RECONSTRUCTING THE EROSIONAL HISTORY OF 19TH-CENTURY EARTHEN FORTIFICATIONS ALONG THE COASTLINE OF THE CHESAPEAKE BAY, MARYLAND, USA

by

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TABLE OF CONTENTS

LIST OF TABLES viii
LIST OF FIGURES ix
ABSTRACT xi

Chapter

1 INTRODUCTION 1

2 BACKGROUND 5

2.1 The War of 1812 5

2.1.1 America's Second War of Independence 5
2.1.2 A Campaign of Terror on the Chesapeake 9
2.1.3 The War Comes to an End 12

2.2 A History of Earthen Fortification in Colonial and Post-Colonial America 13

2.2.1 Systems of Permanent Coastal Fortification 15
2.2.2 Earthen Field Fortification 20
2.2.3 Contemporary Military Manuals 24

2.3 Characteristics of Earthen Field Fortifications 26
2.4 Construction of Earthen Field Fortifications 35
2.5 The Fate of War of 1812 Earthworks 36
2.6 Historical Accounts of Forts Nonsense, Point, and Stokes 38

2.6.1 Fort Nonsense, Annapolis, Maryland 38
2.6.2 Fort Point, Centreville, Maryland 41
2.6.3 Fort Stokes, Easton, Maryland 44

3 GEOGRAPHIC, PHYSIOGRAPHIC, AND GEOLOGIC SETTINGS 48

3.1 Fort Nonsense 49
3.2 Fort Point 50
3.3 Fort Stokes 51

4 FIELD AND LABORATORY METHODS 53

4.1 High-Resolution Surface Modeling of Current Forms with a Terrestrial Laser Scanner 53

4.1.1 Data Collection 54
4.1.2 Scan Registration 54
4.1.3 Data Filtering 55
4.1.4 Digital Elevation Models 56

4.2 Hillslope Diffusion Modeling 58
4.3 Sediment Dating Using Fallout Radionuclides 59

4.3.1 Sediment Sample Retrieval 61
4.3.2 Laboratory Sample Preparation 62
4.3.3 Gamma-ray Spectrometry 62

5 RESULTS 64

5.1 Terrestrial Laser Scanner Data 64

5.1.1 Fort Nonsense 64
5.1.2 Fort Point 66
5.1.3 Fort Stokes 68

5.2 Diffusion Models 69
5.3 Stratigraphic Analysis 70
5.4 Radiometric Dating 71

5.4.1 $^{210}Pb_{ex}$ 72
5.4.2 ^{137}Cs 73

6 DISCUSSION 75

6.1 Terrestrial Laser Scanning 75
6.2 Diffusion Models 76
6.3 Radiometric Dating 77
6.4 Future Work 79
6.5 Recommendations for Earthwork Preservation 80

7 CONCLUSIONS 81

REFERENCES 108

Appendix

A COMPLETE RADIOMETRIC ANALYSIS DATA FOR CORE B AT FORT POINT 122
B COMPLETE RADIOMETRIC ANALYSIS DATA FOR CORE D AT FORT POINT 128

LIST OF TABLES

Table 1: Summary of TLS survey data for Forts Nonsense, Point, and Stokes. . 104

Table 2: Soil descriptions for Cores A and C collected at Fort Point.. 105

Table 3: Summary of $^{210}Pb_{ex}$ and ^{137}Cs data from Core B at Fort Point. 106

Table 4: Summary of $^{210}Pb_{ex}$ and ^{137}Cs data from Core D at Fort Point. 107

LIST OF FIGURES

Figure 1: Map of the Chesapeake Bay region showing the locations of the three earthen fort study sites - Fort Nonsense, Fort Point, and Fort Stokes. 82

Figure 2: Profile of a typical earthen field fortification, showing the parapet and ditch configuration common to all varieties 83

Figure 3: Map displaying the location of Fort Nonsense near Annapolis, Maryland. 84

Figure 4: Map displaying the location of Fort Point near Centreville, Maryland... 85

Figure 5: Map displaying the location of Fort Stokes near Easton, Maryland. 86

Figure 6: Panorama images of the three Maryland study locations 87

Figure 7: View of TLS in use at Fort Point, showing typical setup. 88

Figure 8: Map displaying the locations of sediment cores and modeling profiles at Fort Point. 89

Figure 9: Map displaying the locations of survey stations at Fort Nonsense. 90

Figure 10: Digital elevation model (DEM) of Fort Nonsense displaying 0.1 m contour lines (white lines) against a shaded background depicting relative elevation. 91

Figure 11: Map displaying the locations of survey stations at Fort Point. 92

Figure 12: Digital elevation model (DEM) of Fort Point displaying 0.1 m contour lines (white lines) against a shaded background depicting relative elevation. 93

Figure 13: Map displaying the locations of survey stations at Fort Stokes. 94

Figure 14: Digital elevation model (DEM) of Fort Stokes displaying 0.1 m contour lines (white lines) against a shaded background depicting relative elevation. 95

Figure 15: Graph displaying the results of the diffusion model for Profile B at Fort Point with an estimated initial fort profile (black line), a modeled profile after 200 yrs (gray line), and the actual current topography from TLS data (black dashed line). 96

Figure 16: Graph displaying the results of the diffusion model for Profile D at Fort Point with an estimated initial fort profile (black line), a modeled profile after 200 yrs (gray line), and the actual current topography from TLS data (black dashed line). 97

Figure 17: Bar chart displaying $^{210}Pb_{ex}$ activity versus depth below ground surface from Core B at Fort Point. 98

Figure 18: Bar chart displaying $^{210}Pb_{ex}$ activity versus depth below ground surface from Core D at Fort Point.. 99

Figure 19: Graph incorporating the 100-yr chronostratigraphic marker determined by $^{210}Pb_{ex}$ dating (black X) into the diffusion model for Profile B at Fort Point, with an estimated initial fort profile (black line), a modeled profile after 100 yrs (gray line), and the actual current topography from TLS data (black dashed line). 100

Figure 20: Graph incorporating the 100-yr chronostratigraphic marker determined by $^{210}Pb_{ex}$ dating (black X) into the diffusion model for Profile D at Fort Point, with an estimated initial fort profile (black line), a modeled profile after 100 yrs (gray line), and the actual current topography from TLS data (black dashed line). 101

Figure 21: Bar chart displaying ^{137}Cs activity versus depth below ground surface from Core B at Fort Point.. 102

Figure 22: Bar chart displaying ^{137}Cs activity versus depth below ground surface from Core D at Fort Point. 103

ABSTRACT

A lack of time and manpower led to the hurried, sparsely documented construction of a number of locally-sourced earthen fortifications along Chesapeake Bay tributaries shortly before and during the War of 1812 in Maryland. Many of these defenses have been lost to time and development, and those that remain face uncertain futures due to natural and/or human-induced erosion processes. Geoarchaeological investigations were conducted at three Maryland study locations – Fort Nonsense near Annapolis, Fort Point near Centreville, and Fort Stokes near Easton – to better understand their rates and patterns of degradation. Each fort consists of uniquely shaped earthen parapets and adjacent ditches from which construction material was supplied. These study locations were selected because they appear to be relatively intact and are currently threatened by erosion processes. Terrestrial laser scanner surveys were completed at each site to acquire detailed topographic data used to develop high-resolution surface models depicting the current state of the earthworks. Although these data stand alone as valuable documentary resources, they are coupled with stratigraphic, radiometric, and mathematically modeled data to better understand the rates and spatial patterns of degradation. Our results allow us to estimate the original sizes and shapes of these parapet-ditch configurations and to predict their rates and patterns of erosion over time, noting that their degradation remains an ongoing process. Without some form of slope stabilization, the nature of the material from which these earthworks were constructed will allow for their continued widening and flattening.

Chapter 1

INTRODUCTION

Acting as the gateway to both the political and commercial center of a young United States, the Chesapeake region was a primary target for the British during the War of 1812. A lack of time and manpower led to the hurried construction of a number of locally-sourced earthen fortifications used to hide and protect troops and artillery along the waterways of the Chesapeake. Despite the integral role these earthworks played in the nation's defense, they have largely remained undocumented and unprotected. Most have been obliterated by time and modern development, and the few that remain lie in various states of decay from continuing natural and anthropogenic degradation processes.

This study focuses on three of the four known, intact earthen fortifications associated with the War of 1812 in Maryland – Fort Nonsense near Annapolis, Fort Point near Centreville, and Fort Stokes near Easton (Eshelman et al. 2010; Figure 1). In keeping with the ambitious spirit of discovery, education, and promotion of important War of 1812 sites spurred on by Maryland's bicentennial celebration, this project explores these overlooked resources through a greater understanding of their geomorphic evolution, from initial construction through degradation into their current forms.

Very little information regarding construction and usage of the forts in this study is available in historical documentation, and no contemporary information exists about their initial forms. No formal construction drawings, detailed accounts, or historic imagery are available, and initial shapes and sizes can only be surmised from military manuals of the day. In their current states, the forts appear as little more than nondescript, eroded embankments encircled by ditches.

The archaeological record is not much more telling, with only a handful of archaeological investigations having been performed on similar, contemporaneous earthen fortifications in Maryland (Smolek et al. 1980; Clark, 1981; Weinland and Weber, 1984; Lowery, 1997; Pickett, 2000b; Bilicki, 2003; Gibb, 2012). Of these studies, only one included a detailed geomorphological analysis (Weinland and Weber, 1984). Equally rare are archaeological studies which incorporate analyses of natural processes to assess the degradation of earthen cultural resources, with notable exceptions (Kirkby and Kirkby, 1976; Wainwright, 1994; Hutchinson, 1998; Bullard, 2003a, 2003b; Hutchinson and Stuart, 2003; O'Neal et al. 2005; Londoño, 2008a, 2008b; Alfimov et al. 2013).

Because of basic, constrained embankment-and-ditch configurations and precisely dated construction periods, these earthen forts are ideal candidates for geomorphological analysis of landform change over time. This study offers a novel approach using minimally invasive geospatial, geomorphological, and sedimentological techniques to: 1) estimate the original size and shape of embankments, 2) determine the rate and spatial pattern of degradation, and 3) create precise, multi-dimensional representations of current forms.

Our methods are threefold. First, highly detailed topographic information is collected by terrestrial laser scanning (terrestrial LiDAR, or TLS) instrumentation at all three fort locations. In recent years, TLS has become the gold standard for archaeological site and feature documentation because of its extremely high resolution and efficiency. The large number of survey points recorded by TLS systems proves especially useful when dealing with vegetated, low-relief topography that would, using traditional survey methods, be difficult to separate from the natural topography (Hesse, 2010; O'Neal, 2012; Romero and Bray, 2014).

Second, a mathematical model of landform change is applied to two embankments at Fort Point which allows us to estimate rates and spatial patterns of degradation over time. This data can be used to approximate original sizes and shapes of embankments. Topographic information collected from TLS surveys provides accurate embankment and slope measurements necessary as inputs for a diffusion-based mathematical model of slope degradation. This commonly used model of landscape diffusion assumes transport of material is proportional to the slope, with some parameterization of the cohesiveness of the material being modeled. This type of model is frequently used for dating natural hillslopes (e.g., Nash, 1984; Pierce and Colman, 1986; Hallet and Putkonen, 1994; Hanks, 2000) but can also be used to quantify erosion. It has been successfully applied in archaeological settings on prehistoric Hopewell mounds (O'Neal et al. 2005) and Civil War earthworks (Bullard, 2003a, 2003b).

Lastly, radiometric analyses (^{210}Pb and ^{137}Cs) of accumulated colluvium at the bases of the Fort Point embankments provide chronological benchmarks useful for evaluating the accuracy of the diffusion model. Lead-210 and ^{137}Cs radionuclides have been used for dating sediments and assessing sediment transport in natural landscapes for decades (e.g., Walling et al. 1995; Zheng et al. 2007), but to the best of our knowledge, have not been employed for transport studies on anthropogenic hillslopes.

While the complete degradation analysis is only applied to Fort Point[1], the methods used are applicable to Fort Nonsense, Fort Stokes, and other man-made earthworks of similar configurations and in similar geographical settings. In addition to the information gained about the construction and degradation of early 19th-century earthworks, this study provides insight into archaeological site formation and destruction processes, the effects of erosion on human earthworks, and the redistribution of material culture within an earthwork. It also illustrates the unique opportunity provided by earthworks as a proxy for studying natural landscape processes.

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[1] Time and budgetary constraints allowed for the complete analysis of one fort. Fort Point was chosen because of the high degree of integrity of its remaining embankments and narrowly defined period of construction.

Chapter 2

BACKGROUND

2.1 The War of 1812

2.1.1 America's Second War of Independence

Despite the present-day obscurity of this comparatively small-scale conflict, the War of 1812 was considered, at the time, to be of vital importance to asserting the newly formed United States of America's sovereignty. Independence was achieved following the conclusion of the American Revolutionary War (1775–1783), but supremacy and respect in any of the global arenas – politics, armed forces, and commerce – had not been. A series of deprecations occurred in the years preceding the declaration of war that many Americans leaders felt was best redressed on the battlefield (see: Hickey, 2012).

The War of 1812 is often considered a subsidiary of the Napoleonic Wars (1803–1815), a series of wars between France and Britain sparked by the French Revolution of 1789. France was in control of Europe at the time, and Great Britain was the unrefuted ruler of the seas. Both nations vied for control of Europe and the wider world and encroached upon the trade and maritime rights of neutral nations as a way of putting pressure on the enemy.

France and Great Britain were both aggressors, and in fact, the United States considered going to war with both nations. This proved impractical. A number of serious infractions played into the slow but increasing deterioration of Anglo-

American relationships prior to the war, and most agreed that Great Britain was the greater of the two evils. The relative importance of each offense is debated, but the two primary causes for the declaration of war are agreed upon: British impressment of American seamen, and the Orders-in-Council, a series of formal decrees of commercial warfare enacted by the British government that restricted American trade with Europe (Hickey, 2012).

Near the turn of the 19th century, the British navy consisted of over 850 vessels (National Park Service, 2004). In order to staff their immense fleet, the Royal Navy regularly impressed seamen serving on American merchant ships into naval duty. Although they targeted British seamen who had been recruited into American service, little effort was paid to determining actual citizenship. As a result, many American citizens were caught up in this British dragnet. Between 1803 and 1812, approximately 6,000 American sailors were impressed into the Royal Navy (Hickey, 2012).

The Orders-in-Council consisted of a number of executive orders issued by Great Britain between 1807 and 1812 aimed at restricting trade between neutral nations and France. These decrees skirted or blatantly broke international maritime laws by subjecting any outside trade to transit duties, naval blockades, and routine ship seizures. Between 1807 and 1812, approximately 900 American ships were seized by Great Britain, France, and their allies (Hickey, 2012).

The United States sought to avoid war by instituting a series of self-imposed trade restrictions with both warring European powers. By limiting imports and exports, the United States hoped to use its greatest strength – its economic power – to place an economic stranglehold on Great Britain and France and gain concessions on their trampled maritime rights. The plan proved woefully ineffective – Europe was unaffected, and the United States plummeted into its greatest depression since colonial times (Hickey, 2012).

With seemingly no alternative remaining, war was formally declared against Great Britain on June 18, 1812. The decision was far from unanimous, and received support from only 61% of voting members of the House and the Senate (Hickey, 2012). A great political divide existed between the controlling Republicans and the Federalists. Republicans saw the declaration as not only a way of securing "Free Trade and Sailor's Rights," but also as a means of asserting the fledgling nation's independence, dubbing it a "second war of independence" (Hickey, 2012: 44). Federalists viewed the declaration of full-scale war as unnecessary and unwise, preferring instead to implement increased defensive measures on American coasts and the seas (Hickey, 2012).

Support for the war was similarly divided among regions. Areas in the South and West were generally supportive, but those in the North and East were not. Commercial interests in New England resulted in some states unabashedly opposing the war and continuing to supply the British until naval blockades made it impossible. There was even talk of secession. These political and regional divides significantly hampered American efforts throughout the war (Eshelman et al. 2010).

The United States, well aware that it could not defeat Great Britain on the open seas, initially focused its efforts on invading British colonies in what is now Canada, with plans to barter them for concessions on maritime policies. Annexation of Canada was not a cause of the war, but territorial expansion was in vogue and ridding the continent of a colonial presence did, especially to Republicans, have its allure (Hickey, 2012).

The first American invasion of Canada began in the summer of 1812, shortly after war was declared. What was supposed to be a “mere matter of marching” for American land forces proved to be anything but (Hickey, 2012: 99). Poor planning, poor leadership, and a competent Canadian militia resulted in a sound American defeat. Surprisingly, however, United States naval forces fared much better and provided a much needed boost to the nation’s morale by the close of the campaigning season.

Spring of 1813 brought greatly improved leadership, both in Washington and in the field, and an enlisted force nearly double that of the beginning of the war (Hickey, 2012). American efforts once again centered on Canada. Both nations understood the importance of the Great Lakes – especially Lake Erie and Lake Ontario – as the only efficient means of transport along the border, and both vied for control. American naval forces assumed control of Lake Erie in September of 1813, but no decisive battle for Lake Ontario occurred. The United States experienced comparatively more success along the northern border than in the previous year – especially in the Old Northwest – but reverses and mismanagement ended the campaign in a stalemate.

The United States also found itself occupied with two Native American conflicts in 1813, though one was ending – Tecumseh’s War – as the other – the Creek War – was just beginning. Both are peripherally related to the War of 1812, not only by temporal association, but also due to British involvement (or perceived British involvement).

Tecumseh's War (1811–1813) grew from a religious movement that opposed American expansion in the Old Northwest. A series of land cessations induced Native militancy. Led by Shawnee leader, Tecumseh, and supplied by the British, militant bands of Natives began a series of depredations along the frontier. American retaliation in 1811 led to a full-scale war. The war lasted until Tecumseh's death at Battle of the Thames on October 5, 1813, after which his confederation disbanded (Hickey, 2012).

The Creek War (1813–1814) began as a civil war within the Creek confederation between Creeks amiable to assimilation and those vehemently opposed to it. Spurred on by a recruiting mission from Tecumseh and emboldened by Anglo-Indian victories in the Old Northwest, militant bands of Creeks began conducting raids on white settlements along the southern frontier in 1812. Retaliation by Mississippi militia and volunteers in 1813 escalated the series of raids into a larger war, which lasted until mid-1814 when all factions of Creeks were forced to sign the Treaty of Fort Jackson, conceding defeat and over half of their territory (Hickey, 2012).

2.1.2 A Campaign of Terror on the Chesapeake

Most of the fighting during 1813 focused around the Canada-United States border, but beginning in early 1813, the British expanded their focus to the Chesapeake Bay. The region was considered strategically significant due to its commercial and political importance and as the center of pro-war support. The primary aim was to disrupt coastal trade and destroy warships and government supplies, but liberties were taken to terrorize American citizens in the process and show them the "perils of making war on the Mistress of the Sea" (Hickey, 2012: 154).

The British also hoped to draw American attention away from Canada. Here they did not succeed. Most of the regular army remained on the Canada-United States border, and defense of the Chesapeake fell largely to untrained and poorly organized militia units (Eshelman et al. 2010). To make matters worse, geographically, the Bay was difficult to defend. Its immense size meant that ships could maneuver outside the effective ranges of shore batteries (Totten, 1851). As a result, the British met with little effective resistance during most of their campaign in the Chesapeake.

In February of 1813, the British expanded their blockade of the Atlantic coast to include the Chesapeake Bay and, within weeks, began a series of vicious raids along the entire shoreline. Between early spring and the end of 1813, these raids, led by Rear Adm. Sir George Cockburn, resulted in a large amount of property loss and the perpetuation of fear and anxiety throughout the entire region. Most raids entailed ransacking public or military property, but accounts of looting, rape, and murder also emerged. The British were largely successful and faced very little resistance, but were repulsed a number of times, including by Fort Defiance, an earthen redoubt built to protect Elkton, Maryland (Eshelman et al. 2010).

As the campaign of 1814 opened, the British went on the offensive. After a series of significant defeats at the hands of British allies, Napoleon abdicated the throne in April of 1814. With victory in Europe at hand, Great Britain began to divert more resources to their conflict in North America. What began as a slow trickle of war resources in late 1813 came to a crescendo in 1814, with some 14,000 experienced British troops sent across the Atlantic (National Park Service, 2004).

After achieving success in 1813, the British campaign of harassment and terror in the Chesapeake Bay became a primary focus in 1814. British commanders were ordered to destroy towns at their whim in retaliation for United States depredations in Canada, sparing only towns that provided supplies or paid tribute (Eshelman et al. 2010). The British constructed Fort Albion on Tangier Island as their regional base and commenced with raids in early spring, with frequency and intensity increasing throughout late spring and summer.

Despite the proximity of British activity to the nation's capital, little was done to bolster defenses of Washington, D.C. American leaders believed Washington held little strategic importance for the British, and instead prepared for an attack on Baltimore. The British were aware of this, and with Americans distracted and largely unprepared, entered the nation's capital on August 24, 1814 after defeating American forces at the Battle of Bladensburg. Government officials had already fled the city, and without anyone present to discuss terms of surrender, British forces set fire to a number of public and military buildings, including the White House, the Capitol, the Treasury, and the building housing the War and State departments. British forces left the following day, reconvening with their fleet. Any remaining American forces fled to Baltimore (Eshelman et al. 2010).

Hoping to build on their success in Washington, British forces launched a land and naval attack on Baltimore on September 12, 1814. Having learned their lesson in Washington, the United States strengthened the defenses of Baltimore by constructing over a mile of earthworks and protecting the harbor by purposefully sinking ships and extending masts across the harbor entrance. The formidable British fleet began its 25-hour bombardment of Fort McHenry on September 13. Despite firing more than 1,500 rounds and remaining out of range of American weapons, the British failed to force surrender. Their vessels retreated. British land forces maintained their position outside of Baltimore's earthworks, but upon learning of the Royal Navy's failure, withdrew as well (Hickey, 2012).

This strategic withdrawal of the British ended their campaign in the Chesapeake. The British maintained their presence on Tangier Island and their blockade until the war's end, but no large-scale incidents occurred following the Battle of Baltimore (George, 2000).

