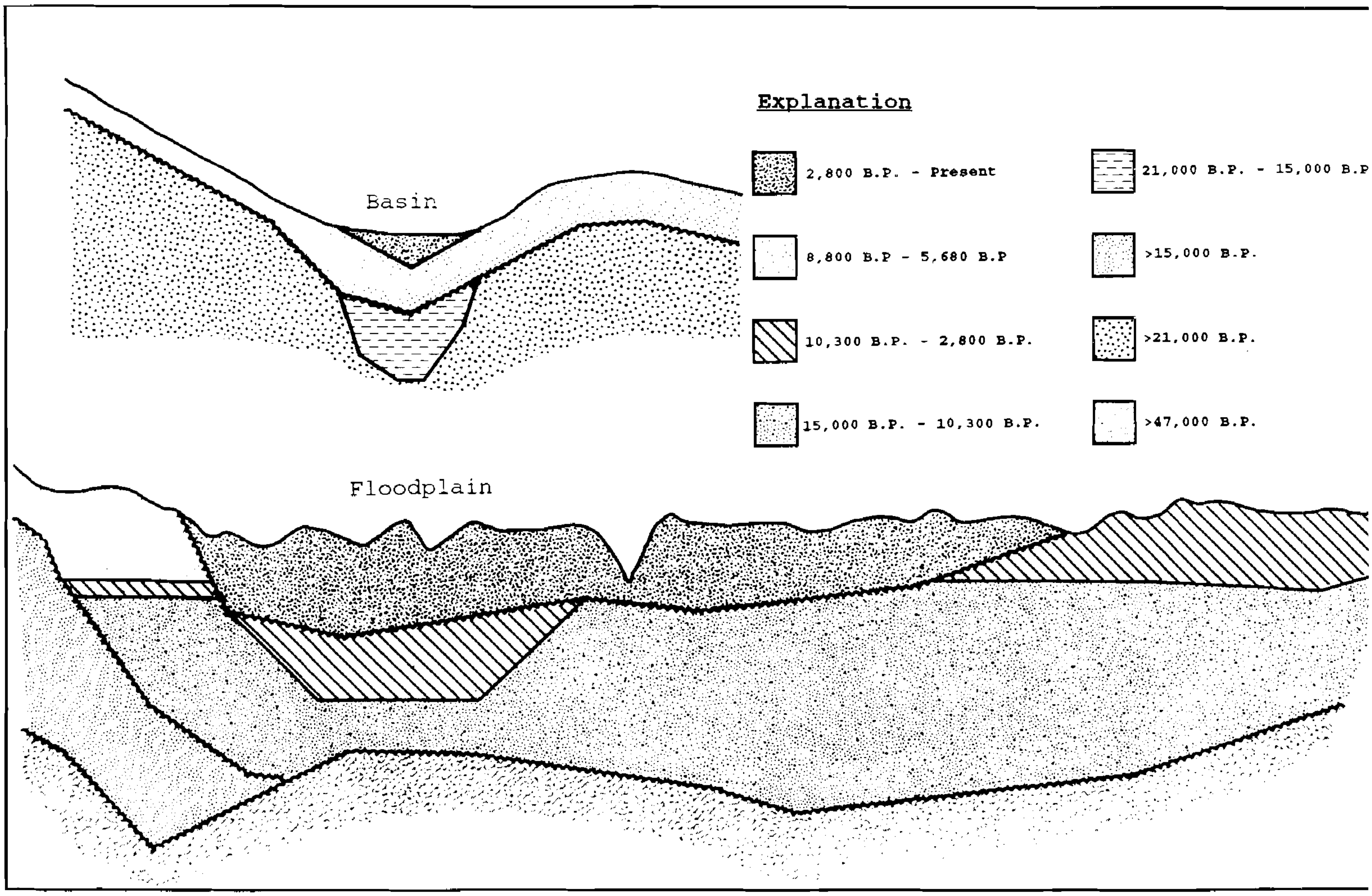



**Figure 16**
**Chronostratigraphic cross-section of the basin and the floodplain**

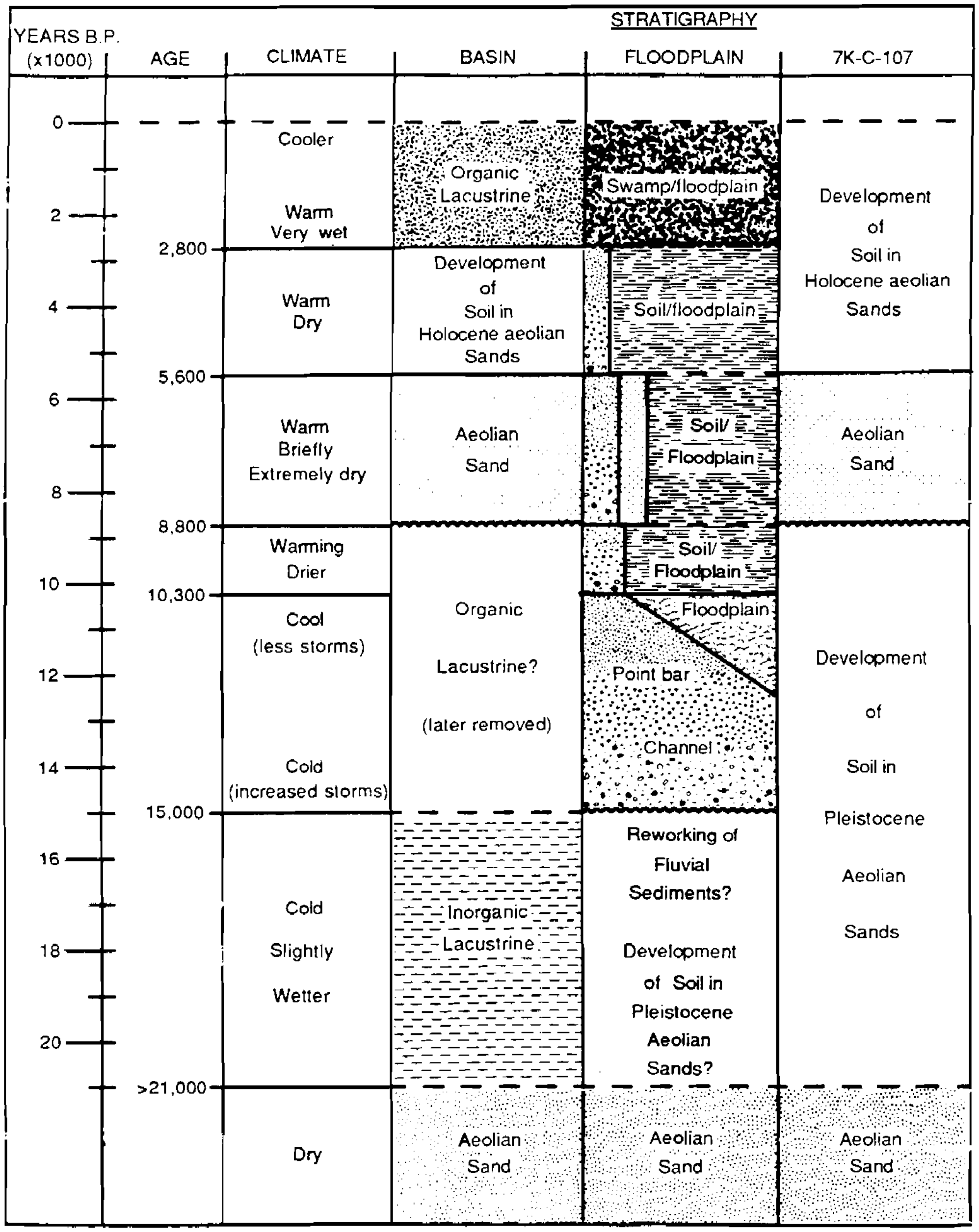



**Figure 17**

**Composite schematic summary of the chronostratigraphic interpretation of the three depositional environments, the dates of significant discontinuities, and the inferred climate**

Channel sediments were also being deposited during this interval but at a significantly reduced rate. There is little evidence of lateral migration and deposition of channel sands, primarily fine to medium sand, only occurred within a narrow region.