When all was said and done, the Chesapeake region was the hardest hit of any land theater of the war, sustaining property damage and financial losses that, even at the time, amounted to millions of dollars. At least 160 military actions occurred, including raids, skirmishes, and full-scale battles (Eshelman, 2013). Most action was restricted to coastal areas within Maryland.

2.1.3 The War Comes to an End

In the same month as the British withdrawal from Baltimore, the routing of British naval forces in Lake Champlain forced a retreat into Canada and essentially ended the conflict along the northern frontier. After three years, the war along the Canada-United States border was a stalemate. Although both sides had experienced victories, control of the strategically important Great Lakes remained divided, and no victories were significant enough to turn the tides of the war.

The final British campaign of the war targeted the Gulf Coast, which held commercial importance and also afforded its occupier control of the Mississippi River. Despite being lightly defended and having what the British perceived as an abundance of allies, this campaign ended in disaster for the British. Following defeats at Mobile and Pensacola, the British suffered the most lopsided defeat of the war at the Battle of New Orleans. The Battle of New Orleans occurred on January 8, 1815 – 15 days after the treaty ending the War of 1812 was signed. It took nearly a month for news of peace to cross the Atlantic. The Battle of New Orleans is considered the last major conflict of the war, although skirmishes did occur in the Chesapeake until the treaty was officially ratified in mid-February 1815 (Hickey, 2012).

Peace negotiations had begun in August 1814. At the time, the British were in a position of dominance. The Orders-in-Council had been repealed at the beginning of the war, but the British refused to budge on the issue of impressment (Hickey, 2012). Furthermore, the British demanded land concessions to protect Canadian assets and Indian allies. Great Britain's control of negotiations waned following the embarrassments at Baltimore and along the Gulf Coast. Both sides, eager to put an end to a war which was seemingly accomplishing little, agreed to the Treaty of Ghent on December 24, 1814. The treaty was ratified by the British government on December 27, 1814, and by the United States government on February 16, 1815, formally ending the war. Relations between the two nations returned to *status quo ante bellum*, or the state in which they existed before the war. Occupied enemy territory was ceded back to its prewar possessor, and neither side gained any concessions. Despite the lack of a clear victory, Americans felt a renewed sense of pride at having once again defended their homeland against a world-class aggressor (Hickey, 2012).

2.2 A History of Earthen Fortification in Colonial and Post-Colonial America

Earthen fortifications have been an integral piece of American defensive schemes since initial settlement by Europeans. While sizes and configurations have varied throughout time in response to methods of warfare and advances in weaponry, the basic premise has remained the same: earthen walls constructed from local soil served to quickly, cheaply, and effectively shield troops and artillery from enemy eyes and projectiles.

The convenience of soil as a building material stems from its availability in nearly all inhabited locations, and its granular, yet compactable nature, capable of being gathered, transported, and formed with the most minimal of tools. Its effectiveness as a material for defensive structures is a result of the unsurpassed ability of soil to absorb ammunition of all types. As early as the late 18th century, experiments were conducted to determine average penetration depths of various caliber guns, from various distances, and into various types of soil (Hughes, 1974). As little as two feet of packed earth was all that was required to stop fire from War of 1812-era small arms, and 10 to 15 feet of solid earth could stop even the largest caliber cannon (Hunt, 1911). While the crudeness of earthen fortifications may have made stone or masonry fortifications appear more capable, the opposite was actually true, especially after the introduction of rifling into warfare during the Napoleonic Wars (Hughes, 1974). The same compressional strength and rigidity that made stone and masonry great building materials also endowed them with a brittleness that resulted in crumbling when impacted by high-power rifled artillery, thus effectively making them obsolete by the end of the American Civil War (1861–1865) (National Park Service, 1998).

Various periods of planned, permanent, systematic fortification were undertaken throughout the nation’s history. Other fortifications – field fortifications, like those in this study – were designed and executed without permanence in mind, often times under duress and with little to no planning.

While purposes and scales of construction may have varied between the two types of fortification, designs, construction methods, and builders' intentions all stem from identical military logic and design theories of the time (Hughes, 2003). Thus, an understanding of the overriding military logic of the time period and of permanent fortification details is essential to understanding their more provisional counterparts, as the latter evolved from the same design theories (National Park Service, 1998). Furthermore, the intended durability and increased planning, effort, and cost of permanent fortification has left a much more indelible mark on the historical record compared to temporary earthworks. In fact, a number of permanent fortifications still exist in conditions similar to when they were constructed hundreds of years ago. Permanent fortifications, therefore, serve as excellent proxies for understanding their less permanent kin which are, by their very nature, comparatively underrepresented in the archaeological record and in historic documentation, but in theory and purpose, are very much the same.

2.2.1 Systems of Permanent Coastal Fortification

In the Colonial era, because of widely dispersed settlements along the entire Atlantic coast and a lack of coordination between them, each individual settlement had a need to erect some variation of coastal fortification. These early fortifications were numerous and large, albeit primitive and hastily constructed. While based on time-tested design principles brought from the Old World, most forts were products of trial and error and lacked the geometric intricacies typical of European forts developed through the science of fortification (Lewis, 1970). With a few notable exceptions, most were simple stockades (Herman, 1992) or constructed of earth, with or without timber or masonry support (Lewis, 1970). Most fortifications were located to protect ports or to cover river passages, not only because these were often the most strategically and commercially important areas, but because the vastness of the inland frontier, at this point, made securing it an almost impossible task (Kaufmann and Kaufmann, 2004).

Little change in purpose or design occurred up to and including the period of the American Revolution, despite the formation of a Corps of Engineers of the Continental Army in 1779 (Clary, 1990), established with the assistance of military engineers on loan from France (Lowe and Hawke, n.d.). Trained engineers were still scarce throughout the war, and as a result, most fortification was constructed by self-taught novices making use of French or British military engineering manuals. The number of forts may have increased during the war, but most were out of necessity and in response to specific threats. Forts were still largely individual enterprises that made use of whatever materials were available (Lewis, 1970). This lack of training, planning, and materials resulted in fortifications that were mostly poorly sited, crude imitations of European fortifications (Lowe and Hawke, n.d.).

The Revolutionary War did, however, change the mindset in regards to military defensive policy. The success of the American and French forces at Yorktown in 1781, due in great part to the contributions of the Corps of Engineers, proved that success could be achieved through structural methods, not just sheer numbers or firepower. Fortifications constructed by competent engineers could supplant the need for a large, professional army, and the expenses that come with it (Clary, 1990). As a result, American engineers traveled to Europe in 1781 to learn, firsthand, from European theorists of the time (National Park Service, 1998). The war also proved that defense of the nation was a job best handled by a central government, not individual states (Clary, 1990). In fact, states showed so little interest in maintaining the forts during peacetime that most fell into disrepair following the war (Lewis, 1970).

With the possibility of United States involvement in the French Revolution looming during the 1790s, the fledgling country sought to preemptively strengthen its coastal defenses (Lewis, 1970). Authorization was passed in 1794 to establish a new Corps of Artillerists and Engineers to begin research into and construction of a series of new coastal defenses (Chartrand, 2012). Designs were developed independently for each location, usually by a European engineer with explicit approval from the state governor (Clary, 1990). Forts were usually sited where past conflict had occurred (Robinson, 1977), and construction was required to be simple and inexpensive (Clary, 1990). Forts were initially open works consisting of sodded earthen parapets, supported, in some instances, by timber or masonry, and an enclosed earthen redoubt (Lewis, 1970). Unclad earthen fortifications were preferred by Congress because they were economical and effective against cannon fire (Kaufmann and Kaufmann, 2004), but the implementation of masonry veneers soon became more commonplace after issues of durability plagued these early bare earth forts (Lewis, 1970). Masonry also allowed fortifications to be built taller and more massive (Hughes, 2003). These masonry-faced forts were typically bastioned stars or pentagons, and a number of forts of significance, including Fort McHenry, were constructed (Chartrand, 2012). This system of fortification came to be known as the First System of fortification.

The United States was not drawn into the French Revolution, and the peace that continued over the following years gave Congress little motivation to devote significant time and money to the upkeep of the First System forts. As a result, all but the most significant forts once again lapsed into disrepair within a decade (Kaufmann and Kaufmann, 2004).

A new period of planning was spurred on by America's participation in the Quasi-War (1798–1800) and the First Barbary War (1801–1805), and by looming threats of war in the years leading up to the War of 1812 (Lewis, 1970; Kaufmann and Kaufmann, 2004). After failing to produce acceptable results or a well-trained body of engineer officers, the combined Corps of Artillerists and Engineers was disbanded, and a dedicated United States Corps of Engineers was formed in 1802. The United States Military Academy was also established at West Point at this time, and was supervised by the Corps. This was the first specialized engineering institution in the United States (in fact, civil engineering degrees were not granted at any American institutions until the 1830s) (Chartrand, 2012). The curriculum centered on military and civil engineering and was modeled on the French military academy, École Polytechnique (National Park Service, 1998).

The Corps quickly gained a reputation as elite military minds and exerted dominance in determining military policy. As engineering meant, above all else, fortification, so too did policies of national defense. Coastal fortification would remain the centerpiece of American military policy for over a century, while only a small regular army was kept, supplemented by a militia that could be called upon as needed (Clary, 1990). Throughout the War of 1812, the Corps consisted of 22 officers, 113 non-commissioned officers and artificers, and approximately 250 cadets (Chartrand, 2012).

With the new Corps established and a pool of American born and trained engineers at their disposal, Congress drafted the Second System of fortification in

1807. Implementation of the new system quickly got underway, and it was a marked improvement over the First System (Lewis, 1970). Three types of fortifications were constructed:

- Open bare-earth batteries, similar to those constructed during the First System but with some variation in shape, remained common yet “relatively insignificant” and still lacking durability (Lewis, 1970: 26).

- Masonry-faced earthen forts were the most extensively built during this program. Materiality and construction technique were carried over from the First System, but many of these forts incorporated new design elements, such as circular or elliptical segments.

- The most significant advancement of the Second System was the construction of all-masonry forts – high-walled, formidable structures containing innovations that provided increased firepower and safety for their garrisons.

Large-scale coordination was still limited, however, and the inconsistency of design from this period reflects this (Lewis, 1970).

The construction of many Second System forts was completed by the outbreak of the War of 1812, and any town of significance was protected by at least one battery (Robinson, 1977). Approximately 60 First and Second System seacoast fortifications – of various size, shape, and strength – were in place by the war’s end (Lewis, 1970). Despite a few notable successes during the War of 1812 (i.e., Fort McHenry), permanent forts along the coast proved largely ineffective (Hughes, 2003). In fact, most large population centers remained in a high state of alarm throughout the entirety of the war (Moore, 1981).

Whereas the First and Second Systems of fortification were essentially emergency undertakings in times of uncertainty – and each ran their course within a decade – fortification during the Third System continued for over a half century. The failures and successes of past systems illustrated the importance of strong coastal defense, and as such, “elevated seacoast fortification from the status of an emergency measure to a position of foremost importance among this nation’s major methods of defense” (Lewis, 1970: 36).

2.2.2 Earthen Field Fortification

While coastal fortifications of the First, Second, and Third Systems were planned in advance of intended usage and with permanence in mind, many fortification scenarios did not allow for significant amounts of time for planning or construction. In these situations, provisional earthworks, such as those in this study, were quickly constructed, and were not intended for use beyond a particular conflict or short-term occupation.

The efficiency and effectiveness of earthen field fortification resulted in increased usage throughout the history of American warfare until reaching a peak in the Civil War, where it was regarded as fact that adequate earthwork protection enabled defenders to hold off forces of three to four times their size (Hunt, 1911; Lowe, 2001) and “digging in” became as instinctual as eating or drinking (Lowe, 2001: 58). This advantage proved especially important for fortifications built in advance of British raids along the Chesapeake during the War of 1812, where inexperienced militia and townsfolk often did not have had the assistance of trained regular troops to defend their homes.

The intangible benefits of field fortification are also appreciable. The sense of safety and protection – not only from opposing forces, but also from natural elements – granted by fortifications surely helped entrenched troops cope during sieges lasting days, weeks, or months (Wise, 2014). Another psychological benefit is the “sense of order … imposed upon the chaos of combat" provided by delineated territory and a clear mission: hold this ground (Lowe, 2001: 73). It provided an untrained army the sense of security and confidence needed to defeat a professional army.

Despite the availability of a "published, systematic approach" to fortification (Babits, 2011: 114), styles of warfare in early America did not regularly necessitate the construction of temporary field fortifications during battle. Except for peripheral skirmishes, prior to the Revolutionary War, wars were still fought using traditional European-style "gentleman's" methods with rigidly regulated armies moving *en masse* in a linear fashion and with a general sense of propriety that didn't lend itself to the advantages provided by fortification (National Park Service, 1998). Troops were of the belief that "[t]he honorable and only way to fight … was to fight in the open as they had been taught" (George, 2000: 156).

As a result, field fortifications were usually only used as last resort measures when retreating or to conceal artillery (National Park Service, 1998). If conditions dictated rapid concealment for infantry, they were more likely to utilize existing means of cover (i.e., sunken roads, stone walls, topographic barriers) than to construct entrenchments (Lowe and Hawke, n.d.).

The French and Indian War (1754–1763) marked the first time entrenchments were utilized with purpose and regularity by an army in America. Earthen fortifications were constructed with the aid of British engineering manuals, usually with disastrous results, such as the poorly sited Fort Necessity constructed by Lt. Col. George Washington in 1754 (Kaufmann and Kaufmann, 2004; Lowe and Hawke, n.d.).

Field fortification played an increased role during the Revolutionary War as a method of equalizing the disparity between the large, well-equipped, disciplined British army and small, poorly equipped, untrained colonial army (National Park Service, 1998). Earthworks were used primarily as coastal fortifications (Fryman, 2000), defenses for harbors, towns, and garrisoned areas (Lowe and Hawke, n.d.), or as positions from which a defense could be maintained against greatly superior numbers (National Park Service, 1998). European (mostly French) engineers were under the employ of the Corps of Engineers of the Continental Army and played an important role by constructing, or training others to construct, field fortifications (National Park Service, 1998).

The time between the end of the Revolutionary War and the beginning of the War of 1812 saw no major advances in methods or weapons of warfare (Hughes, 1974). An American "guerilla" style of warfare may have been slowly developing since the start of the war, but the American military still strived for legitimization through adoption of traditional, respected European styles of warfare (Chet, 2003) which still favored older smoothbore weaponry (James, 2012). As a result, field fortifications during the War of 1812 served much the same purpose as they had during the Revolutionary War (National Park Service, 1998).

However, the United States did not have the influx of European military engineers this time around and instead had to rely on those trained at West Point. For the first time, formal, wholly American training merged with European precedents. Perhaps the best examples of this new hybrid approach to field fortification were found on the frontier. Frontier field fortifications often employed less conventional methods, such as the inclusion of hastily built wooden structures, buttressed with earth, and existing buildings (National Park Service, 1998). Other examples include breastworks of hogsheads of tobacco constructed to defend Nottingham, Maryland (Lucas and Swain, 2014) and a series of earthen fortifications constructed during the Battle of New Orleans which incorporated brambles, fence posts, cotton bales, and an existing mill race (Greene, 2009).

The use of earthworks in American warfare reached its zenith during the Civil War. This was due, in large part, to new tactics resulting from the wide-spread introduction of rifled firearms and artillery. The smoothbore technology relied upon in previous wars dictated linear, massed, open field formations and movements due to the limited range and accuracy of the weaponry (National Park Service, 1998). Rifling, however, allowed for accuracy of firearms at over 900 feet and increased the effective range for artillery to twice what it was only a decade before (Fryman, 2000). This enhanced lethality resulted in nearly "every movement and position of both armies … covered by field fortifications" (National Park Service, 1998: 8).

The advent and proliferation of airplanes, submarines, and cruise missiles essentially ended the widespread use of field fortification, and World War I (1914–1918) marked the last time that entrenchments were heavily depended upon. However, field fortification still has a role in modern warfare, as witnessed during the Vietnam and Gulf Wars (Lowe and Hawke, n.d.), and by the fact that United States military manuals contained detailed instructions about earthwork construction up until 2013 (U.S. Department of the Army, 1985; U.S. Department of the Army & U.S. Department of the Navy, 2013).

2.2.3 Contemporary Military Manuals

Provisional earthworks constructed without engineer influence were modeled after those that were, and beginning in the 18th century, military manuals were developed and available to aid novices in the design and construction of field fortifications. In the absence of pristine remnants, detailed sketches or accounts, or pre-Civil War photographs, contemporary military manuals offer an opportunity to envision what these earthworks may have originally looked like. Even if the earthworks did not conform exactly to the idealized forms prescribed by the manuals, comparisons assist in illuminating the builders' intentions. Contemporary accounts do indicate, however, that an adherence to "the prescribed rules of field fortification" was important, and efforts were made to conform to models as much as circumstances would permit (Greene, 2009: 125).

Militiamen may not have been formally educated in the art of fortification, but as armed conflicts were more frequent during the early years of the United States, the general public may have been more acquainted with examples of fortification than might be expected (Hughes, 2003). Herman (1992) suggests that the principles and vocabulary of fortification were actually quite familiar to the educated and interested public of the early 19th century, as theories and technical drawings had been published in civilian literature, like encyclopedias and dictionaries, for decades.

A number of military manuals discussing "proper" field fortifications were available by the onset of the War of 1812. Most drew on the work of the most influential military engineer of the 17th and 18th centuries, Sébastien le Prestre de Vauban. Vauban is credited with turning defensive engineering into an art and a science and revolutionizing fortification design (National Park Service, 1998). His writings influenced methods of fortification for centuries to come and inspired many other military engineering theorists. Vauban's genius stemmed from the understanding that topography should dictate design and that function should determine form (Herman, 1992).

Near the middle of the 18th century, Guillaume Le Blond published *Élémens de Fortification* (1739). Though not especially notable for revolutionary thinking, that fact that it was translated into English at the turn of the century by Col. Jonathan Williams – "the father of the corps of engineers" – is significant (Beach and Rines, 1904: n. pag.). Williams served as the Chief Engineer of the Corps of Engineers and the first Superintendent of the United States Military Academy from the school's establishment in 1802 until the outbreak of the War of 1812 (Beach and Rines, 1904). Williams also included his own appendix which he hoped would serve as an introduction to fortification suited to the nature of warfare in America (Williams, 1801b). His high regard for the treatise – he stated that he "believe[d it] to be the most approved, in a Country where these branches of the Art military are in the highest perfection" in a letter to Thomas Jefferson (Williams, 1801a: n. pag.) – and familiarity with its content resulted in its use as the primary engineering manual used by American military engineers throughout the War of 1812 (Kaufmann and Kaufmann, 2004).[2]

Another notable translated military manual appeared at the Academy following the War of 1812 and became the chief source for educators for nearly two decades. This work, *A Treatise on the Science of War and Fortification* (O'Connor, 1817), was

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[2] Other military manuals of note published prior to the War of 1812, which include details on field fortification, include Muller (1746), de la Mamie de Clairac (1749), de Saxe (1756), Tielke (1769), Adye (1801), Gay de Vernon (1805), Duane (1809, 1810), de Tousard (1809), de Martemont (1810), Müller (1811), and Hoyt (1811).

translated by West Point engineering instructor John Michael O'Connor and combined French engineer Simon François Gay de Vernon's manual of the same name with an appendix containing "the best principles and maxims of celebrated writers, such as Guibert, Lloyd, Tempelhoff, and Jomini" (O'Connor, 1817: v). The adoption of this manual coincided with a change in curriculum from theory-based to one more focused on mathematics and physics (Fryman, 2000).

O'Connor's work fell into disuse after the publication of Dennis Hart Mahan's *A Treatise on Field Fortification* in 1836. Mahan was an influential military engineer and West Point instructor whose writings stood as the principle reference for field fortifications up until the 20th century. By the outbreak of the Civil War, most officers had either been taught by Mahan at West Point or had read his works (National Park Service, 1998). His writings stressed consideration of topography – using it as a potential weapon – and an intimate knowledge of enemy weaponry and maneuvers (Fryman, 2000). Detailed, explicit instructions assured that they were accessible even to novices.

2.3 Characteristics of Earthen Field Fortifications

Dependent on purpose and topographical considerations, defensive earthworks existed in a variety of shapes and sizes. Linear earthworks (i.e., trenches, breastworks), with simple and easily adaptable shapes well-suited for nearly any defensive situation, varied in width from 5 to 40 ft (1.5 to 12.2 m)[3], and in length from

[3] For purposes of clarity, sections which discuss historical background will utilize the English system of measurement which was standard for the time period and location. Système International (SI) equivalents will be presented in parentheses. Sections not discussing historical information will present only SI units.

a few feet to many miles (Fenwick, 1833; Lowe and Hawke, n.d.). Detached earthworks, intended to hold positions beyond the main perimeter or temporarily impede an enemy's approach, could be partially open (i.e., redans, lunettes) or fully enclosed (i.e., redoubts, star forts, bastioned forts).

Size and configuration was often dictated by topography, local geology, and the size of the garrison, and could be altered by increasing the number or length of sides (Fenwick, 1833). The general rule of thumb prescribed 3 linear ft (0.9 m) of space along the parapet for each infantryman, and 15 to 18 linear ft (4.6 to 5.5 m) for artillery (Mahan, 1862) with an allowance of 4 to 6 ft (1.2 to 1.8 m) behind artillery for recoil (Graves, 1992). Additional considerations had to be made if the fortification was to be occupied for an extended length of time. Treatises of the time period prescribed an allowance of 18 sq ft (1.7 sq m) per man and 216 sq ft (20.1 sq m) per piece of artillery so that conditions were not over-crowded (Fenwick, 1833).

Despite differences of overall shape and size, the methods of construction and general profile forms are virtually the same for all varieties of earthen field fortifications, and despite minor alterations called for by advances in weaponry, have generally remained unchanged since the 17th century (Babits, 2011).

Proper siting was arguably the most important contributing factor to a fortification's effectiveness. The primary intent of field fortification was not always to cause immediate destruction of an enemy, but also to influence an enemy's route of travel, either away from areas of importance or towards areas that were better defended (Totten, 1851). In general, high ground was advantageous for the commanding view of the surrounding area and the increased field of fire that it offered (Robinson, 1977). Natural obstacles, such as vegetation and rocks, were useful as additional cover, but could also intrude on the field of fire (Hughes, 2003). These, along with marshes, waterways, and precipices, also served to impede the enemy's progress (Greene, 2009). As a result, fortifications were often sited near or adjacent to these natural barriers (Fenwick, 1833).

In coastal settings, fortifications benefitted from positioning at river bends, junctions, and other chokepoints for the increased field of fire (Hughes, 2003). The river systems of the Chesapeake Bay are extensive, but their meandering pathways offered great defensive positions. Coastal fortifications may have benefitted from increased range when placed at the water's edge, but could inflict equal amounts of damage to ships by ricocheting shots off the water. Coastal defenses, therefore, did not always have to be placed at the shoreline (Adye, 1801; Mahan, 1862).

From a practicality standpoint, well-drained soils were a necessity, especially for fortifications intended to be occupied for any significant length of time. Many works were enclosed, and poor drainage could have led to pooling or swampy conditions which would have undoubtedly affected the mobility and disposition of its occupants. As a result, some fortifications, including Fort Point and Fort Stokes, were constructed on prehistoric shell middens, in part, for the good drainage that they provided (Babbits, 2011). Additional drainage in the form of wooden gutter systems may have been employed to divert water away from the interior of the fortification (Mahan, 1862).

Optimal siting also took offensive and defensive weaponry into account. Ranges between weapon classes varied considerably – musket fire was effective to about 900 ft (274 m) (Hughes, 1974), whereas heavy artillery could achieve distances of 6,000 ft (1,829 m) (Graves, 1992). Similar variations existed within weapon classes due to ammunition type, gunpowder charge, elevation, and angle of fire (Adye, 1801).

In their simplest form, provisional earthworks consisted of an embankment, called a parapet, formed from and surrounded by a ditch on one or both sides (Figure 2). The parapet provided protection for troops and artillery that were stationed behind it, and thus had to be of a height and thickness to provide adequate protection. Height varied by fortification type. Linear entrenchments, called breastworks, were typically the height of an average man's chest (approximately 5 ft [1.5 m]). Defenders would stand up to fire, and crouch or kneel down below the parapet to reload (National Park Service, 1998). Taller parapets, recommended to be between 6 and 7.5 ft (1.8 to 2.3 m), required a banquette, or firing step, on the interior which defenders would step upon to fire and step off of to reload (Greene, 2009). Parapets may also have been topped by head logs – logs placed horizontally along the parapet to afford additional protection – or with soft, vegetated soil to prevent the scattering of gravel or gravelly soil if stuck by ammunition (Mahan, 1862; National Park Service, 1998).

The thickness of the parapet was largely determined by the type of ammunition it was expected to stop. A thickness of 3 to 4 ft (0.9 to 1.2 m) would be adequate for withstanding musket fire, a thickness of 9 to 12 ft (2.7 to 3.7 m) for standard field artillery (Mahan, 1862), and a thickness of 18 to 24 ft (5.5 to 7.3 m) for heavy artillery (Greene, 2009). The general rule of thumb was to create a barrier as thick as possible, ideally 1.5 to 2 times the penetration depth of the enemy's arms capability (Mahan, 1862; Cole, 2010). Experiments were conducted to determine average penetration depths of various caliber guns, from various distances, and into various media, results of which were published in military manuals beginning near the end of the 18th century (Hughes, 1974).

The most common weapon used during the War of 1812 was the musket. Rifles were also used, but to a considerably lesser extent, as well as carbines, blunderbusses, and a variety of other civilian arms. Large-caliber, smoothbore muskets were accurate to about 150 ft (45.7 m) (James, 2012). At this distance, Mahan (1862) estimates projectile penetration to be between 9.5 to 10 in (0.2 to 0.3 m) into compacted clay and sand. The most common field gun of the War of 1812 was the 6-pounder. At a range of approximately 1,800 to 2,100 ft (548 to 640 m), round shot fired by a 6-pounder field gun could penetrate 7 ft (2.1 m) into compacted clay and sand (Graves, 1992). The most common Royal Navy armament was a mixed battery of 18-pounder long guns and 32-pounder carronades (Lardas, 2009). At a range of 2,640 ft (805 m) – considerably less than its maximum effective range – round shot fired from an 18-pounder could penetrate 4.5 ft (1.4 m) into compacted clay and sand (Mahan, 1862).

Parapet dimensions were also influenced by soil type and the rapidity of construction. Penetration depth is significantly dependent on grain size, with larger grain sizes (sand and gravel) being more effective than smaller grain sizes (silt and clay) at stopping projectiles (Cole, 2010). Small grain sizes are ineffective because there is less crushing of grains, which aids in stopping the projectile, and also "a less uniform packing order," which reduces effective density and the pressure required to stop the projectile (Cole, 2010: 87). The moisture content, degree to which a soil is frozen, and size, shape, elasticity, and sorting of grains also play roles in determining the projectile-stopping effectiveness of soil (Cole, 2010). Fortifications constructed rapidly, without soil compaction and "time to settle," also required extra thickness (Abbot, 1868: 134).

The interior slope of the parapet was often reinforced with revetment, which acted as a retaining wall to prevent slumpage, assist in construction, and add additional thickness. Revetment could be of any material, but was generally of wooden planks, logs, fascines[4], wickerwork, stone, brick, sandbags, or makeshift concrete formed of soil mixed with clay, water, and straw (Mahan, 1862; Babits, 2011). In some instances, existing fence posts, piles of logs, or other debris were used as makeshift revetment (National Park Service, 1998). Slopes were often sodded to provide additional reinforcement and prevent erosion. According to Mahan (1862: 36), the ideal sod is of "fine short blade, and thickly matted roots" and may have been fastened to the bare surface with wooden pegs (Babits, 2011).

The interior slope of the parapet was to be, ideally, equal to one-third of its height, as this was determined to be the most comfortable angle for a defender leaning over to fire his weapon (Mahan, 1862). At the base of the interior slope was the banquette, which stood to a height of 4 to 4.5 ft (1.2 to 1.4 m) below the parapet crest and extended outward from the parapet 2 to 4 ft (0.6 to 1.2 m), depending on the ranks of men lining the parapet. The end farthest from the parapet sloped or stepped to the interior grade (Fenwick, 1833).

The exterior parapet slope may have been divided into two segments: an upper superior slope that sloped at a rather shallow angle to allow fire into the ditch, and a lower exterior slope that was left as the natural slope formed when earth was tossed

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4 Tightly bound bundles of twigs.

from the ditch (Mahan, 1862). A berm was often left where the exterior slope joined the ditch for men to stand on during construction and to prevent slumpage of the parapet back into the ditch. Soil type dictated the width of the berm, ranging from as little as 1.5 ft (0.5 m) in firm soils to 6 ft (1.8 m) in marshy soils. The berm was seen as a defect, however, as it allowed attackers to gain a foothold before scaling the exterior slope (Mahan, 1862). As a result, it was sometimes constructed with a downward slant (Greene, 2009).

The other main component of an earthen field fortification is the ditch. A ditch excavated on the interior of the parapet was useful as a time saving measure, as each shovelful of earth not only built up the parapet, but also lowered the interior surface (Lowe, 2001). Interior ditch fortifications could be constructed twice as fast compared to those with an exterior ditch. However, as one of the main functions of the ditch was to serve as an obstacle for the enemy (Mahan, 1862), exterior ditches were preferred and were more common, especially for semi-permanent forts and those which sheltered artillery (National Park Service, 1998). Ditches were sometimes excavated on both sides to "strengthen a section of parapet, to adapt to shallow topsoil, or to respond to uneven terrain" (National Park Service, 1998: 11).

Exterior ditches were thought to be most effective when at least 20 ft (6.1m) wide and at least 6 ft (1.8 m) deep (Mahan, 1862), but dimensions were largely dependent on the amount of earth needed for parapet construction (Fenwick, 1833). A depth below 12 ft (3.7 m) was considered too difficult and dangerous for builders, and a width too great may have made the ditch indefensible from behind the parapet (Mahan, 1862). However, a depth too shallow or a width too narrow may have allowed an attacker to cross the ditch and reach the parapet. The slopes of the sides of the ditch were dependent on the nature of the soil, but often made as steep as the angle of repose would allow (Fenwick, 1833). In all cases, the slope of the ditch nearest the parapet – the scarp – must be less steep than the opposite slope – the counterscarp – in order to support the weight of the overlying parapet (Mahan, 1862). The bottom of the ditch may be flat or V-shaped, the latter making enemy congregation in the ditch more difficult (Brackenbury, 1888). The ditch was sometimes flooded or filled with an abatis, a line of sharpened tree branches often tied together and pointing towards the approach of the enemy, to form an even more imposing obstacle (Greene, 2009).

A small mound of dirt, termed a glacis, was sometimes erected directly in front of the ditch, highest atop the counterscarp and gradually sloping back down to the surrounding grade like a ramp. The purpose of the glacis was to raise the enemy up to be within the plane of fire from behind the parapet (Mahan, 1862). Accounts indicate that due to either a lack of time or necessity, glacis were not often constructed (Mahan, 1862; Greene, 2009). Other features common to provisional earthen field fortifications include wells or cisterns, bombproofs[5], magazines[6], and traverses[7].

Some modifications and additions were necessary for artillery defenses. Guns were fired either *en barbette* – over the top of the parapet – or through holes in the parapet, called embrasures (National Park Service, 1998). Embrasures offered additional protection to artillery and troops stationed behind the parapet, but because they limited the field of fire and structurally weakened the parapet (Mahan, 1862),

[5] Wood-and-earth structures within which troops could take shelter from bombardments.

[6] Earth-covered, wood-framed, waterproof structures for storage of gunpowder and ammunition.

[7] Embankments erected inside enclosed fortifications to intercept enfilade fire and shield entrances to enclosed forts.

were primarily only used when the enemy had settled into a fixed position (Fenwick, 1833). The barbette method offered no restrictions on the field of fire, and was utilized when the enemy had not yet taken up a fixed position (Fenwick, 1833). The weight of artillery also required floor reinforcement via layers of fascines and the construction of gun platforms – timbers and wooden planks that would steady artillery and prevent the wheels from sinking into the ground (Greene, 2009).

The overall form and appearance of provisional earthen field fortifications generally followed these accepted guidelines. However, variations existed for a variety of reasons. The availability of an engineer and the training of those constructing the earthwork reportedly had a marked effect on its quality (National Park Service, 1998). The intended duration of occupancy also led to variations, as longer usage generally dictated construction of more elaborate fortifications (Babits, 2011) which continued to evolve during occupancy (National Park Service, 1998). Conditions during construction (National Park Service, 1998), such as poor weather or enemy fire, along with innovations developed from the field experience of those constructing the fortification (Lowe, 2007), also led to variations of form.

As armed conflicts with Native Americans began almost immediately following settlement, colonial inhabitants would have also been familiar with Native American defensive earthworks. Large-scale earthworks followed the same basic parapet and exterior ditch configurations as those of European design (Lowe and Hawke, n.d.), and archaeological evidence suggests that Native Americans constructed hastily made entrenchments during battle in much the same manner as their Anglo-American combatants (Scott, 1994). Despite this, research indicates that American ideas of field fortification are entirely European (Lowe and Hawke, n.d.).

2.4 Construction of Earthen Field Fortifications

When an engineer officer was available, fortification features, such as the locations and extents of the parapet and ditch, would be laid out and staked by the engineer (Babits, 2011). Troops or conscripted laborers would be placed at intervals of approximately 4.5 to 6 ft (1.4 to 1.8 m) to begin excavation of the ditch or ditches. Working parties would be formed and rotated, and, according to Mahan (1862), should consist of one man with a pickaxe stationed at the center of the ditch, four men to shovel loose earth onto the parapet, one man to spread the dirt, and one man to pack it. Other men may be employed building revetments, constructing and positioning abatises, laying gun platforms, or clearing timber in the "killing zone" (Abbot, 1862; Greene, 2009). Tools employed by the laborers consisted of spades, shovels, earth-rammers, mallets, mattocks, pickaxes, saws, hatchets, bill hooks, carts, and wheelbarrows (Greene, 2009). In more urgent situations, any available digging device was utilized (Lowe, 2001).

The amount of effort and time necessary for construction varied with fortification size, workforce size and experience, available tools, and weather and ground conditions (Mahan, 1862; Doyle, 1998). Historic estimates vary greatly in terms of how much earth a man was capable of moving per day – from 43 cu ft (Abbot, 1868) to 810 cu ft (Gibbon, 1860) (1.2 to 22.9 cu m) – depending on soil conditions and worker experience. Mahan (1862) estimates between 108 and 216 cu ft (3.1 and 6.1 cu m) per man, per day.

A general rule of thumb indicates that the necessary time for construction, in hours, could be obtained by "[multiplying] the area of the section of the trench in square feet by the interval between diggers (not less than 6 feet), and divid[ing] this product by 27" (Scott, 1861: 288). One account describes adequately equipped, rotating squads of 12 to 15 men able to construct a parapet of thickness and length suitable for the protection of an entire brigade from musket fire, in 40 minutes (Smyth, 1865).

Other observations indicate that paid workmen were considerably more efficient than troops, and that "exertions are nearly doubled" when battle is imminent (Abbot, 1868: 134). Work apparently did not end upon completion, as contemporary engineer records indicate that earthworks were in almost constant need of repair from erosion and rodent burrowing, and that sodding was ongoing throughout its functional life (McBride, 2014).

2.5 The Fate of War of 1812 Earthworks

In comparison to the Revolutionary War and the Civil War, the smaller scope of the War of 1812 has perhaps resulted in less public interest, and consequently, sites related to the War of 1812 have not been as well preserved (Eshelman et al. 2010). According to a 2007 report to Congress, only 47% of the War of 1812 battlefields and 40% of non-battlefield resources that were surveyed remain intact (National Park Service, 2007). Earthen fortifications have fared even worse: of the 48 War of 1812 earthworks identified in Maryland by Eshelman et al. (2010), the earthen forts in this study represent three of only four known, surviving examples (Pickett, 2000b; Gibb et al. 2013).

Concern for the degradation of these national icons is not a new phenomenon; famed architect Benjamin Henry Latrobe lamented the degraded condition of the New Orleans earthworks during a site visit only four years after the battle occurred, penning

> This ditch and something of a bank extending from the river road to the swamp will probably remain for many years, because the ditch serves as a plantation drain. But the soluble quality of the earth and the

> exceedingly heavy rains of the climate would otherwise, in a few years, destroy every vestige of a work which saved the city and the whole country of the delta from conquest (Latrobe, 1951: 46).

Earthworks, like natural hillslopes, are degraded through natural and anthropogenic processes. In a general sense, corners will smooth out, embankments will flatten, and ditches will infill as soil is transported downslope from the crest and scarps. Experimental earthworks reveal that this begins almost immediately and slows with time as vegetation is established and slopes are stabilized. Most geomorphic change happens rapidly, within the first decade or two (Bell, 1996). Changes are most dramatic in the ditch, which will widen and shallow at a quicker pace than the embankment. Somewhat surprisingly, colluvial transport from the embankment provides only a slight contribution to ditch sedimentation, proving the effectiveness of the berm (Bell et al. 1996).

The main threat to coastal earthen fortifications is shoreline erosion, but other natural processes of degradation include mass wasting, surface erosion, frost heave, tree throw, and bioturbation. Human-induced degradation occurs via development, deforestation, agricultural production, looting, tourism, and recreational usage. In addition to surficial processes, shape deformation of earthworks can be caused by soil compaction (Proudfoot, 1965) or internal movement (Ashbee and Jewell, 1998).

In the Chesapeake Bay region, soil creep and slope wash are of the greatest detriment to historic earthworks. Neither process can be completely stopped, but a variety of methods intended to manage these process have been employed with varying degrees of success. The National Park Service, overseer of a large number of military earthworks of various eras, employs five major management techniques: prescribed burning, mowing, herbaceous-trimming, woody-trimming, and forestation (Aust et al. 2003). A number of studies have found that the best method for combatting erosion is a passive approach whereby natural forest procession is allowed to proceed (Andropogon Associates, 1989; National Park Service, 1998; Aust et al. 2003).

Management strategies continue to evolve, but the threats remain constant. Through the application of our methods, we hope to not only increase our understanding of the study forts, but also illuminate patterns of degradation that may be useful for their preservation.

2.6 Historical Accounts of Forts Nonsense, Point, and Stokes

2.6.1 Fort Nonsense, Annapolis, Maryland

Fort Nonsense (18AN550 / NRHP #84000408) is an earthen fortification situated on the north side of the Severn River near Annapolis, Anne Arundel County, Maryland (Figures 1, 3, and 6A). Fort Nonsense was one of a small number of forts constructed to defend the Annapolis Harbor and is the only one that remains. The fortification is roughly circular in shape and consists of two arcs of earthen embankments and ditches with a pathway in between. Documentation concerning the construction of Fort Nonsense is nonexistent, though it was likely constructed either with funds appropriated for the fortification of Annapolis in 1777 or to bolster existing defenses during the War of 1812 (Weinland and Weber, 1984).

The first reference to Fort Nonsense in historic documentation is its inclusion on a U.S. Coast Survey map executed in 1844 (U.S. Coast Survey, 1846). No references were made to Fort Nonsense on earlier 1781, 1819, or 1823 maps of the Annapolis Harbor (Captaine du Chesnoy, 1781; Brantz, 1819; Sherburne, 1823). A map published in 1814 does not depict Fort Nonsense, but does make reference to an unnamed, protected hilltop covering the rear of nearby Fort Madison:

> Fort Madison is said to be commanded, by a hill in its rear, down to the Men's shoes on the Terre plain: I have never seen the premises, not have I any sketch of that part of the approach. The Esplanade is reputed to be under great incumberance, by means of culture and thickets, on private property not purchased with the scite of the Fort [Madison] (Tatham, 1814).

The 1814 map was created by topographer and engineer William Tatham, but based on a pencil sketch by Brig. Gen. William H. Winder. Curiously, Winder complained of a lack of landward defense for Fort Madison in an 1814 letter to Secretary of War John Armstrong (Winder, 1814). If Fort Nonsense did exist prior to 1814, it was apparently dilapidated to the point of disuse and obscurity, and certainly unmanned.

A lack of documentation may imply unplanned construction during a time of distress. During the Revolutionary War, Annapolis twice feared attack by the British – once in March of 1776 when a British sloop was stationed offshore and again in March 1781 when British warships blockaded the harbor for a short period (Weinland and Weber, 1984). Throughout much of the War of 1812, Annapolis was in a state of high alarm. The city, which served as a military camp and seat of the state government, was subject to a number of British blockades and feints. Though never attacked, contemporary records indicate a city in almost constant terror (Eshelman et al. 2010). The city's defenses played a continually decreasing role after the War of 1812, and post-1814 construction is unlikely (Weinland and Weber, 1984).

The exact purpose of Fort Nonsense is as unclear as its date of construction. Its location at the highest point in Annapolis, its great distance from the Severn River, and scant documentary evidence indicates that it may not have served as a battery, but instead as a lookout, signal station, or redoubt to cover the rear of Fort Madison. The fort is located approximately 1,000 ft (305 m) from the nearest historic (ca. 1850) shoreline of the Severn River and approximately 1,980 ft (604 m) from mid-channel. Although this was well within the maximum ranges of the largest smoothbore artillery guns of the time period – approximately 6,000 ft (1,830 m) – it was near the limits of their effective distances (approximately 2,400 ft [730 m]) (Graves, 1992; McKenney, 2007).

A 1983 archaeological survey noted the possible presence of three embrasures in the northern embankment. Evidence also indicated that this northern embankment may have been shifted or rebuilt sometime in the mid-19th century, possibly resulting from renewed interested in Fort Madison in 1847 or during the Civil War when troops were stationed in Annapolis. The existence of these possible embrasures is therefore unable to be positively associated with a pre-rebuilding function. No evidence of artillery placement, or rebuilding, was uncovered along the south embankment facing the Severn River (Weinland and Weber, 1984).

In addition to the footnote of the 1814 Tatham map, one more historic correlation of Fort Nonsense to Fort Madison was made in an 1846 report on the condition of Fort Madison by Capt. Engr. Fred A. Smith to Col. J. G. Totten, Chief Engineer and member of the Board of Engineers. In it, Smith discusses the distance and alignment between Fort Nonsense and Fort Madison, suggesting an existing relationship between them (Weinland and Weber, 1984).

All evidence considered, Fort Nonsense was most likely built as a redoubt for protection of Fort Madison. No definitive construction date can be had, but authoritative sources agree that a ca. 1810 date – shortly after construction of Fort Madison had been completed – is likely (Weinland and Weber, 1984; Eshelman et al. 2010; D. Lowe, personal communication, May 7, 2015; M. Kerns, personal communication, June 10, 2015). Fort Nonsense likely fell into disrepair shortly after, and remained in that condition throughout the first half of the 19th century. Fort Severn was turned over to the U.S. Naval Academy in 1845 and ceased being operational, leaving Fort Madison as the sole permanent defense of the Annapolis Harbor. A renewed interest in Fort Madison followed, and a number of surveys and repairs were completed in the following decade (Weinland and Weber, 1984). With this likely came the clearing and possible rebuilding of Fort Nonsense sometime before the end of the Civil War. It likely never saw usage during wartime and was probably rarely manned.

The fort was previously under the jurisdiction of the United States Navy, Carderock Division of the Naval Surface Warfare Center, but was transferred to Anne Arundel County in 2000. A Phase II archaeological survey was conducted in 1983 (Weinland and Weber, 1984) and Fort Nonsense was subsequently listed on the National Register of Historic Places (NRHP #84000408) in 1984. It remains exceptionally well-preserved and appears to be under no threat of development.

2.6.2 Fort Point, Centreville, Maryland

Fort Point (18QU620 / MIHP QA-429) is an earthen fortification situated along the southwest shore of the Corsica River near Centreville, Queen Anne's County, Maryland (Figures 1, 4, and 6B). The fort was constructed to protect nearby Centreville, but little historical documentation exists concerning its construction. Fort Point is a complex, roughly star-shaped configuration of high embankments and a surrounding ditch. Its location atop a high bluff jutting into the Corsica River offers a commanding view in all directions. The fort was constructed upon a partially submerged prehistoric shell midden that was first recorded during a 1992 archaeological survey of the Eastern Shore (Thompson, 2000). The historic component of the site – the fort itself – was recorded in a 2000 survey undertaken by the Jefferson Patterson Park and Museum as part of an American Battlefield Protection Program endeavor (Pickett, 2000b). No archaeological testing was conducted.