Approximately one meter of fine to medium sand was deposited at the archæological site during this time interval. These sediments were deposited above a well developed B horizon such that an overlying A horizon must have been removed prior to their deposition. Grain size characteristics of the fine to medium sand plot in the same general field as sediments deposited in the basin and the sequence of fine to medium sand deposited on the floodplain during this interval (figures 7 through 10).

The beginning of this period is a continuation of the generally dry conditions seen at the end of the previous time period, although, precipitation along with the frequency of large storms is likely to have decreased. Water table elevations remained low and the basin is likely to have dried out for extended periods of time, perhaps annually. Large upland areas may have opened up as grasslands. The low water table elevations also contributed to low base flow to the St Jones River and its tributaries.

Sedimentation of channel sands was significantly reduced during this interval. The distribution of radiocarbon dates indicates that the channel remained stable with little, if any, lateral migration. Sediments deposited on the floodplain consist primarily of highly organic silty clay likely to have formed as much by soil forming processes and slow aggradation through a slow influx of loess as by overbank deposition. These sediments are preserved on the northeastern side of the floodplain. Bioturbation and pedoturbation are likely to have removed any evidence of thin laminations from individual depositional events. A small amount of incision coupled with the rapid rate of aggradation during the previous time period may have created high bank heights, and contributed to the low frequency that overbank events occurred during this interval. The floodplain is likely to have been covered by grasses. Periodic fires contributed to the high percentage of charcoal in the sediments.

At approximately 8,800 years B.P. conditions became even drier. Upland areas experienced extended periods of drought and a shift toward open grasslands may have occurred for extensive areas. Although average conditions were very dry, this period may have been marked by periodic rainfall events that contributed to the removal of the A horizon at the archæological site and to colluvial deposition of poorly sorted sediments along the southwestern side of the floodplain. These rainfall events did not, however, cause bankfull conditions to occur frequently on the St Jones River and its tributaries, as is indicated by the low rates of vertical accretion of overbank deposits for this period. At some time during the interval from 8,800 to approximately 5,700 years B.P., a brief period of extremely dry conditions reduced grassland vegetation sufficiently to allow æolian erosion and deposition over extensive areas.

Prior to æolian deposition in the basin, deflation removed the organic sediments that had been deposited during the interval from 15,000 to 10,300 years B.P. Although the basin remained dry throughout this time period (10,300 to 2,800 years B.P.) it is likely that the fine to medium sand in the basin was deposited during a short period of time. That is, deposition of æolian sand in the basin is probably coeval with the deposition of æolian sand on the floodplain. Deflation is also likely to have removed A horizons from many areas adjacent to the basin prior to burial of the exposed B horizons by the æolian sands.

The archæological site is also likely to have experienced some degree of deflation prior to the deposition of the æolian sand. As with the basin, approximately one meter of sediments were deposited during a short period of time. It is likely that the prevailing wind during the short interval that sediments were deposited at the basin and the archæological site was from the southwest, because æolian sands were carried beyond the archæological site and onto the southwestern side of the floodplain surface. Approximately 80 cm to one meter of æolian sediments were deposited along the southwestern side of the floodplain during this brief period of extremely dry climatic conditions. Æolian sedimentation is likely to have contributed to a general smoothing of the upland landscape.

Following the period of extreme dryness, climatic conditions returned to being warm and generally dry. Although climatic conditions may have been slightly wetter, the frequency of storms was still significantly reduced. The basin remained dry allowing for soil development on the basin surface. Soil development also began at the archæological site. Continued loess input contributed to the development of a thick A horizon. Deposition on the floodplain continued to be primarily silty clay. Periodic flooding of the floodplain may have occurred, but rarely as an extreme event, such that sedimentation rates remained very low. Soil development continued in these soils. Some areas below the highly organic silty clay along the northeastern side of the floodplain may have experienced leaching of organic matter resulting in the development an E horizon.