The most significant threat to Centreville occurred in early August, 1813 as the British occupied nearby Kent Island and recommenced with raids on the Eastern Shore (Hickey, 2012). A series of skirmishes, collectively referred to as the Battle of Slippery Hill, occurred between British land and naval forces and the Maryland Militia, 38th Regiment just south of Queenstown on August 13, 1813. After volleys were exchanged, the American militia withdrew to Centreville, while the British sacked nearby houses (Eshelman et al. 2010). Though it is possible Fort Point was erected in preparation for or as a result of these events, no mention of the fort is made in commanding officer Maj. William H. Nicholson's recounting of the skirmish and retreat (Goodwin, 2010).

The first contemporary mention of Fort Point is in reference to an Independence Day celebration being held at the fort on July 5, 1813, placing construction of the fort at least a month before the skirmish at Queenstown (Emory, 1950). A 1912 *Centreville Observer* newspaper article claims that the fort was constructed in response to a British attempt to enter Baltimore. This may refer to one of two "attempts." The most notable attempt – the British siege on Fort McHenry –

began on September 12, 1814 and culminated in the British defeat and eventual withdrawal from the region (Hickey, 2012). It is highly unlikely that fort construction would have commenced just as the British presence in the region was coming to an end. The more feasible "attempt" may be the British reconnoitering of Baltimore harbor in April of 1813. Though it was not an attack or an attempt to enter the city, American forces did fire on the British, and panic was induced (Hickey, 2012).

All historical sources considered, the most plausible period for construction of Fort Point was between April and July of 1813, when British raids in the Upper Bay were at their peak. The first documented existence on a map is a U.S. Geological Survey topographic map surveyed between 1895 and 1900, and published in 1901 (U.S. Geological Survey, 1901).

Fort Point's involvement in the war is also uncertain. The *Centreville Observer* article claims one shot was fired, which sailed over the HMS Surprise as she proceeded up the Corsica River toward Centreville. Caught by surprise, the British vessel purportedly unloaded its crew on the opposite shore and withdrew from the Corsica River the following day. The fort was manned day and night following this event until the close of the war (*Centreville Observer*, 1912). Though the HMS Surprise was indeed involved in the latter part of the Chesapeake Campaign (Drez, 2015), no other sources confirm this or any accounts of the fort's involvement.

Fort Point is currently privately owned and maintained. It sits within a lightly wooded grove adjacent to an extensive lawn and boat dock. The fort is sparingly landscaped. A narrow pathway the south embankment and passes through the heavily eroded north embankment. This pathway is visible in a photograph published in 1912 (*Centreville Observer*, 1912). Although being described as "recently cut" in the same newspaper article, it may have originally served as a sally port[8]. The most significant threat to Fort Point is shoreline erosion. Despite being nearly "a dozen feet from the edge of the water" in 1912 (*Centreville Observer*, 1912), the shoreline has retreated significantly to the point where an estimated 30% of the fort has been lost to erosion. Riprap has recently been introduced to the most severely damaged bank.

2.6.3 Fort Stokes, Easton, Maryland

Fort Stokes (18TA313) – historically referred to as Fort Stoakes – is an earthen fortification situated along the north shore of the Tred Avon River in Talbot County, Maryland (Figures 1, 5, and 6C). The fortification consists of a series of breastworks which, along with two barges (Tilghman, 1915), served to protect the nearby town of Easton during the British raiding campaigns of 1813 and 1814. The fort sits atop a previously undocumented, partially submerged prehistoric shell midden. The historic component of the site was first documented in 1997 (Lowery, 1997). A metal detector survey was conducted in 2000 by the Jefferson Patterson Park and Museum as part of a larger American Battlefield Protection Program endeavor. No artifacts definitively linked to the War of 1812 were recovered (Pickett, 2000b).

Easton held a place of prominence as not only the richest town in the region (*Easton Star-Democrat*, 1947), but also as home to a recently constructed armory that functioned as a repository of arms and ammunition for the entire Eastern Shore. Residents rightfully believed that Easton's commercial and military importance, as well as its nearness to three major rivers, made it an inviting target for attack. Citizens pleaded with the Governor and Council of the State for protection in a letter dated

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[8] A protected entrance

March 23, 1813, but their request for state assistance was denied. They were advised to rely on their militia (Tilghman, 1915).

Five days later, rumor reached the town that the British fleet was beginning its ascent up the Third Haven River, now the Tred Avon, toward Easton. A contemporary account indicates that citizenry and militia met at the courthouse square, marched to the point, and immediately commenced construction of the fort (Tilghman, 1915). A crew of nearly 100 men worked throughout the night, completing the fort by the following morning (Dawson, 2012). Many of the militia members were shipbuilders under the employ of James Stoakes, owner of the local shipyard and namesake of the fort. An attack never materialized, and it was learned that the supposed enemy ships were nothing more than transport vessels loaded with lumber (Tilghman, 1915).

A total of six guns were reportedly mounted at the fort. A garrison house was also constructed to house militia members stationed at the fort, as Fort Stokes was kept in a state of readiness for the remainder of the war (Tilghman, 1915). The garrison likely consisted of the Talbot Volunteer Artillery Company, the Easton Light Infantry Blues, and a company of volunteers from neighboring Caroline County (Hopkins, 1861; Tilghman, 1915). Although Fort Stokes had the capacity to "effectually shelter 500 men, and entrench a score of pieces of artillery" (Garey, 1881: n. pag.), it was routinely manned by only a few guards and reinforced further during periods of alarm (Tilghman, 1915).

One such period of alarm occurred on October 19, 1814. The British fleet advanced up the Choptank River, reaching as far as Castle Haven, approximately 8 mi (12.9 km) south of Easton. Word spread that an attack on Easton was imminent, and Fort Stokes was fully manned. Any plan of attack was thwarted by stormy weather, which scattered British vessels and forced them to revert their course. The militia retained their presence at the fort until November 2, 1814, when the British fleet withdrew from the Choptank River. One account from a participant in the building of Fort Stokes alleges construction during this period, but this account is dismissed by the author as the foggy memory of a “very aged man” (Tilghman, 1915: 152). The fort was reportedly also used as a shelter for townspeople and their belongings during raids on neighboring towns, and as a communications outpost where small boats reported on movement of the British fleet (*Easton Star-Democrat*, 1947).

The first documented existence of Fort Stokes is on an 1847 U.S. Coast Survey map (U.S. Coast Survey, 1847). Though no label is applied, fort features are clearly extant on the point where Fort Stokes is situated. A detailed account of the fort’s configuration and condition nearly a half century later was published in 1861 in *The Easton Star*:

> The Fort is a right angled parallelogram, about 280 feet [85.3 m] long, by 50 feet [15.2 m] in breadth. Its plan was the best known to the science of that day. The base of its outer glacis coincides with the river’s bank, giving it full command of all the water for miles in front, and especially of the only channel by which the enemy could approach. It is pierced for twenty guns of the largest calibre, the embrasures being wide enough not only for heavy ordnance, but also for a few seats to accommodate those who might become fatigued in a severe engagement - a capital idea this; but one which modern engineering has repudiated on the ground that it would be safer for those not engaged in the fight, to get out of the way. Two fosses[9] run parallel to the parapet, 60 feet [18.3 m] apart. The inner one was intended for the Infantry to hide themselves in or as a place of security when not actively employed at the front works, and it is said that it was always looked upon with favor by the garrison as a charming locality for roasting oysters. The

[9] Ditches

> magazine is in the centre, and of such solid masonry that no missile of what momentum soever, can reach its stores of ammunition. Indeed the whole structure is built of the most indestructible material – all found in the neighbourhood, and the very best clay the country produces, with here and there a little sand. The floor of the fosse next to the main parapet has been, of late years, ingeniously paved in mosaic, composed of oystershells, oakleaves, and cowlitter (Hopkins, 1861).

This account alleges an 1812 construction date, but offers no additional details.

Aside from serving as a picnic ground (*Easton Star-Democrat*, 1939) and pistol shooting range (Hopkins, 1861) following its decommission, the fort has remained largely undisturbed by humans. The fort location was spared from recent residential development, which now surrounds it, and is currently protected from disturbance by a federal Delmarva fox squirrel habitat conservation easement. Shoreline erosion poses a serious threat to the integrity of the site. As the 1861 *Easton-Star* article indicates, the outer works of Fort Stokes were constructed at the historic shoreline (Hopkins, 1861). Though the features and general plan of the fort are still discernible, a significant portion of the fort appears to have already been lost to a receding shoreline. A previous landowner has confirmed the severe state of localized erosion, claiming a loss of approximately 6.1 m since the mid-19th century – including one trench – and an average of 0.9 m of shoreline per year in recent years (Pickett, 2000a; Dawson, 2012).

Chapter 3

GEOGRAPHIC, PHYSIOGRAPHIC, AND GEOLOGIC SETTINGS

Fort Nonsense, Fort Point, and Fort Stokes are situated along banks of tributary rivers of the Chesapeake Bay, which lies within the Embayed Section of the Atlantic Coastal Plain Physiographic Province (Figure 1). The Chesapeake Bay formed as a drowned river valley of the Susquehanna River approximately 8,000 yrs BP as a result of the Holocene rise in sea level. It still retains the main features of its former terrestrial river valley, with a meandering outline, extensive dendritic tributary network, and a triangular cross-section (Dyer, 1995).

The Chesapeake Bay is a microtidal estuary, with tidal fluctuations between 0.3 m and 0.6 m, and small wave heights generally less than 0.9 m during fair weather conditions (U.S. Army Corps of Engineers, 1990). Sedimentation is characterized by sediment influx from the Susquehanna River in the upper portion of the bay, by shoreline erosion and biological production of sediment in the central part of the bay, and by shoreline erosion and an influx of ocean sediment in the lower part of the bay (Langland et al. 2003). As a whole, the Bay has high sedimentation rates, ranging from 0.001 m yr^{-1} to 0.01 m yr^{-1}, and also suffers from severe shoreline erosion in many areas (which, in part, contributes to the high sedimentation rate) (Cronin et al. 2003). The average annual rate of erosion is approximately 0.3 m, but preferential erosion due to localized topographical and hydrologic characteristics leads to rates of up to 3 m yr^{-1} in some reaches (Coulombe, 1986). Erosion is more serious within the bay than along its tributaries (U.S. Army Corps of Engineers, 1990).

The Maryland portion of the Atlantic Coastal Plain consists of fairly flat to moderately rolling uplands and very flat lowlands. Sediments are mostly unconsolidated Cretaceous to Pliocene sands and clays of terrigenous and marine origin, capped by Quaternary gravels, sands, silts, and clays. Sediments dip gently southeast. Sequences of strata reveal a history of sea level fluctuations and generalized southward progradation along the eastern edge (Delmarva Peninsula) (Vokes, 1957).

The Chesapeake Bay divides the Atlantic Coastal Plain into western and eastern sections. The Western Shore is of greater elevation and relief compared to the Eastern Shore. Relief is due mainly to incising by high-velocity streams which have formed fluvial and estuarine terraces along the major drainages. Conversely, the Eastern Shore contains comparatively low-gradient streams with wide and shallow valleys, and many low-lying wetlands (Vokes, 1957).

The climate of the Chesapeake Bay region is humid continental, with moderate temperatures, abundant precipitation, and well defined seasons. Mean annual temperatures range from 12°C to 14°C. Precipitation ranges from 1.0 to 1.2 m and is relatively evenly distributed throughout the year, with slight peaks in summer months. A strong climatic influence is exerted by the Bay and the Atlantic Ocean, which helps to depress significant temperature fluctuations in winter and summer (Maryland Department of State Planning, 1973).

3.1 Fort Nonsense

Fort Nonsense (38°59'14.12"N, 76°28'10.78"W) is located in an upland setting approximately 381 m northeast of the Severn River near Annapolis, Anne Arundel County, Maryland (Figure 3). It is currently located within a lightly wooded grove surrounded by a manicured park, and occupies the highest point in Annapolis (25 m AMSL).

The surficial geology is mapped as Paleocene-Eocene-aged Aquia Formation (Glaser, 1976). Topography of the surrounding area is relatively gently sloping on the north side of the Severn River, a common characteristic of the broad alluvial terraces that border many of the Chesapeake's rivers and streams (Kirby and Matthews, 1973).

On-site soils are mapped as well-drained Sassafras fine sandy loam (SaB) with 2 to 5 percent slopes (Soil Survey Staff, 2014). A typical natural soil profile consists of a very dark gray to dark grayish brown loamy surface layer atop a yellowish-brown, friable fine sandy loam and strong-brown, firm sandy clay loam subsoil. Parent material is loose, very coarse sand and small gravel (Kirby and Matthews, 1973). Sassafras fine sandy loams have low susceptibility to erosion (K factor = 0.15) (Soil Survey Staff, 2014).

Upland woodlands in the region are largely hardwood forests dominated by red and white oaks, sweetgum, and yellow poplar. Conifers, especially Virginia pine, are common in areas which have been cleared or cutover. Scrub brush, primarily Virginia pine, blackjack oak, and sweetgum, are common in sandy areas. Tidal areas support coarse grasses and larger vegetation that tolerate salt or brackish water (Kirby and Matthews, 1973). Vegetation on and immediately surrounding the fort consists primarily of mature apple trees – remnants of a former orchard – and holly trees planted in 1952 (Weinland and Weber, 1984).

3.2 Fort Point

Fort Point (39° 4'4.35"N, 76° 5'14.23"W) is situated atop a high wave-cut bluff along the southwest shoreline of the Corsica River near Centreville, Queen Anne's

County, Maryland (Figure 4). It is currently located within a landscaped, wooded grove adjacent to an extensive lawn and boat dock at an elevation of 6 m AMSL.

Centreville is situated near the margin of the Talbot and Wicomico terraces, two regions formed by separate stands of Chesapeake Bay sea level. The western portion of Queen Anne's County, including Fort Point, lies on Talbot terrace. Talbot terrace is generally flat and covered by a thin layer of loess overlying Pleistocene-aged Kent Island Formation. The loess is composed of silt removed from the floodplain of the ancient Susquehanna River (Shields and Davis, 2002).

On-site soils are mapped as well-drained Downer soils (DOE) on 15 to 30 percent slopes (Soil Survey Staff, 2014). A typical natural Downer series soil profile consists of a dark brown sandy loam or loamy sand surface layer underlain by dark yellowish brown to yellowish brown sandy loam subsoil. Parent material is brown to strong brown loamy sand, sand, or loamy coarse sand, often with subrounded gravels (Shields and Davis, 2002). Downer soils have very low susceptibility to erosion (K factor = 0.05) (Soil Survey Staff, 2014).

Woodland consists primarily of oaks, hickory, yellow-poplar, red maple, sweetgum, blackgum, holly, beech, dogwood, Virginia pine, and loblolly pine. Well-drained soils, like the Downer series, are more conducive to oak, poplar, and hickory (Shields & Davis, 2002). Vegetation on and immediately surrounding the fort consists of mature ash, beech, juniper, and small conifers.

3.3 Fort Stokes

Fort Stokes (38°45'59.24"N, 76° 5'58.90"W) is located atop a low bluff along the north shoreline of the Tred Avon River near Easton, Talbot County, Maryland

(Figure 5). The fort is located within a densely wooded area at an elevation of 1.8 m AMSL.

The surficial geology is mapped as Miocene-aged undivided Chesapeake Group abutting Pleistocene-aged Kent Island Formation (Owens and Denny, 1986). Fort Stokes is situated on Talbot terrace and shares regional characteristics similar to Fort Point (Reybold, 1970).

On-site soils are mapped as well-drained Hambrook-Sassafras complex (HfB) on 2 to 5 percent slopes (Soil Survey Staff, 2014). A typical Hambrook soil profile consists of a surface layer of friable dark grayish brown loam, followed by a yellowish-brown loam, yellowish-brown sandy clay loam, yellowish-brown sandy loam, and strong brown loamy sand subsoil series. Parent material is brownish yellow sand (Soil Survey Staff, 2012). A typical Sassafras soil profile consists of a surface layer of dark yellowish-brown sandy loam, followed by yellowish-brown sandy loam with less organic matter. Subsoil is reddish-brown to yellowish-red sandy clay above a strong-brown sandy loam. Parent material is strong-brown sand (Reybold, 1970). On-site soils have moderate susceptibility to erosion (K factor = 0.37) (Soil Survey Staff, 2014).

Historically, the region's natural vegetation consisted of forests of mixed oak and pine. Hambrook-Sassafras soils are well-suited for mixed hardwoods, especially white oak, black oak, and scarlet oak, and Virginia and loblolly pine. Common understory species are sassafras, dogwood, greenbriar, American holly and lowbush blueberry (Reybold, 1970; Soil Survey Staff, 2012). Vegetation on-site is dominantly oak and loblolly pine, with maple and crabapple also present.

Chapter 4

FIELD AND LABORATORY METHODS

4.1 High-Resolution Surface Modeling of Current Forms with a Terrestrial Laser Scanner

A Trimble GX Advanced Terrestrial Laser Scanner was used to collect topographic data at Fort Nonsense, Fort Point, and Fort Stokes (Figure 7). This instrument provides data regarding the distance to surfaces in a survey domain by measuring the time of flight of emitted pulses (up to 5,000 pulses per second) of green light (532 nm) with a factory-tested accuracy of approximately 1.3 mm at a distance of 100 m. The distance measurements are coupled with data regarding the azimuth and zenith of the emitted pulse to place each point in a local Cartesian coordinate system that originates at the instrument. Each data point consists of the three-dimensional coordinates of the first surface reflection along any vector.

To capture points across a landscape, a TLS instrument rotates on its base (around a vertical axis) to scan near- and far-field features. The instrument collects substantially greater numbers of data points from closer features than from the far-field area (i.e., tens of thousands vs. few, or none). Resolution of data depends on the spacing of successive points at a given distance and the size of the light pulse on a surface. These factors determine the minimum identifiable surface area (i.e., smallest individual object) able to be detected and the amount of data points collected within a survey domain.

The end product of a TLS survey is a detailed, three-dimensional point cloud representative of all reflective surfaces scanned. Each data point minimally has a coordinate within three-dimensional space (XYZ coordinate), and can also be described with a laser return-intensity value as well as color information estimated by an on-board camera (RGB values). The precision of TLS point clouds is influenced by equipment capabilities, scan settings, scan registration, and surface roughness, the largest of which defines the overall amount of error.

4.1.1 Data Collection

Terrestrial laser scanner surveys were completed at Fort Nonsense, Fort Point, and Fort Stokes during the months of April and May of 2014. The local XYZ coordinates, as well as return-intensity values and true-color information, were collected for all surface returns. Scans were conducted from multiple vantage points (survey stations) within each site location to ensure complete coverage and avoid large gaps in data caused by obstacles (i.e., large trees and rocks) and negative relief (i.e., ditches and pits). Temporary benchmarks in the form of 0.08 m ceramic targeting spheres were placed throughout the survey domain to enable multiple scans to be co-registered in post-processing. Each benchmark was positioned to ensure visibility from multiple survey stations. Resolution was set to collect returns at a spacing of 0.005 m at a distance of 50 m.

4.1.2 Scan Registration

Within each site, the XYZ locations of the individual ceramic spheres were used to provide a registration framework for the merging of the individual point clouds from each survey station. The spherical shape of the benchmarks limits registration errors because the mathematically modeled central point is easily calculated from different scan locations. The location of a single sphere within an individual scan was matched to the same sphere location in a different scan to merge both scenes together. A root mean square error (RMSE) of the distance between these coordinate pairs was calculated to assess error of fit. In this study, the highest registration RMSE value calculated among all scene merges at each site is referred to as the registration error.

4.1.3 Data Filtering

A raw point cloud often includes data points representing vegetation, surface debris, anthropogenic landscape modification, erroneous water reflections, and far-field returns outside of and unrelated to the survey purview. In order to generate a surface model representing the current bare-earth form of each earthwork, extraneous returns were filtered and removed from the finalized point cloud.

Because of the small, well-defined extents of the sites and the denseness of ground surface returns, manual filtering was used to remove unwanted data. Although a number of automated data filtering techniques exist, manual filtering allowed for the highest degree of accuracy and was feasible due to the small areal extent of the sites. Each point cloud was first cropped to the approximate extents of the current fort configuration, and then further dissected into thin slivers which could be individually rotated to show profile views. Because of the dense returns of the ground surface, the comparatively sparse, scattered underbrush and ground vegetation returns were easily discernible and subsequently removed. Other topographic anomalies, like tree trunks, large rocks, and walkway lighting, were recognizable by the vertical stacking of points that was not characteristic of the natural grade. Individual slivers were then stitched back together to recreate the complete, filtered scene.

4.1.4 Digital Elevation Models

Digital elevation models (DEMs) were created from the filtered point clouds of each fort. The DEMs developed in this study are based on raster data models which utilize a standardized grid of user-defined cell sizes that is created on the horizontal (XY) plane of the point cloud. The elevation value of each cell may be defined as the minimum, average, or maximum value, in the vertical (Z) direction, of all elevation values residing within the XY plane of a given cell. The raster format allows for easy GIS-based data analysis and standardization among other available forms of geospatial data (i.e., digital orthoimagery, satellite imagery, airborne LiDAR).

Interpolation of cells lacking data was completed using inverse distance weighting of values of the surrounding cells. Inverse distance weighting interpolation works by recognizing that spatial variance is a function of distance and that values of closer proximity are more influential than those farther away. Inverse distance weighting is ideally suited for the creation of realistic topography when point clouds are dense enough to capture the extent of local surface variation (Childs, 2004).

All three point clouds were converted to DEMs using a grid cell size of 0.1 m by 0.1 m, which was chosen based on ground surface characteristics, spatial resolution adequacy, and computational feasibility. Each cell contains the minimum Z value of the points within its XY bounds to generate a model that best represents the bare surface. Each DEM was georeferenced to high-resolution (0.15 m) orthoimagery published by the U.S. Geological Survey in 2012. Contours were created in 0.1 m increments to represent local topography.

ENDNOTES

Field data was collected with Trimble PointScape software, which serves as the software interface to the instrument. Point clouds were registered and error was computed with Trimble RealWorks software. CloudCompare, open-source software originally developed by Daniel Girardeau-Montaut, was used for manual filtering of data. ESRI ArcMap was used for rasterization, interpolation of missing elevation values, surface profile creation, contouring, and scene georeferencing.

4.2 Hillslope Diffusion Modeling

The degradation of one interior Fort Point embankment and one exterior embankment-and-ditch configuration was assessed through the application of a simple linear diffusion model whereby the downslope transport of sediment is a function of the local topographic gradient. By modeling the degradation of a series of possible initial embankment and embankment-and-ditch configurations, chosen based on fortification design principles prescribed by 19th-century military manuals, we were able to compare their modeled, degraded forms to the current TLS-derived profiles of Fort Point to evaluate likely initial shapes and sizes. Degraded profiles can be developed for sequential time steps to assess the rate and pattern of degradation between 1814 and 2014 (the date of TLS scans), and also to predict possible future landform profiles.

Diffusion modeling is most commonly used for assessing geomorphological change in natural landscapes, but is also well-suited for modeling the degradation of gently-sloping, transport-limited anthropogenic embankments (O'Neal et al. 2005). While evidence suggests that sediment flux on transport-limited hillslopes varies nonlinearly with slope (c.f. Roering et al. 1999; Gabet, 2000), linear models have proven adequate for addressing downslope sediment movement on small-scale slopes of low to moderate gradient (i.e., where linear and nonlinear processes do not diverge) (Schumm, 1967; McKean et al. 1993; Clarke and Burbank, 2010).

A linear diffusion model operates on the assumption that sediment flux is proportional to the rate of change in elevation. Sediment flux, $S_{f,i}$ (m^2), per unit length, Δx, is calculated using the following equation,

$$S_{f,i} = -\kappa \frac{\Delta z}{\Delta x} \tag{1}$$

where κ is the soil diffusivity constant ($m^2 yr^{-1}$), Δz is elevation change, and $\frac{\Delta z}{\Delta x}$ is the hillslope gradient.

Elevation change within each bin of length Δx is expressed as

$$\Delta z = \left(\frac{\Delta t}{\Delta x}\right) S_{f,i} - S_{f,i+1} \tag{2}$$

where t is time in years. If the amount of material entering a bin exceeds what is eroded, the average elevation of that bin increases and vice versa. When Equation 2 is applied to each bin in the profile over increments of t, the result is an approximation of the diffusion process. The value of κ in the model is adjusted so that the difference between the initial and modeled profiles results in a thickness of colluvium equal to depths revealed in sediment cores. An RMSE value is calculated based on variance of the modeled profile from the observed profile to assess error of fit.

4.3 Sediment Dating Using Fallout Radionuclides

Measurements of excess ^{210}Pb ($t_{1/2}$ = 22.3 yrs) and ^{137}Cs ($t_{1/2}$ = 30.2 yrs) in sediment cores extracted from the ditch and footslope of a Fort Point embankment were used to provide chronostratigraphic markers for calibration of the diffusion model.

Lead-210 is a natural geogenic radionuclide that is part of the ^{238}U-series decay chain. It results from the radioactive decay of radon gas (^{222}Rn), the daughter of metallic ^{226}Ra. Radium-226 is naturally occurring in soil and rocks, and while some ^{222}Rn is diffused into the soil matrix, that which is near the soil-air boundary escapes into the atmosphere. Atmospheric ^{222}Rn decays into ^{210}Pb within a matter of days, and is then washed out of the atmosphere through precipitation and dry fall. Lead-210 accumulates in surface soils and decays into stable ^{206}Pb. Because ^{210}Pb is also produced through the *in situ* decay of ^{226}Ra – termed supported ^{210}Pb – the background rate of this process must be subtracted from the total ^{210}Pb activity in order to get an estimate of the unsupported, or excess atmospheric ^{210}Pb activity at each depth ($^{210}Pb_{ex}$) (Lowe and Walker, 1997). Activity levels of $^{210}Pb_{ex}$ at each sample depth can be correlated to approximate ages through the application of dating models. However, since ca. 100 yrs is commonly regarded as the maximum age[10] of measurable ^{210}Pb, for purposes of solely establishing a chronological benchmark, we assign an age of 100 yrs to the depth where $^{210}Pb_{ex}$ activity is no longer detected.

The accuracy of $^{210}Pb_{ex}$ age-depth correlations can be validated by comparison to peak-activity levels of ^{137}Cs. Thermonuclear weapons tests in the 1950s and 1960s injected ^{137}Cs into the stratosphere, where it circulated globally and was deposited onto the landscape, primarily through precipitation. Cesium-137 fallout began in 1954, peaked during 1963-64 (herein referred to as 1963), and decreased to nearly imperceptible levels by the mid-1980s (Zapata et al. 2002). Whereas ^{210}Pb provides a relative chronology referenced to the top of the soil column, ^{137}Cs provides one or more absolute age markers by relating the depth of initial activity (1954) and peak-activity (1963) to the depth below ground surface (Van Metre et al. 2004).

Lead-210 and ^{137}Cs have proven to be reliable indicators of sediment age and soil redistribution tracers in a variety of terrestrial environments (e.g., Wallbrink and Murray, 1993; Walling et al. 1995; Zapata, 2003; Zheng et al. 2007; Le Roux and

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10 After five half-lives, the amount of remaining ^{210}Pb is roughly equivalent to measurement error.

Marshall, 2010). The uncultivated and intact nature of Fort Point provides a setting amenable to well-stratified soil deposits devoid of extensive mixing resulting from tillage. The small areal extent and ditch constraints of the embankment hillslopes limit sources of radionuclide input and allow us to make a direct correlation between soil deposited at the footslope and soil eroded from the slope.

4.3.1 Sediment Sample Retrieval

A total of four sediment cores were collected at Fort Point on December 23, 2014 (Figure 8). Cores A and B were retrieved, side by side, from the middle of the ditch at the base of the southwestern slope of the southernmost embankment. This location was selected because it appeared unaltered by landscaping and lacked the dense, uniform periwinkle ground covering characteristic of most other embankment slopes. This coring location is nearly adjacent to the path of the exterior embankment diffusion model profile (Profile B).

Cores C and D were retrieved, side by side, from near the base of the interior slope along the eastern embankment. This location was selected because it appeared undisturbed. This coring location lies along the interior embankment diffusion model profile (Profile D).

The moist, cohesive nature of the soil allowed us to recover intact sediment cores using 3-in diameter aluminum core tubing. Core tubes were pressed into the ground by hand, or driven with a mallet if movement became obstructed by roots. Core tube penetration continued until undisturbed subsoil was reached, as determined by previous soil borings. Core tubes were manually removed, sheared to size, and capped to prevent contamination. Sediment cores were refrigerated to abate microbial activity prior to drying in the laboratory.

Measurements were taken in the field to determine compaction. By measuring the length of the retrieved sediment core and dividing it by the depth reached below ground surface, a ratio was determined which equates cored sediment thickness to *in situ* sediment thickness. Compaction was assumed to occur evenly throughout the length of the sediment core.

4.3.2 Laboratory Sample Preparation

Two sediment cores, one from each retrieval location, were chosen for radionuclide activity counting and subsequently sampled and prepared for gamma-ray spectrometry. Core tubing was halved using electric cutting shears to reveal the intact sediment core. One-centimeter sample sizes have been shown to provide an adequate depth resolution for both ^{210}Pb and ^{137}Cs (Loughran et al. 2002). Sediment cores were thus divided into 1-cm increments from the exposed surface to well below the perceived depth of activity, beyond which 2-cm increments were sampled. The mass of each wet sample was recorded before being placed in a drying oven at ca. 100^{o}C for a minimum of 8 hrs. Dry sample mass was recorded and deducted from wet sample mass to establish moisture content and bulk density. Samples were ground using a mill grinder or mortar and pestle. Approximately 8 g of dried, ground sample was tightly packed into a cylindrical, air-tight polyethylene vial, at which time an exact sample mass was recorded. The counting geometry of all samples was identical to that of the standard reference material used for calibration of the gamma detectors.

4.3.3 Gamma-ray Spectrometry

Measurements of ^{210}Pb, ^{214}Bi, and ^{137}Cs activity in the sediment samples were conducted simultaneously by gamma-ray spectrometry, using a low-energy High

Purity Germanium (HPGe) Canberra well detector operated by the University of Delaware School of Marine Science and Policy.

Each sample was counted for a period of 24 hrs. Lead-210 was detected at 46.5 KeV, ^{214}Bi at 610.0 KeV, and ^{137}Cs at 661.7 KeV. To determine the amount of $^{210}Pb_{ex}$ activity, supported ^{210}Pb must be subtracted from the total ^{210}Pb activity count. Because ^{226}Ra and ^{210}Pb are considered to be in radioactive equilibrium, measurement of *in situ* ^{226}Ra activity can be used for determining supported ^{210}Pb (Walling et al. 2002). In this study, ^{214}Bi, a decay product of ^{226}Ra, was used as a proxy for supported ^{210}Pb to calculate $^{210}Pb_{ex}$ activity.

Chapter 5

RESULTS

5.1 Terrestrial Laser Scanner Data

5.1.1 Fort Nonsense

The TLS scan of Fort Nonsense was conducted on April 18, 2014. Atmospheric conditions were dry and overcast. Ground cover was sparse and springtime leaf regrowth was minimal. Dead, dry leaves were the primary ground cover and were minimal, ranging from 0 cm on embankment crests and slopes to no more than 3 cm in depth in areas of negative relief. A significant amount of woody debris was present in portions of the ditch from maintenance of the surrounding park. These materials were temporarily relocated during scanning.

A total of 10,596,002 raw TLS data points were collected from nine survey stations (Figure 9; Table 1). After accounting for scattered far-field returns, a total of 10,022,737 points fell within the approximate current footprint of Fort Nonsense, representing a 94.6% scanning efficiency. A registration error of 1.00 cm was achieved during post-processing scene merging. A total of 6,782,955 points, representing bare earth or ground cover returns from within the site footprint, remained following vegetation filtering. These account for 67.7% of total returns collected from within the site footprint.

The resulting DEM reveals an elliptical configuration of two arcs of earthen embankments – a larger one to the north and a smaller one to the south-southwest –

separated by two openings roughly opposite each other (Figure 10). Each embankment is flanked by an exterior ditch of a length proportional to the embankment. The interior of the fort is relatively flat except for a circular depression on the interior of the southern embankment.

The length of the fort, measured from the outside edges of opposite ditches in a linear north-northeast to south-southwest direction, measures 28.1 m. The fort is roughly symmetrical around this axis. The width, at the widest point in a linear west-northwest to east-southeast direction, measures 25.3 m. The width narrows asymmetrically to the southeast. The lengths along the crests of the northern and southern embankments are 26.6 m and 14.4 m, respectively. The lengths along the perimeters of the northern and southern ditches are 45.3 m and 21.4 m, respectively. The fort occupies an area of approximately 633 m^2.

The topographic relief and steepness of the exterior slope of the northern embankment-ditch complex is greater than that of the southern. Relief of the northern embankment is 1.59 m from the highest point of the embankment to lowest point of the ditch. Relief of the southern embankment is 1.03 m from the highest point of the embankment to lowest point of the ditch. The opening on the west side of the fort measures 3.6 m wide. The opening on the southeastern side measures 11.5 m wide and is flanked by depressions which may be drainage ditches.

A series of two approximately 1-m wide shallow depressions along the crest of the northern embankment most likely represent two of the three possible embrasures noted during the 1983 archaeological survey (Weinland and Weber, 1984). Evidence of the third embrasure is not visible. Surrounding the northern edge of the northern ditch is a possible intact portion of a glacis. The gradual slope on the interior of the northern embankment may be an eroded remnant of a gun platform and/or ramp (D. Lowe, personal communication, May 7, 2015). A noticeable 2.4-m wide shallowing in a northeast section of the northern ditch is most likely attributable to a dense collection of landscaping debris present at the time of the scan.

A 4.2-m wide depression at the center of the southern embankment may also be evidence of a south-facing embrasure. A slight shallowing of a 3.6 m section of the southern ditch is most likely a remnant of trenching involved in the 1983 archaeological survey (see Weinland and Weber, 1984). The circular depression along the interior of the southern embankment measures ca. 5.9 m in diameter. While described as a borrow pit[11] in Weinland and Weber (1984), this depression is more likely the remnants of a well (D. Lowe, personal communication, May 7, 2015) or a post-construction disturbance. Wells were common in fortifications intended to be occupied for any length of time, and were generally 8 to 10 ft (2.4 to 3.0 m) in diameter and lined with brick, stone, or wood (Cooling and Owen, 2010). No traces of these materials were noted in Weinland and Weber (1984), though it is possible that brick or stone lining was removed after the fort was decommissioned or that wooden lining has since decomposed.

5.1.2 Fort Point

The TLS scan of Fort Point was conducted on May 6, 2014. Atmospheric conditions were dry and sunny. Underbrush was sparse due to landscaping and that which was present was cropped closely to the ground (ca. 5 cm). There was little

[11] A pit used solely as a source of building material.

natural surface debris present. The interior surface of the fort and interior embankments were bare or covered with a thin layer of moss or grass.

A total of 8,520,946 raw TLS data points were collected from seven survey stations (Figure 11; Table 1). After accounting for scattered far-field and erroneous water returns, a total of 7,556,870 points fell within the approximate current footprint of Fort Point, representing an 88.7% scanning efficiency. A registration error of 2.15 cm was achieved during post-processing scene merging. A total of 5,537,461 points, representing bare earth or ground cover returns from within the site footprint, remained following vegetation filtering. These account for 73.3% of total returns collected from within the site footprint.

The resulting DEM reveals a massive, roughly star-shaped line of embankments with an encircling ditch (Figure 12). The southwestern portion of the fort remains intact with definable features. A significant part of the northern section of fort has been lost to shoreline erosion and the eastern portion has lost some definable features due to slope processes. The interior surface is relatively flat. Salients, formed where stretches of embankments meet, are the most stable and prominent portions of the fort. The slightly concave stretches of embankment between these salients may indicate embrasures that have since collapsed (note the aforementioned 1912 *Centreville Observer* article which mentioned their existence) or openings to allow enfilade fire into the ditch. A series of two depressions along the eastern embankment, each measuring ca. 3.3 m wide, may also be remnants of embrasures. The most notable feature is the half-bastion[12] located in the south for landward defense. The

[12] An angular structure projecting outward from the exterior wall of a fort consisting of one face and one flank.

inclusion of the half-bastion indicates knowledge of military engineering principles and the likely involvement of a professional engineer.

The length of the existing portion of the fort, from north to south, is 38.4 m. The width, measured east to west, is 37.3 m. The overall length along crests of the existing embankments is 80.7 m. The length along the perimeter of the remaining ditch is 51.2 m. The current earthworks are contained within an area of 1,240 m^2. The narrow pathway that traverses the fort measures 2.8 m wide. Topographic relief of the fort, from the highest crest of embankment to the lowest point of the ditch, is 2.53 m.

5.1.3 Fort Stokes

The TLS scan of Fort Stokes was conducted on April 2, 2014. Atmospheric conditions were dry and a mixture of sun and clouds. Vegetation was leaf-off. Leaf ground cover was present over the majority of the survey domain and ranged from 0 cm on embankment crests to 7 cm in depth in ditches. Minor amounts of natural surface debris (i.e., logs and branches) were relocated to outside of the survey domain for the purposes of the survey.

A total of 6,092,125 raw TLS data points were collected from seven survey stations (Figure 13; Table 1). After accounting for scattered far-field and erroneous water returns, a total of 5,761,491 points fell within the approximate current footprint of Fort Stokes, representing a 94.6% scanning efficiency. A registration error of 1.24 cm was achieved during post-processing scene merging. A total of 3,046,323 points, representing bare earth or ground cover returns from within the site footprint, remained following vegetation filtering. These account for 52.9% of total returns collected from within the site footprint.

The resulting DEM reveals a series of four nearly parallel embankments separated by three ditches in a roughly northwest-southeast orientation (Figure 14). The embankment-ditch complexes are truncated to the southeast by the eroding shoreline. The middle and westernmost ditches are connected with a short ditch segment intersecting both larger ditches at a nearly 90^{o} angle. The easternmost ditch exhibits a marked curve to the southwest as it reaches the shoreline, indicating a possible former connection between it and the ditches to the west. Any clear evidence of this connection has been obliterated by shoreline erosion. Any evidence of additional embankments or ditches to the west and southwest has also been lost to erosion.

The current length of each embankment, from west to east, is 18.4 m, 15.7 m, 10.9 m, and 20.2 m, respectively. The current length of each ditch, from west to each, is 23.9 m, 14.7 m, and 21.9 m, respectively. The length of the connecting ditch segment is 5.2 m. Topographic relief from the highest point of any embankment to the lowest point of any ditch is 1.34 m. Relief and steepness is roughly uniform among all embankment-ditch complexes. The current extent of the fort occupies an area of 666 m^2.

Embankments and ditches are oriented in a direction that indicates armaments were directed southwest, directly facing any vessels proceeding up the Tred Avon River. No features of gun placement are discernable, nor are any topographical indications of the garrison that was purportedly constructed nearby.

5.2 Diffusion Models

Diffusion models incorporating topographic and sedimentological data were applied to two profiles at Fort Point (Figure 8). Profile B extends 10 m from the crest of the south embankment, down the exterior slope, and through the ditch. Our model indicates the best-fit initial configuration for the embankment and ditch is a sinusoidal crest of 1.3 m above the current local grade, a berm 0.5 m wide, and a tapered, slightly V-shaped ditch ca. 3 m wide and 1.7 m deep (Figure 15). O'Neal et al. (2005) indicate, however, that a variety of initial embankment crest shapes (i.e., sinusoidal, trapezoidal, and triangular) will result in similar long-term profiles. The required value of κ for this model (see Equation 1) is 0.0035 $m^2 yr^{-1}$. This value is consistent with other diffusion models of similar material (Hallet and Putkonen, 1994). An error-of-fit (RMSE) value of 0.0377 was achieved.

Profile D extends 7 m from the crest of the eastern embankment and down the interior slope. Our model indicates the best-fit initial form of the embankment is a sinusoidal crest of 1.6 m above local exterior grade (2.27 m above interior grade), which slopes down to a 1-m wide banquette or gun platform raised 0.57 m above interior grade (Figure 16). The required value of κ for this model is 0.0048 $m^2 yr^{-1}$. This value is consistent with other diffusion models of similar material and comparable to the value required for the modeling of Profile B (Hallet and Putkonen, 1994). An RMSE value of 0.0216 was achieved.

5.3 Stratigraphic Analysis

Four cores were collected at Fort Point (Figure 8). Cores A and C were used for textural analysis. Soil descriptions for these cores are presented in Table 2. Cores B and D were submitted for radiometric analysis and retrieved adjacent to Cores A and C, respectively.

The following soil profile description was taken from Core A, which is useful as a proxy for stratigraphic analysis of Core B. Measurements have been adjusted for compaction and represent depths below surface. The upper 20 cm of Core A was a very dark gray (10YR 3/1) translocated silt loam surface horizon (Ap). From 20 cm to 35 cm was a brown (10YR 5/3) silt loam transitional horizon (AB) between modern organic accumulation and historic colluvium. From 35 cm to 50 cm was a yellowish brown (10YR 5/4) slightly gleyed fine sandy loam (Btg). From 50 cm to 68 cm was a yellowish brown (10YR 5/4) fine sandy loam exhibiting minor characteristics of a fragipan (Btx). From 68 cm to 75 cm was a yellowish brown (10YR 5/4) slightly gleyed fine sandy loam (2Btg). From 75 cm to 79+ cm was a yellowish brown (10YR 5/6) medium to coarse sand (2C). The unconformity between 2Btg and 2C represents the 1813 post-construction surface.

The following soil profile description was taken from Core C, which is useful as a proxy for stratigraphic analysis of Core D. Measurements have been adjusted for compaction and represent depths below surface. The upper 18 cm of Core C was a very dark gray (10YR 3/1) translocated silt loam surface horizon (Ap). From 18 cm to 28 cm was a dark grayish brown (10YR 4/2) silt loam transitional horizon (AB) between modern organic accumulation and historic colluvium. From 28 cm to 36 cm was a brown (10YR 5/3) fine sandy loam transitional horizon (BA). Horizons AB and BA are downslope colluvium accumulations. From 36 cm to 42 cm was a yellowish brown (10YR 5/4) fine sandy loam (Bt). From 42 cm to 45+ cm was a slightly gleyed yellowish brown (10YR 5/4) fine sandy clay loam (Btg). The unconformity between BA and Bt represents the 1813 post-construction surface.

5.4 Radiometric Dating

A total of 60 samples, 30 from each of Cores B and D, were prepared and analyzed for radionuclide activity. Summarized results are presented in Tables 3 and

4. Complete data are presented in Appendices A and B. Bar charts of radiometric activity are presented in Figures 17, 18, 21, and 22. Because the commonly accepted maximum age of detectable ^{210}Pb is ca. 100 yrs (see section 4.3), an age of 100 yrs is assigned to the depth interval where $^{210}Pb_{ex}$ activity drops below detectable levels. Atmospheric input of ^{137}Cs began in 1954 and reached its maximum in ca. 1963; thus, the initial appearance and peak activity levels in each core are correlated to those dates.

5.4.1 $^{210}Pb_{ex}$

Excess ^{210}Pb activity was detected to an adjusted depth of 27.53 cm in Core B (Figure 17; Table 3). Activity peaks between 0 cm and 1.20 cm and decreases with depth until dropping below detectable levels at 27.53 cm. We assign an age of 100 yrs to this depth. A spike in activity is reported near the terminus of the core, a likely result of sample contamination.

Excess ^{210}Pb activity was detected to an adjusted depth of 23.78 cm in Core D (Figure 18; Table 4). Activity peaks between 0 cm and 1.03 cm and decreases exponentially to a depth of 5.17 cm. A spike in activity occurs from 5.17 cm to 10.34 cm. Activity levels decrease between 10.34 cm and the terminus of the core. Activity drops below detectable levels at 23.78 cm. We assign an age of 100 yrs to this depth.