Several local studies have recognized a similar history for the early to middle Holocene. Webb (1990) and Webb et al. (1989) studied 4 basins in Delaware and recognized a break in sediment accumulation that lasted from 11,000 to 6,000 years B.P. in 3 of the basins, and a break from 11,700 to 2,700 years B.P. for the fourth basin. They interpreted the break in sedimentation to represent an extended period of lowered water levels due to a regional drop in water table elevations. Webb et al. (1989) also recognized that organic sediments were often desiccated and removed from the basin by æolian deflation. Although several studies of the fluvial response to Holocene climatic change in the midwest and southwest have provided a similar chronology, studies within the region by Scully and Arnold (1981) and McNamara (1985) did not provide sufficient resolution to allow a comparison with this research.

A warm dry "xerothermic" period has also recognized by many archæologists in the mid-Atlantic region. Prior to this investigation, research during Phase I and Phase II investigations at the archæological site recognized buried soil and archæological horizons. Because of the upland position of site on the landscape, burial was thought to be by æolian deposition. archæological artifacts found at the site provided sufficient stratigraphic control to date the period of æolian burial. Æolian deposition of the fine to medium sand was estimated to have occurred at some time during the interval from approximately 9,500 to 3,000 years B.P.

In his study of several sites in Anne Arundel County in Maryland, Curry (1980) also investigated the burial of archæological horizons by æolian sands, and the processes necessary for æolian deposition. This research suggested that æolian burial occurred during the interval from 5,000 to 3,000 years B.P. McNamara (1982) investigated the burial of archæological artifacts at another site in Anne Arundel County in Maryland, and placed the date of burial during the interval from 5,500 to 2,760 years B.P. Custer and Watson (1987) studied archæological stratigraphic discontinuities at several sites in northern Delaware and concluded that discontinuities represented the period from approximately 8,500 to 4,000 years B.P.

Although only a limited amount of pollen data is available for this interval for the mid-Atlantic region, numerous researchers have used the available data to reconstruct a Holocene climatic chronology. Most of this research has generally supported the Blytt-Sernander chronology of environmental episodes (Custer 1984). The interval from 10,300 to 2,800 years B.P. spans three episodes: "pre-Boreal", "Boreal", and "Atlantic". Climatic conditions during the end of the pre-boreal episode were thought to be generally cooler and drier than present. Conditions during the Boreal were warmer and drier than present, and during the Atlantic, warmer and wetter than present (Sears 1942; Deevey 1957; Wendland and Bryson 1974; Custer 1984).

### 2,800 BP TO EUROPEAN SETTLEMENT

Sediments deposited during this interval are primarily a sandy silt with a high percentage of organic debris. A radiocarbon date a few centimeters above the base of these sediments provided a date of 2,020 years B.P. A weakly developed A horizon may be present below these sediments but above the fine to medium sand deposited during the previous time period.

Sediments deposited on the floodplain during this interval consist primarily of clayey silt with a high percentage of organic debris. The percentage of organic debris appears to increase with depth within these sediments. In many areas across the floodplain these sediments are essentially peat. Occasional layers of fine to medium sand are found within the clayey silt. The presence of this basal sand supports the interpretation of the lower contact as a basal erosion surface. In most areas a thin layer of fine to medium sand also separates these sediments from the older underlying sediments. Pollen analyses of these sediments suggests considerably wetter climatic conditions, with a gradual shift toward cooler conditions throughout the period.

A thickened A horizon is found at the archæological site. Artifacts recovered from near the base of these sediments have been dated to be approximately 3,000 to 3,200 years old.

A significant increase in precipitation occurred at the beginning of this interval. The low percentage of coarse sediments within floodplain deposits of this period suggests that this change was largely related to an increase in total annual precipitation and did not necessarily reflect an increase in the frequency of large storms. Generally warm climatic conditions continued from the previous time period. The warm and wet climatic conditions contributed to a rapid response by the vegetative community.

The increase in precipitation increased water table elevations causing the basin to be flooded for extended periods of time, perhaps annually. Since the rate of evapotranspiration was higher during this interval than the previous interval that the basin was flooded (21,000 to 10,300 years B.P.) precipitation during this interval would have to be greater to raise water table elevations an equivalent amount. Sediments deposited in the basin during this interval consist primarily of organic debris. However, loess is likely to have continued to contribute sediment during occasional warm summer months. Loess deposition at the archæological site toward the end of this interval may also have increased the thickness of the A horizon and may have contributed to the burial of artifacts at the site.

An abrupt change is seen in the character of the floodplain sediments at the beginning of this interval. Conditions are likely to have become swamp-like with a high percentage of dead plant debris and often very little inorganic sediment being reworked and deposited. Although limited lateral migration of a channel may have occurred for a brief period of time, it appears that erosion of the silty clay and older sediments deposited during previous time intervals is likely to have occurred primarily through repeated avulsions.

The floodplain surface established during this interval is also slightly lower in elevation than the surface at the end of the previous time period. This difference has created a narrow terrace along the southwestern side of the floodplain, and a wide terrace on the northeastern side of the floodplain. Soil development is likely to have started on the terraces at this time.

Several types of evidence generally support the paleoenvironmental conditions presented here for this time period. Although several of the basins investigated by Webb et al. (1989) and Webb (1990) indicated a change to wetter climatic conditions at approximately 6,000 years B.P., at least one basin indicated a change to wetter conditions at approximately 2,650 years B.P.

Through a statistical analysis of a global set of radiocarbon dates, Wendland and Bryson (1974) established that the most significant botanic discontinuity in the environmental record occurred approximately 2,760 years B.P and that the most significant date of cultural change, throughout the globe, occurred approximately 2,510 years B.P. Environmental change during this period may also have contributed to a shift by Woodland Indians in Delaware to an agricultural community (Custer 1984).

## European Settlement to Present

Extensive mottling of sediments within the basin and outside the basin indicates that water levels fluctuate. During 1992, the basin was not flooded at anytime during the year, even after heavy rainfall. Water level measurements from open hand-auger holes outside the basin indicated that water level elevations were low, although water levels within basin sediments remained high following several rainfall events. Aerial photographs from previous years indicated that during wet years the basin is flooded for at least part of the year.

An Ap horizon was present at all augering and coring locations. Sediments within this horizon for the areas outside the basin are very sandy. The Ap horizon within the basin sediments appears to have a higher percentage of organic debris. Aerial photographs indicate that the basin has been periodically cleared since as early as 1930. Although it appears that the areas adjacent to the basin have not been farmed for at least two to three years, aerial photographs indicate that these areas are actively farmed.

Pollen analysis of floodplain sediments indicates that approximately 14 cm of sediments have been deposited since European Settlement. These sediments are primarily a clayey silt. The floodplain is forested, although, some open grassy areas exist. The location of the stream channels appears to be influenced by the vegetation. There is evidence of soil development on both the older terraces, as well as the sediments deposited since European settlement.

A thick Ap horizon was also found at the archæological site. The area is also disturbed by recreational activities, primarily "dirt bikes".

Since European Settlement farming activities have changed the landscape significantly, primarily through the clearing of forested areas. Farming activities are also likely to have contributed to a general smoothing of the landscape. In the area of the Bay basin plowing appears to have deflated the surface such that the underlying æolian sands are considerably thinner in some areas.

The vegetation in the basin appears to have been cleared periodically. Plowing of this area is likely to have occurred during a period of dry years. Organic rich sediments may also have been removed from the basin and used to increase the organic content of adjacent fields.

There is considerable evidence that water levels in the basin, and in areas adjacent to the basin, have fluctuated due to changes in wet years and periods of extended drought. Although the basin may perch water for short periods of time, is it likely that the basin remains flooded only during periods where water table elevations are sufficiently high to allow water to flow into the basin from the adjacent soils.