Both profiles display evidence of minor post-depositional mixing exhibited by a slight deviation from an exponential decay curve (Binford et al. 1993). Mixing can result from physical, biological, and chemical processes occurring after deposition, or may be indicative of multiple sediment inputs (i.e., sediment from both sides of a ditch). These profiles are comparable to other activity profiles affected by anthropogenically-influenced erosion and deposition (i.e., Walling et al. 2002).

Results of $^{210}Pb_{ex}$ dating of Core B are in agreement with modeled data for Profile B (Figure 19). The 100-yr chronostratigraphic marker for Core B, as determined by $^{210}Pb_{ex}$ analysis, is at 27.53 cm below ground surface; modeled data suggests an age of 108 yrs for this same depth. Modeled data suggests the 100-yr surface near Core B to be at a depth of 24.54 cm, a difference of 2.99 cm (4% of colluvium depth).

Results of $^{210}Pb_{ex}$ dating of Core D are not in agreement with modeled data for Profile D (Figure 20). The 100-yr chronostratigraphic marker for Core D, as indicated by $^{210}Pb_{ex}$ analysis, is at 23.78 cm below ground surface; modeled data suggests an age of 187 yrs for this same depth. Modeled data suggests the 100-yr surface in Core D to be at a depth of 9.18 cm, a difference of 14.60 cm (41% of colluvium depth).

5.4.2 ^{137}Cs

Cesium-137 activity was detected to an adjusted depth of at least 29.93 cm in Core B (Figure 21; Table 3). Peaks in activity were encountered at 8.38 cm and 15.56 cm. Activity decreases linearly with depth, reaching a minimum of 3.32 mBq g^{-1} at 27.53 cm, but does not drop to 0 mBq g^{-1} within the limits of the core. This indicates post-1954 deposition of the entire sampled portion of the core, and possibly beyond. A correlation of peak activity levels (at 8.38 cm and 15.56 cm) to a date of 1963 may be possible, and does agree relatively well with modeled data. Modeled data suggests a depth of 10.34 cm for 1963, within the range identified by ^{137}Cs activity.

Cesium-137 activity was detected to an adjusted depth of at least 22.75 cm in Core D (Figure 22; Table 4). A peak in activity is reported between 0 cm to 1.03 cm. Activity levels decrease linearly to a minimum of 1.64 mBq g^{-1} at 22.75 cm, but do not drop to 0 mBq g^{-1} within the limits of the core. This indicates post-1954 deposition of the entire sampled portion of the core, and possibly beyond. A correlation of the peak activity level at 1.03 cm to a date of 1963 may be possible, and does agree relatively well with modeled data. Modeled data suggests a depth of 3.34 cm for 1963, a difference of 2.31 cm. A spike is encountered between 22.75 cm and the terminus of the core, and is likely attributed to instrumentation error or core contamination.

Despite the relative agreement of 1963 age-depth benchmarks between modeled and radiometric data for each core, the uniformity of ^{137}Cs activity throughout both cores is an indicator of post-depositional redistribution (Gellis et al. 2009). The typical vertical distribution of ^{137}Cs activity in an unmixed sediment profile consists of a peak slightly below the surface, followed by an exponential decrease to imperceptible levels below the 1954 surface (Walling et al. 2002). Neither ^{137}Cs activity profile in this study exhibits this typical distribution.

Chapter 6

DISCUSSION

Analysis of our topographic, stratigraphic, radiometric, and mathematically modeled data provides us with geospatial details of current earthwork forms, metrics for understanding past and future rates and patterns of degradation, and insights into their initial construction. In absence of detailed construction drawings or eyewitness accounts, methods used in this study offer the best – perhaps, only – method for objective reconstruction of initial forms. Apart from simply providing measurements, accurate surface models and knowledge of initial forms provide a wealth of information about military tactics, weaponry, the availability of trained engineers, the amount of time and material necessary for construction, and the true intentions of builders.

6.1 Terrestrial Laser Scanning

Terrestrial laser scanning proved to be an effective method for documenting these anthropogenic earthworks. Topographic subtleties, indicative of possible fortification features and not discernible to the naked eye, were able to be detected at Fort Nonsense (embrasures, glacis, gun platform/ramp, drainage ditches) and Fort Point (embrasures, openings for enfilade fire). Placing fortification features in a larger context also made relationships between individual components visible. For example, the half-bastion at Fort Point – though visible on the ground – did not become recognizable until the relationship between the individual embankments became evident. Features such as those mentioned above may play a large role in writing or correcting the historical narrative of each fort.

The digital data resulting from the TLS scans present unique educational and preservation opportunities not available prior to this study. Uses include visually-appealing presentation material, spatial data which may be further manipulated and analyzed, and benchmarks for future erosion studies at each fort. Geospatial data from this study (raw and filtered point clouds, and bare-earth DEMs) will be made available to the public through an online data repository.

6.2 Diffusion Models

Modeling of hillslopes is rarely applied in anthropogenic settings (c.f., Bullard, 2003a, 2003b; O'Neal et al. 2005), but our study reinforces the findings of previous applications that show this method to be a simple and effective means of documenting geomorphic evolution. Our models of Fort Point indicate rapid erosion of slopes and severe rounding of corners within the first few decades, with degradation slowing as slopes stabilize. These findings echo observations at experimental earthworks at Overton Downs and Wareham, where forms failed rapidly and appeared as eroded features within decades (Bell et al. 1996). Whereas findings at these experimental earthworks were based on incremental observations spaced years apart, our model allows for temporal refinement to increments as small as fractions of a year. Because of a floating diffusivity parameter (κ), our model is material-independent and accounts for the inverted stratigraphy typical of earthworks and which Weinland and Weber (1984) found to be a significant factor in slowing erosion. Our diffusivity values, however, are in agreement with values for similar materials and in similar environments (i.e., Hanks et al. 1984; Hallet and Putkonen, 1994; O'Neal et al. 2005).

Our model does not, however, account for any revetment (most likely sod, if any), which may have helped stabilize slopes, especially in the earlier years.

Our diffusion models also yielded initial forms that are in accordance with typical forms prescribed by contemporary military manuals and practical dimensions. The model of Profile D, for example, indicates a crest height of 1.7 m above the firing step: the approximate height of an upright man. A shorter height would not have provided adequate protection, and a greater height would not have allowed for comfortable firing over the parapet. The exterior slope and dimensions of the berm and ditch along Profile B also conform to military manual specifications.

6.3 Radiometric Dating

The inclusion of chronostratigraphic markers obtained through radiometric dating offers benchmarks useful for quantitatively validating our diffusion models. Results were promising, but inconsistencies between $^{210}Pb_{ex}$ and ^{137}Cs activity profiles require further investigation. Whereas $^{210}Pb_{ex}$ dating provides chronostratigraphic markers in agreement with modeled data from Profile B and within reason for Profile D, ^{137}Cs activity suggests soil profiles too homogenous to provide reliable ages. Mechanical mixing of sediments within this landscaped setting would be the simplest explanation for the atypical ^{137}Cs profile. However, the lack of correlation for this high degree of mixing in the $^{210}Pb_{ex}$ data and lack of visual evidence in the soil profile makes this unlikely.

Cesium-137 activity also indicates post-1954 deposition of the entire sampled lengths of both sediment cores. This would indicate average sediment accumulation rates of 0.50 cm yr^{-1} and 0.40 cm yr^{-1} at Cores B and D, respectively. We associate sedimentation accumulation to be largely the result of parapet and ditch scarp and counterscarp erosion. These rates are unlikely for soils of very low erodibility (K factor = 0.05), slopes which have been stabilized by vegetation for nearly two centuries, and an immediate physiographic setting devoid of any obvious modern disturbances. Furthermore, they are not in accordance with rates of degradation observed at Overton Down and Wareham (Bell et al. 1996), or those calculated for vegetated Civil War earthworks of similar soil composition (Azola, 2001).

If not largely a result of physical mixing, downward diffusion of ^{137}Cs offers the best explanation. A number of studies have shown a greater downward mobility of ^{137}Cs in comparison to $^{210}Pb_{ex}$ (i.e., Torgersen and Longmore, 1984; Farmer, 1991; Bryant et al. 1993; Crusius and Anderson, 1995; Benoit and Rozan, 2001; Abril, 2004; Amos et al. 2009). Both $^{210}Pb_{ex}$ and ^{137}Cs rapidly and strongly adhere to terrigenous particles, but often preferentially (Fukumori et al. 1992). Whereas ^{137}Cs is immobilized by strong bonds in clay-rich sediments, it is not strongly bound to organic particles and is therefore relatively mobile in environments, like our study site, that are rich in organics (Bryant et al. 1993). Cesium-137 is more water soluble than ^{210}Pb, and with increased organic sediment porosity and a lack of immobilizing bonds, may migrate downward through pore water diffusion (Bryant et al. 1993; Farmer, 1991; Abril, 2004). Furthermore, humic acids present in organic-rich sediment have been shown to keep ^{137}Cs in a dissolved form (Torgersen and Longmore, 1984). On the contrary, $^{210}Pb_{ex}$ has a strong association with organic matter (Teramage et al. 2013; Taramage et al. 2015), even exhibiting increased adsorption in the presence of organic compounds (Yang et al. 2015). In a study of similarly forested areas, Korobova et al. (1998) found that vertical migration of ^{137}Cs was most pronounced in local depressions with organic and gleyed soils and in woodlands with sandy soils.

Downward diffusion of ^{137}Cs usually results in an elongated tail into deeper sediments (Amos et al. 2009), which, while not apparent in the profiles for Cores B and D, may exist at deeper depths. We hypothesize that the lack of correlation between the two radionuclide activity profiles is attributable to minor mechanical mixing resulting from multiple sediment inputs and differential movement of ^{137}Cs relative to $^{210}Pb_{ex}$ due to pore water diffusion. For purposes of this study, we opt to rely on $^{210}Pb_{ex}$ data, which, due to its ability to tightly bind to both mineral and organic matter, is generally considered to be more reliable than ^{137}Cs for sediment dating (Bruland, 2008). Future applications of this method should, however, account for these discrepancies.

6.4 Future Work

Refinement of radiometric dating methods offers the greatest opportunity for the advancement of work performed in this study. The radiometric analysis of additional sediment cores and the development of a local reference inventory would provide a larger frame of reference for comparative purposes (Pennock and Appleby, 2002). Deeper downcore analysis would provide more insight into atypical behavior identified in all cores, such as the elongated tail of ^{137}Cs indicative of diffusion. Furthermore, radiometric analysis of the unconformity between the 1813 post-construction surface and overlying colluvium could provide a chronostratigraphic marker useful for radiometric data validation. Finally, the application of one or more $^{210}Pb_{ex}$ dating models (commonly CFCS, CRS or CIC; see Corbett and Walsh, 2015) can increase temporal resolution of activity-derived dates and provide more than a single 100-yr chronostratigraphic marker. Of course, budgetary and time constraints may limit application of these improvements, but the potential for numerous, precise validation markers makes the incorporation of radiometric data into diffusion models very attractive.

6.5 Recommendations for Earthwork Preservation

Our results indicate that, despite stabilization by vegetation, erosion is a slow but ongoing process. Despite the numerous studies that prescribe a "hands off" approach as the best means for preserving these earthworks (i.e., National Park Service, 1998; Aust et al. 2003), our study indicates that without some form of slope stabilization, these earthworks will continue to widen and flatten over time, possibly fading completely into the landscape within centuries. Shoreline erosion is also a major destructive force at Forts Point and Stokes, and without shoreline stabilization, the risk of losing chunks of these forts with each storm event is conceivable (see Coulombe, 1986). Although not specifically addressed in this study, our TLS datasets provide invaluable resources for monitoring coastal erosion processes at these forts.

Newspapers published during the 100- and 125-year anniversaries of Maryland's involvement in the War of 1812 lamented the decayed, undistinguished status of Fort Point and Fort Stokes (*Centreville Observer*, 1912; *Easton Star-Democrat*, 1939). Unfortunately, little has changed in the past century, and these same cries are echoed today. These newspaper articles provide a disheartening reminder that well-intentioned attempts at preservation often go unfulfilled. We hope that data and analyses contained herein provide both an impetus and vital starting point for researchers and conservationists. In light of the increased interest and monetary grants provided by Maryland's bicentennial celebration of the War of 1812, the timely delivery of this information can hopefully provide the stimulus for the promotion and preservation of these important historic resources.

Chapter 7

CONCLUSIONS

This multifaceted approach to analyzing the geospatial nature of Forts Nonsense, Point, and Stokes, and retelling the geomorphic history of Fort Point, offers a unique, comprehensive, and non-destructive method for investigating the erosional processes that have been at work for the past ca. 200 years. Our TLS data provide a useful means for evaluating the current dimensions of the earthworks at sub-decimeter scale resolution. When our data are coupled with hillslope diffusion models, we are able to assess the rates and patterns of erosion. The critical parameter for such models, the diffusivity constants of 0.0035 and 0.0048 $m^2\ yr^{-1}$, are found to be typical for these types of surface materials in temperate climates. Comparisons to the stratigraphy and ^{210}Pb activity of downslope colluvium accumulations indicate that our models are well constrained and effective as a method of inferring initial construction forms. Our mathematical models, field data, and radiometric data suggest that the earthworks have continuously eroded since their construction and will continue to widen and flatten over time. Because of the poor vegetation cover under the dense forest canopies at each site, complete erosion of these sites is possible over the next few centuries without intervention. To preserve these sites will require some level of shoreline stabilization at Forts Point and Stokes, and some amount of slope stabilization at all three locations.

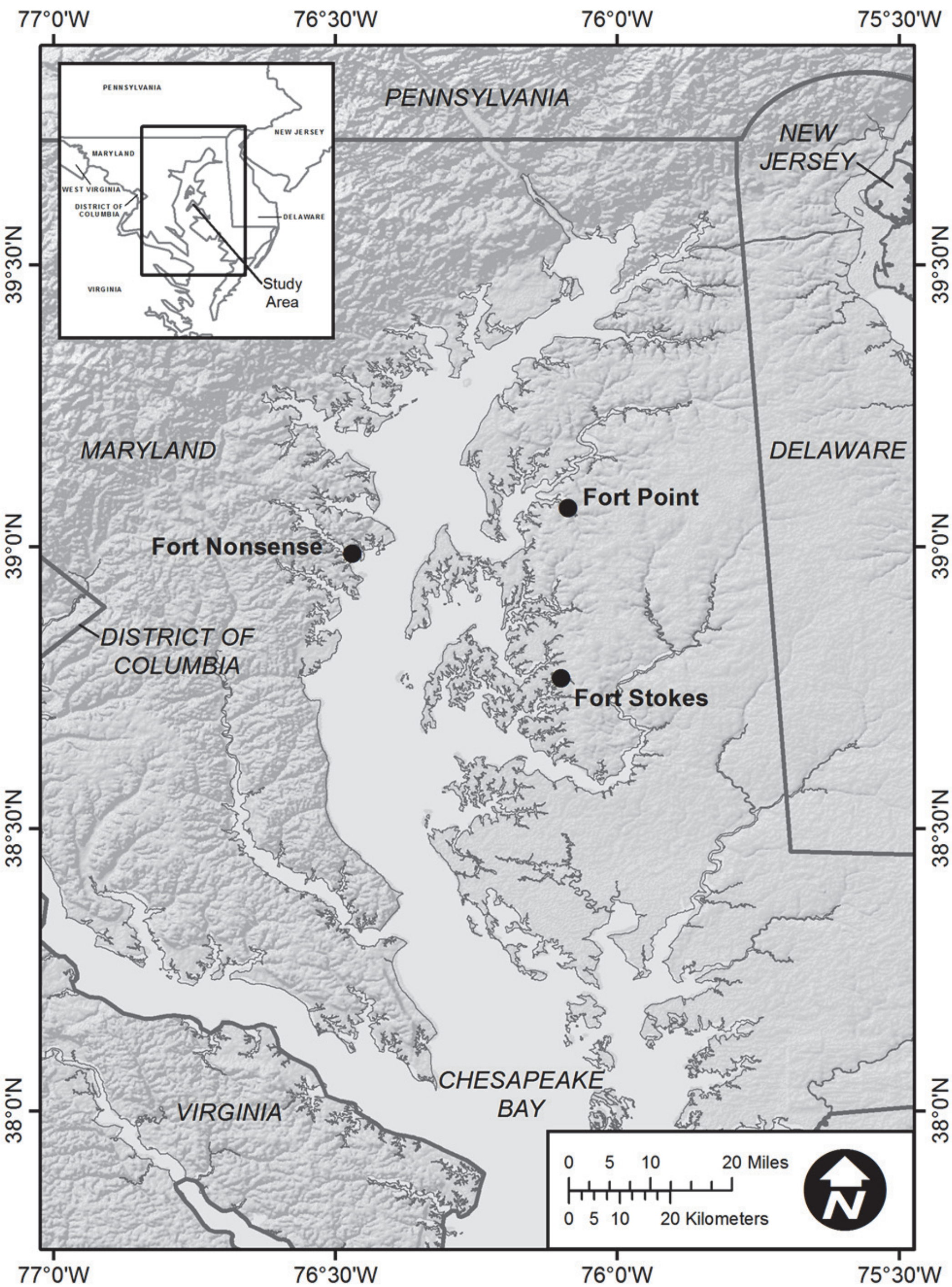

Figure 1: Map of the Chesapeake Bay region showing the locations of the three earthen fort study sites - Fort Nonsense, Fort Point, and Fort Stokes.

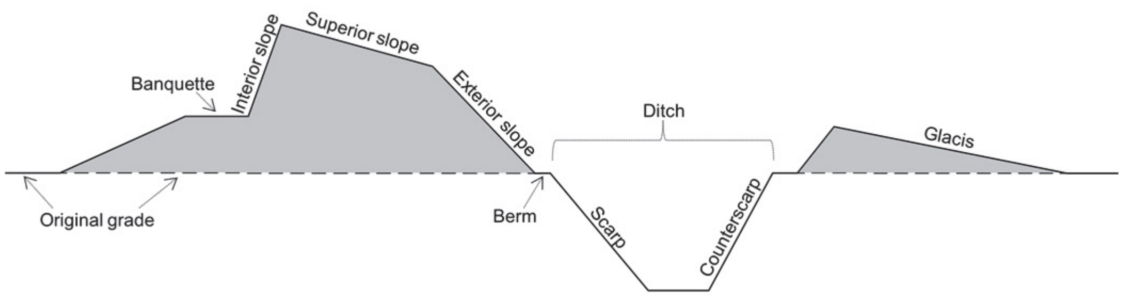

Figure 2: Profile of a typical earthen field fortification, showing the parapet and ditch configuration common to all varieties. Modeled after Mahan, 1862.

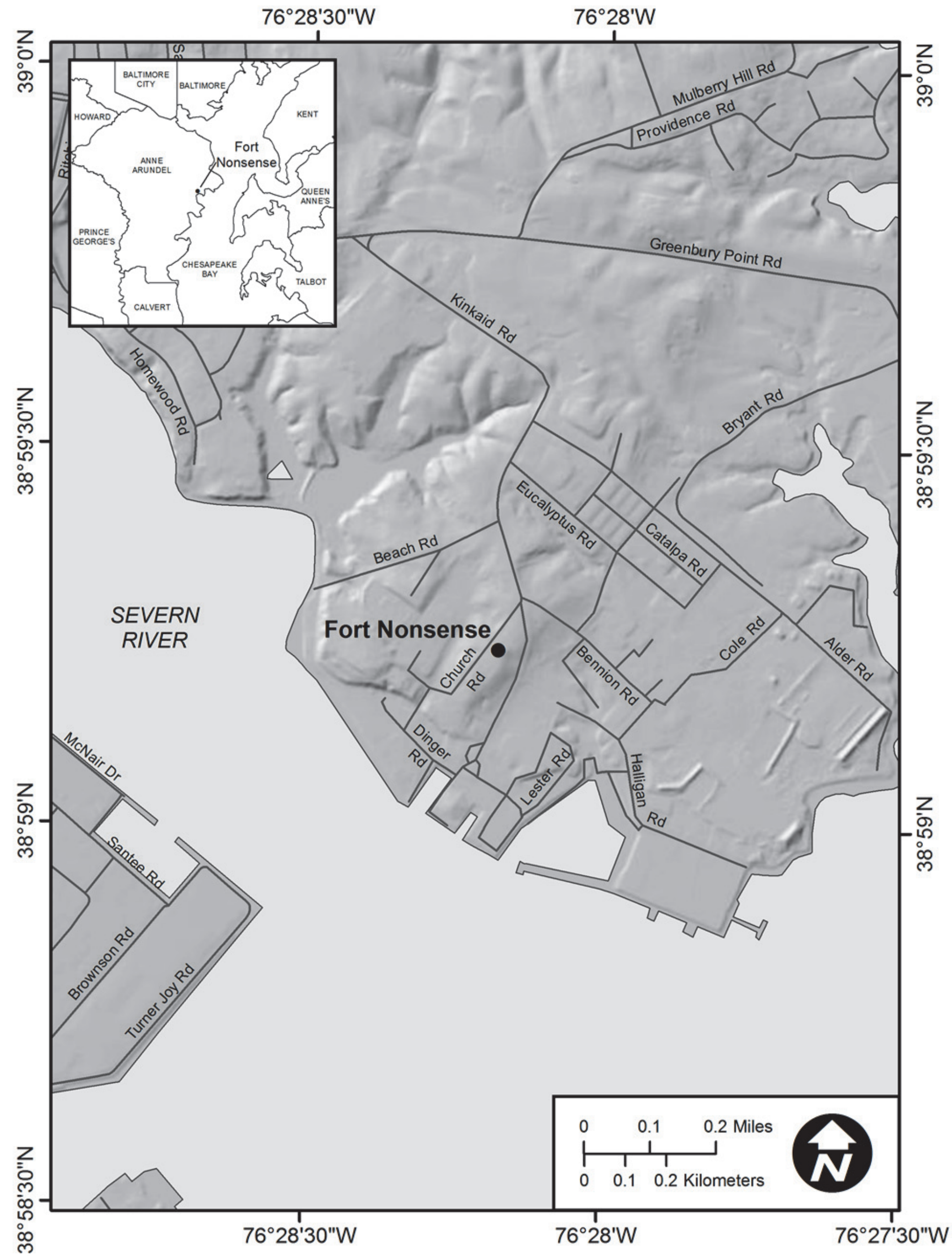

Figure 3: Map displaying the location of Fort Nonsense near Annapolis, Maryland.

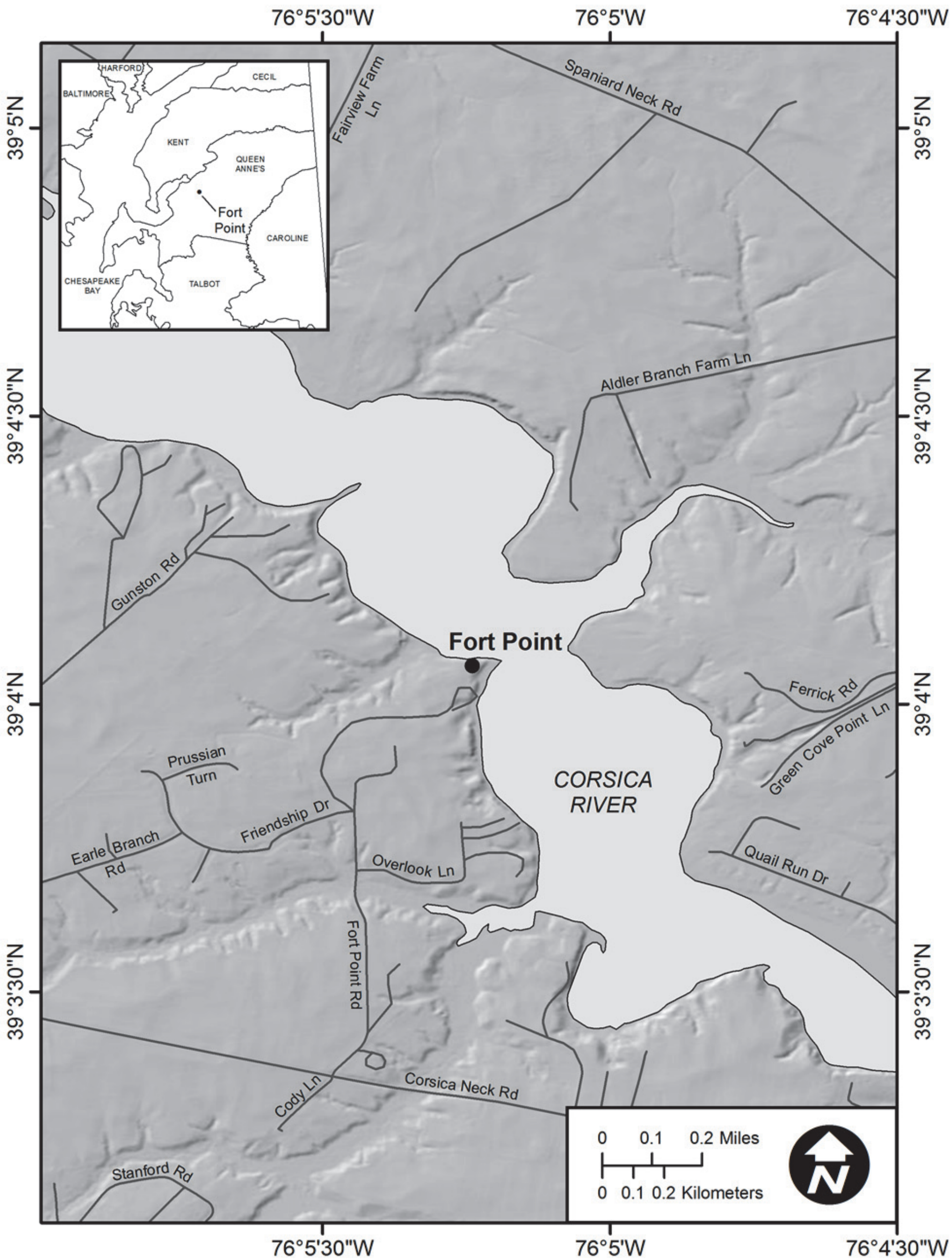

Figure 4: Map displaying the location of Fort Point near Centreville, Maryland.

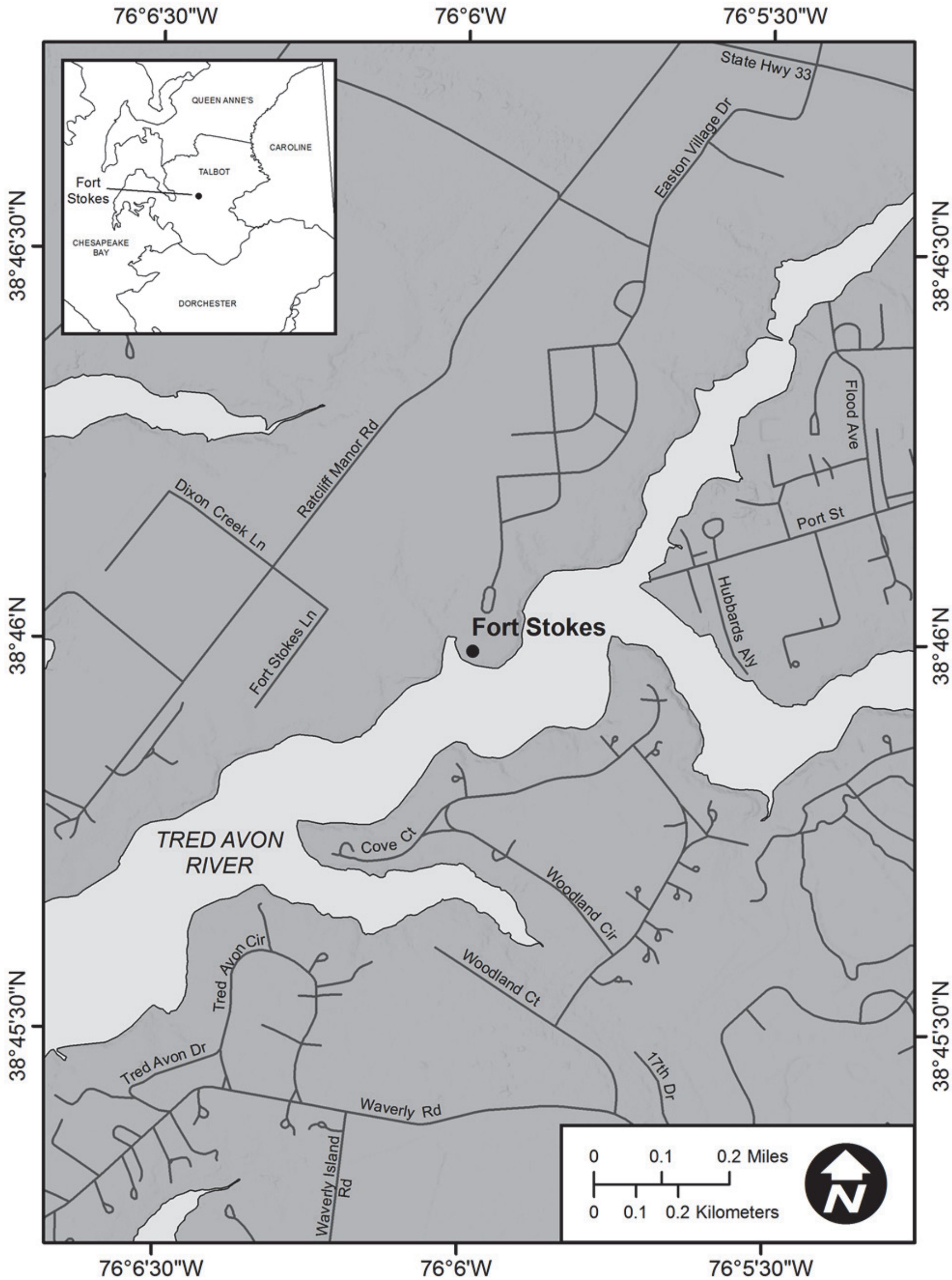

Figure 5: Map displaying the location of Fort Stokes near Easton, Maryland.

Figure 6: Panorama images of the three Maryland study locations: A) Fort Nonsense, B) Fort Point, and C) Fort Stokes.

Figure 7: View of TLS in use at Fort Point, showing typical setup. The Trimble GX Advanced Terrestrial Laser Scanner rotates around a fixed axis (tripod), collecting data points which are communicated via a network connection to the laptop and modeled using specialized software.

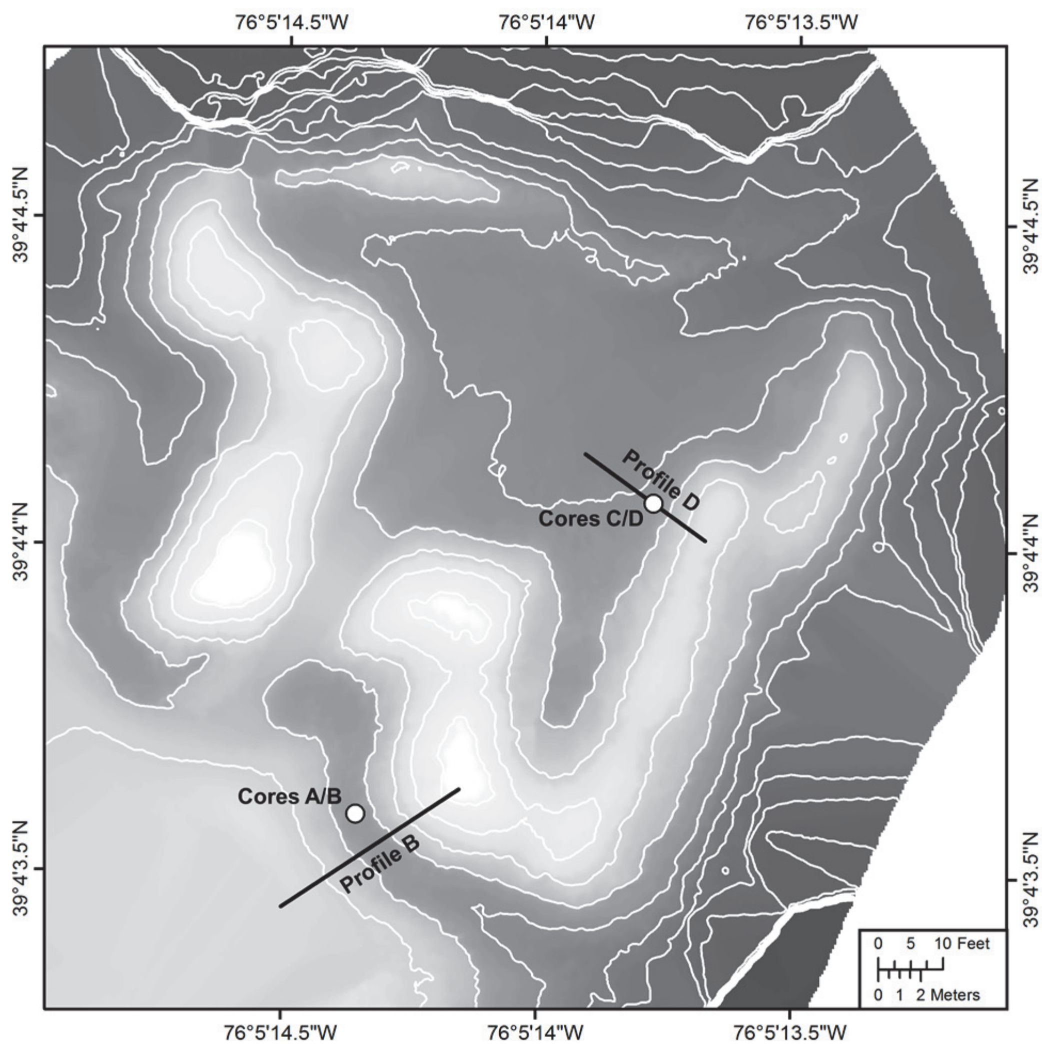

Figure 8: Map displaying the locations of sediment cores (dots) and modeling profiles (lines) at Fort Point.

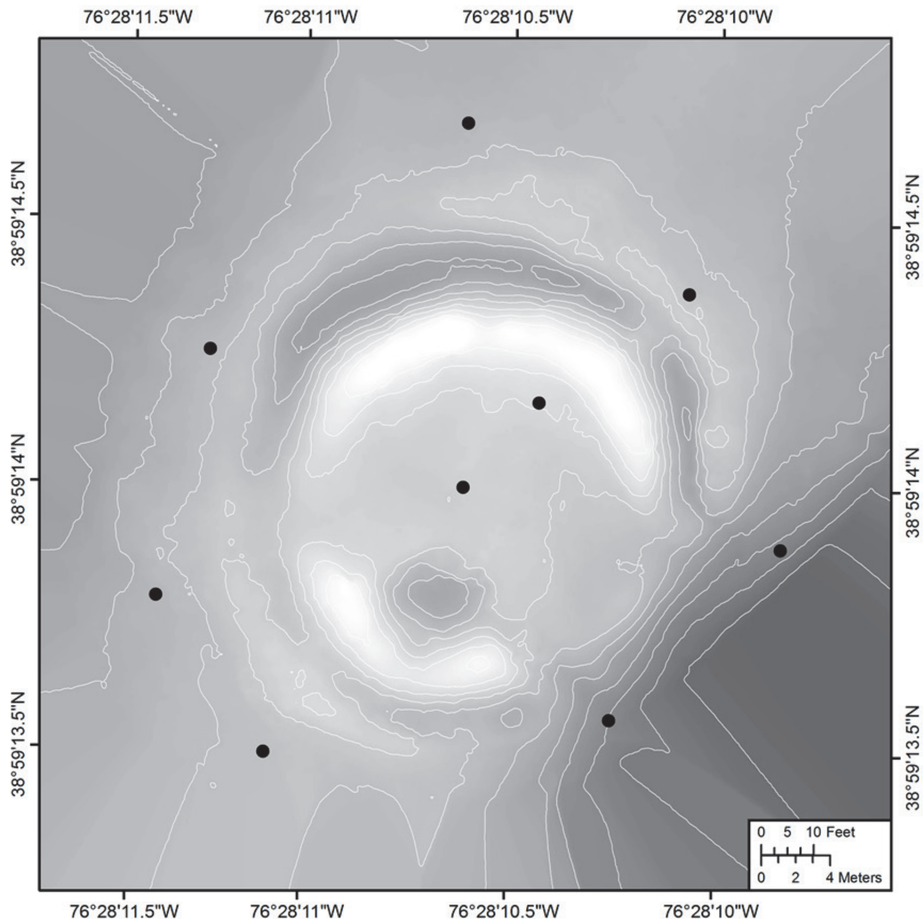

Figure 9: Map displaying the locations of survey stations at Fort Nonsense.

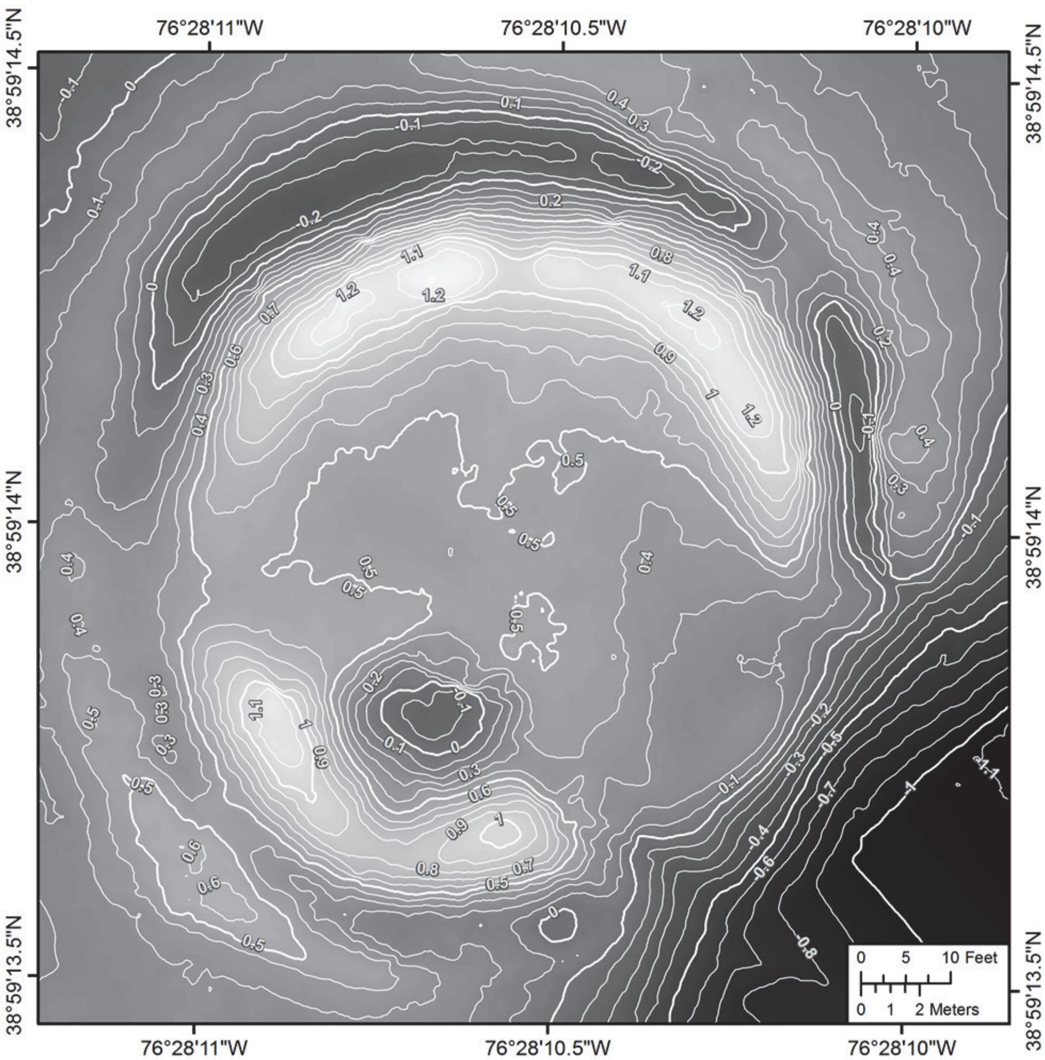

Figure 10: Digital elevation model (DEM) of Fort Nonsense displaying 0.1 m contour lines (white lines) against a shaded background depicting relative elevation.

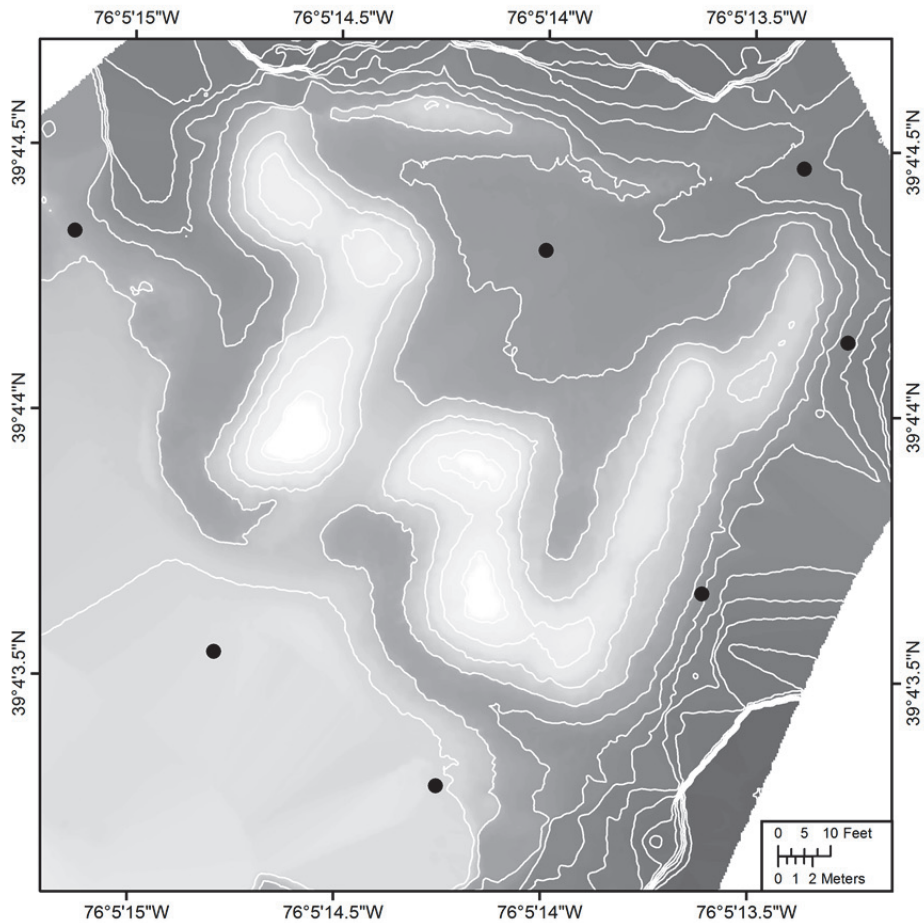

Figure 11: Map displaying the locations of survey stations at Fort Point.