Farming activities are likely to have occurred at the archæological site up until the rail line separated the site from the adjacent fields. Recreational activities are likely to have affected the area for only the past 50 years.

The clearing of upland areas may have contributed to an increase in sedimentation rates on the floodplain. The floodplain is also likely to have been cleared for lumber, but there is no indication that the floodplain surface was farmed at any time. The construction of several mill ponds and finally Silver Lake has contributed to decreasing the gradient of the streams, while increasing the frequency that the floodplain surface is flooded.

Several authors, including Wolman et al. (1957), Coleman, (1982) and Bolakas (1985), have recognized an increase in the rate of floodplain alluviation following European Settlement. Phillips (1990) supports the influence that water table elevations have on the flooding of bay basins. Sneddon (1990) investigated the anthropogenic impact on basins and concluded that the succession from open water conditions to forested conditions is likely to be the result of a reduction in the frequency of fire. The soils developed on the terraces and on northeastern side of the floodplain have been mapped by Matthews et al. (1971). The rail line was constructed 1856, and Silver Lake was completed around 1865.

# 6. CONCLUSIONS

The object of this study was to reconstruct the Late Quaternary geomorphic history of the area surrounding archæological Site 7K-C-107. Geological research involved the study of several geomorphic features in the vicinity of the site. The first area studied was a bay basin located 400 m southwest of the site. The second part of the study area investigated was the floodplain located just to the northeast of the site.

The methods employed in this research included: 1) detailed surveying of the topography; 2) developing a detailed subsurface stratigraphy primarily through hand-augering and coring, but also employing GPR in the study of the basin; 3) using grain size analyses to compare sediments collected from the basin, the floodplain and the archæological site; and 4) using radiocarbon dating and palynology to provide chronostratigraphic control.

Most studies in the mid-Atlantic region have relied on palynology to evaluate paleoenvironmental change. The pollen record for this region is, however, discontinuous at best, such that few detailed geomorphic histories incorporating paleoenvironmental change have been developed.

A different approach to this problem was employed for this research. Primarily through an evaluation of the record of the type of sediment being deposited during each of the time periods that were developed through radiocarbon control, a detailed Late Quaternary history of the geomorphology for the area was developed.

Although this approach to developing a paleoenvironmental history has been employed by several researchers in the field of alluvial stratigraphy, most of these studies have involved very large (>1,000 $km^2$) drainage areas which has made it difficult to discuss how the alluvial record applies to a small (<50 $km^2$) areas along the river systems. This study has successfully used data from a small drainage area such that the conditions observed in the alluvial stratigraphy could be easily compared to the conditions on the adjacent upland areas.

Conclusions from this study suggest that the Late Quaternary landscape surrounding the site consisted of sand dunes with local interdune swales and deflation areas.

From approximately 21,000 - 15,000 years B.P., many interdune areas became flooded, due to an increase in precipitation. Large scale æolian erosion and deposition was slowed, and sediments deposited in the basin during this time consisted primarily of loess. There is no record of any sediments being deposited within the floodplain sequence during this time.

From 15,000 - 10,300 years B.P, thick sand and gravel units were deposited by the St. Jones River, suggesting an increase in the frequency of large storms and runoff. Although there isn't any record of sediments from the basin for this time, the basin is likely to have remained flooded.

By 10,300 years B.P., vertically accreted deposits dominated floodplain sedimentation, suggesting a change toward drier climatic conditions. Generally dry conditions continued until approximately 2,800 years B.P. During a brief period occurring at some time during the interval from approximately 8,800 - 5,680 years B.P., an extended period of drought contributed to extensive æolian erosion and deposition on the upland landscape.

About 2,800 years B.P., the climate became wetter, and the bay basin was again flooded. The St. Jones River now flowed through swampy wetlands, eroding older deposits and leaving two terraces on either side of the present floodplain.

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