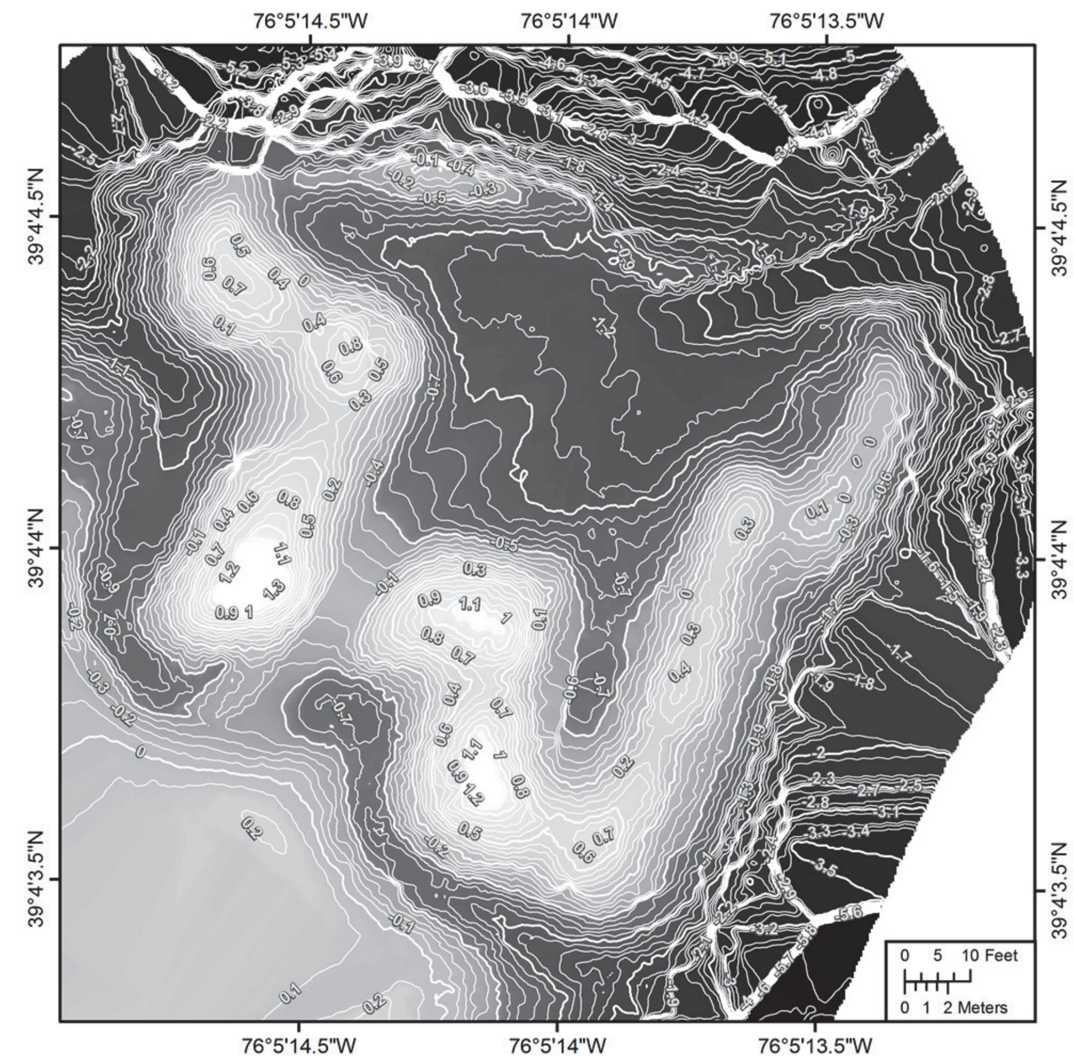

Figure 12: Digital elevation model (DEM) of Fort Point displaying 0.1 m contour lines (white lines) against a shaded background depicting relative elevation.

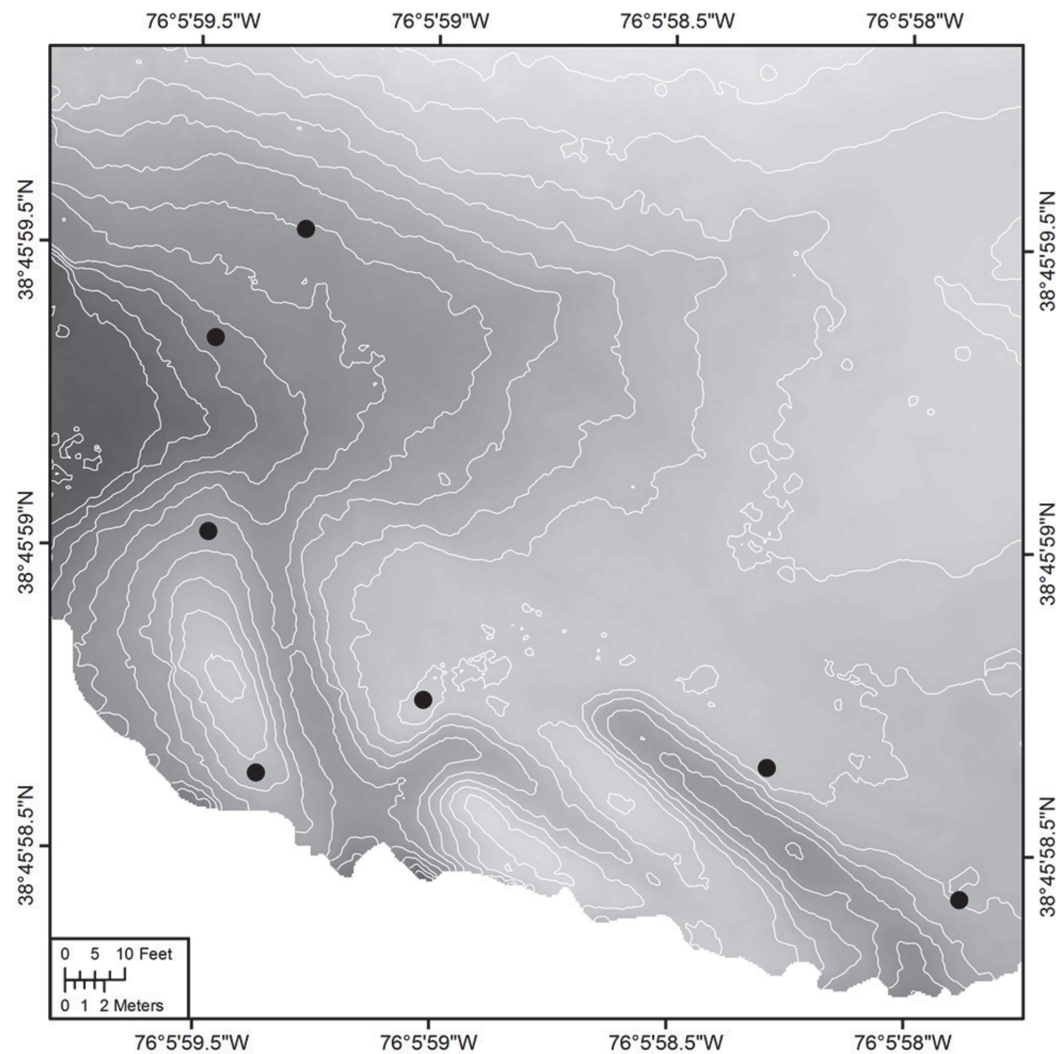

Figure 13: Map displaying the locations of survey stations at Fort Stokes.

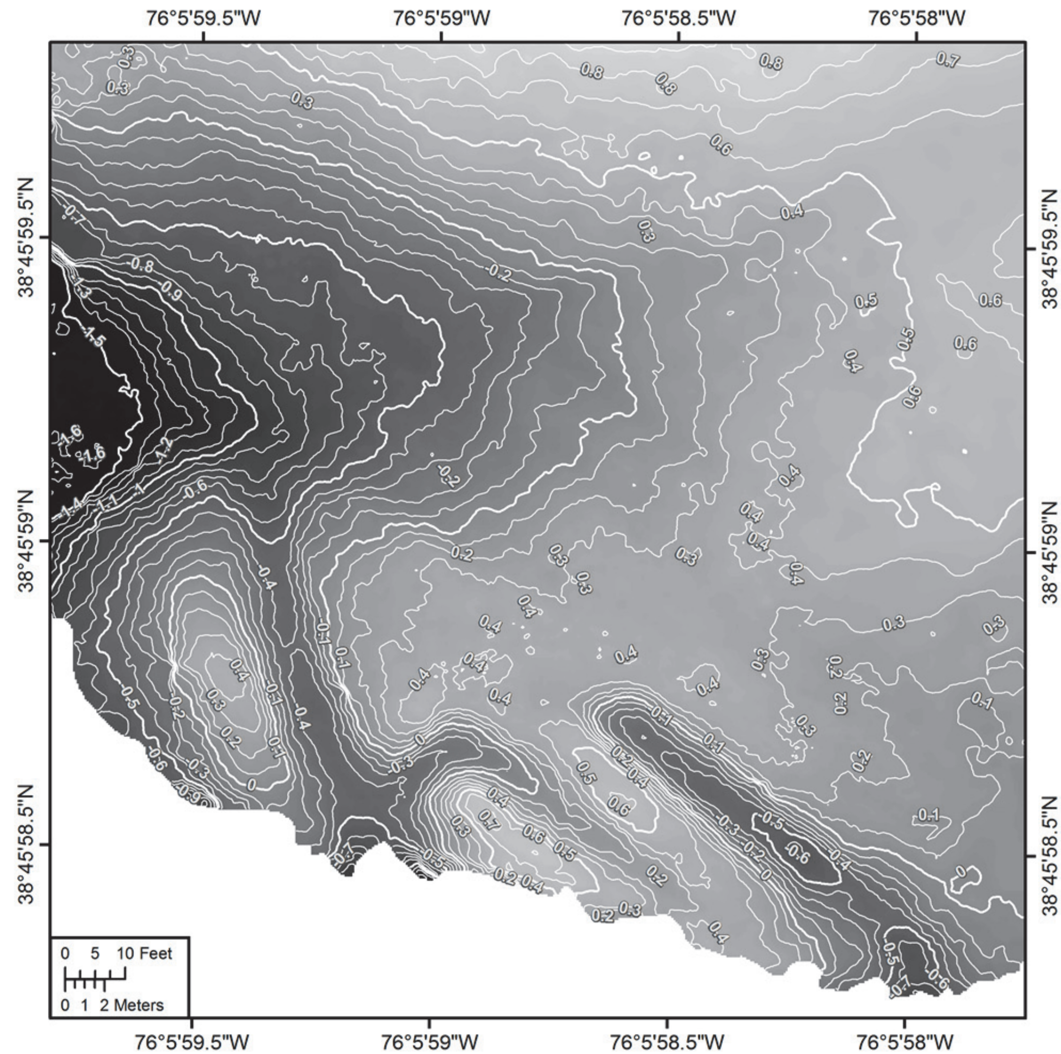

Figure 14: Digital elevation model (DEM) of Fort Stokes displaying 0.1 m contour lines (white lines) against a shaded background depicting relative elevation.

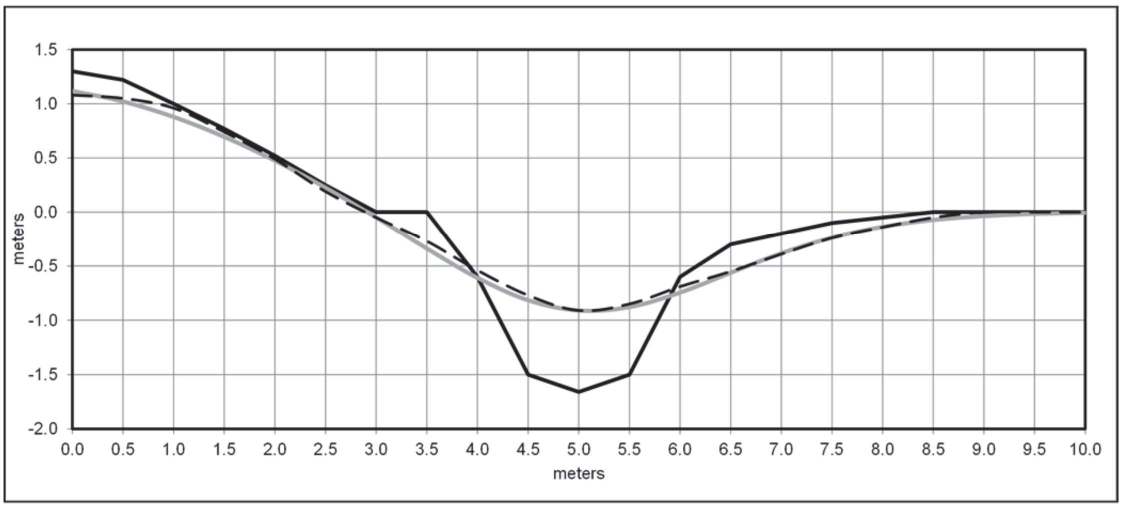

Figure 15: Graph displaying the results of the diffusion model for Profile B at Fort Point with an estimated initial fort profile (black line), a modeled profile after 200 yrs (gray line), and the actual current topography from TLS data (black dashed line). The diffusivity, κ, is 0.0035 $m^2\ yr^{-1}$.

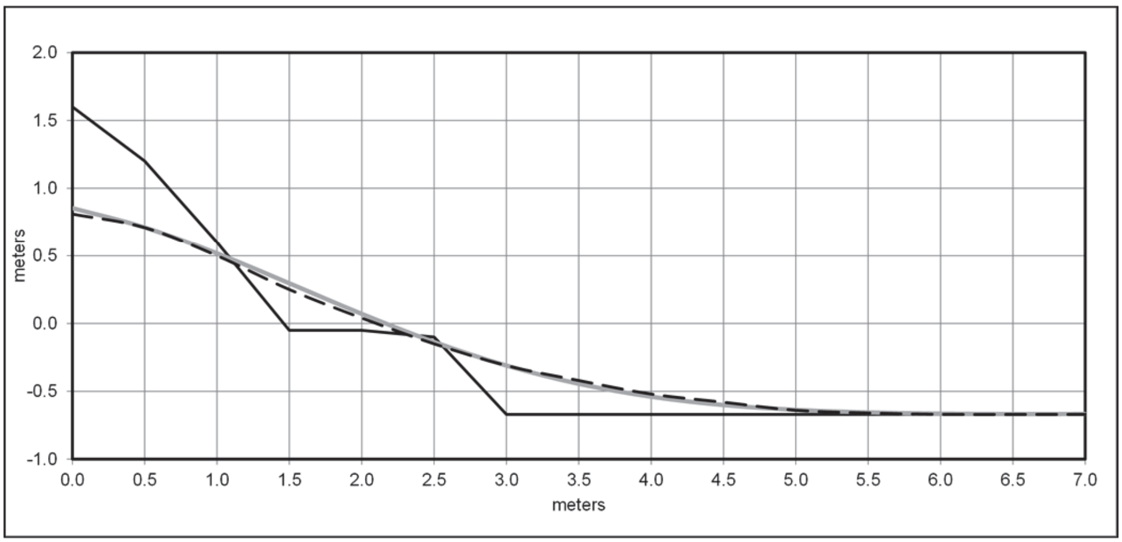

Figure 16: Graph displaying the results of the diffusion model for Profile D at Fort Point with an estimated initial fort profile (black line), a modeled profile after 200 yrs (gray line), and the actual current topography from TLS data (black dashed line). The diffusivity, κ, is 0.0048 $m^2 yr^{-1}$.

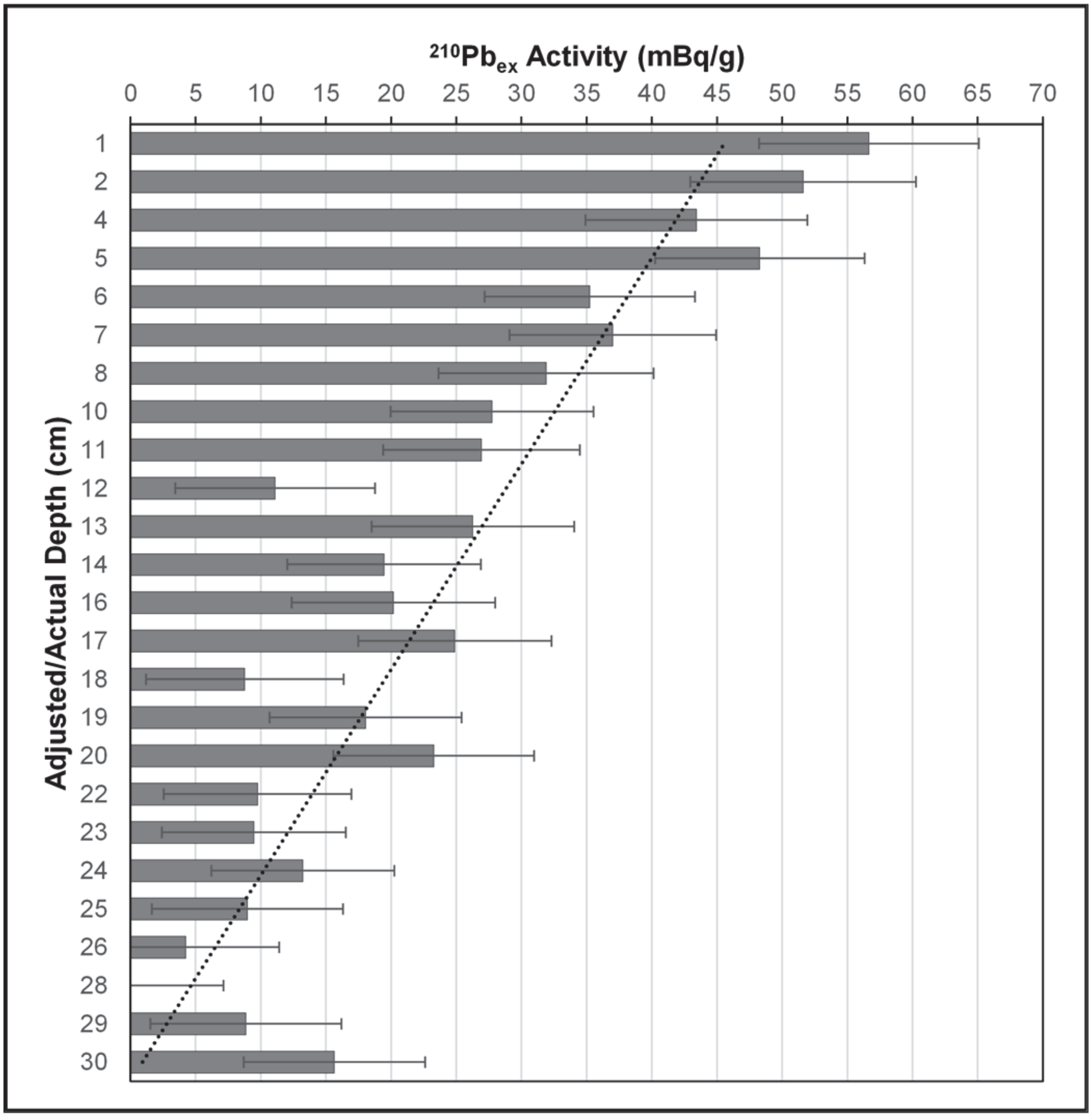

Figure 17: Bar chart displaying $^{210}Pb_{ex}$ activity versus depth below ground surface from Core B at Fort Point. These data suggest the 100-yr chronostratigraphic marker to be located at 27.53 cm.

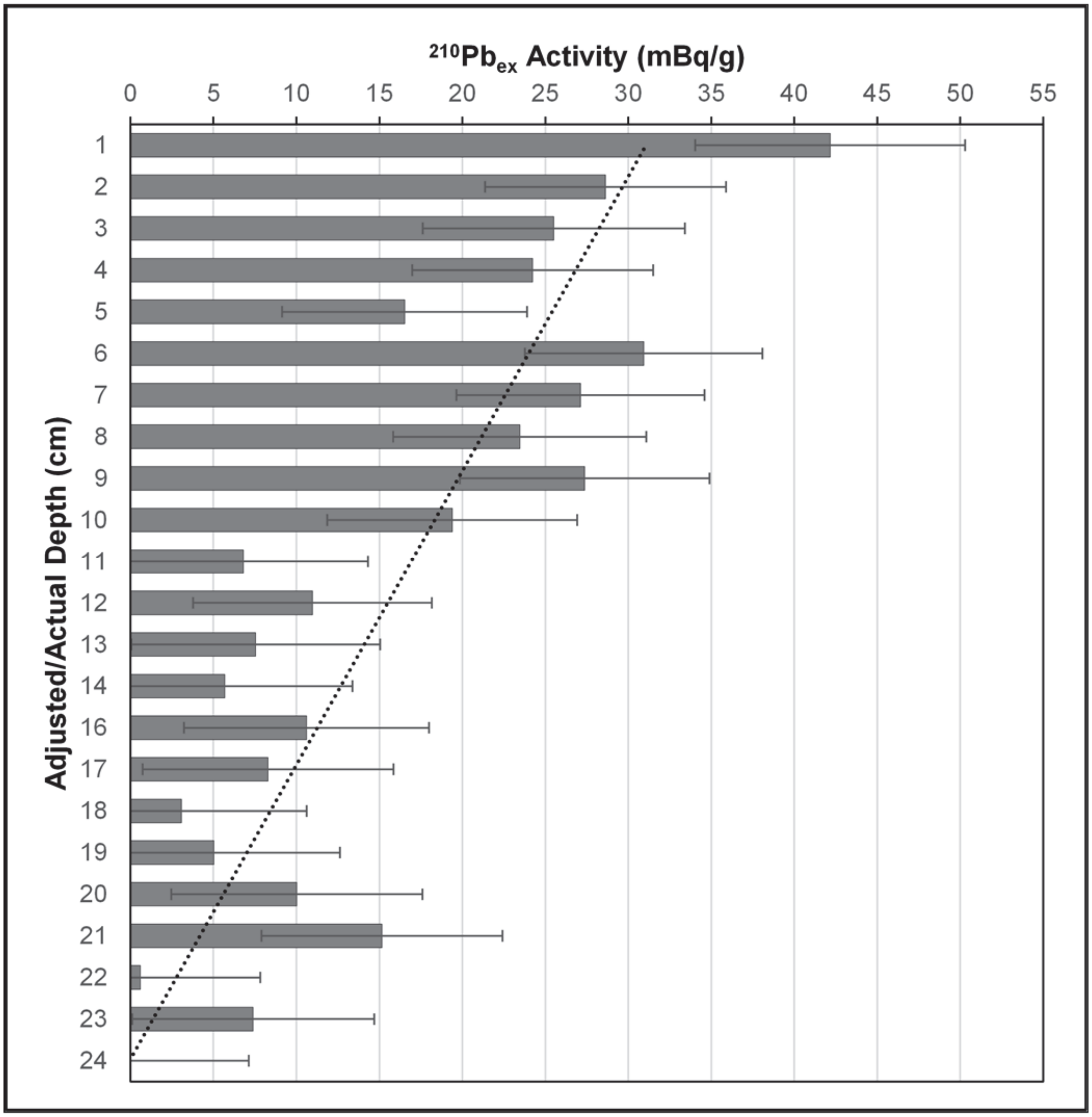

Figure 18: Bar chart displaying $^{210}Pb_{ex}$ activity versus depth below ground surface from Core D at Fort Point. These data suggest the 100-yr chronostratigraphic marker to be located at 23.78 cm.

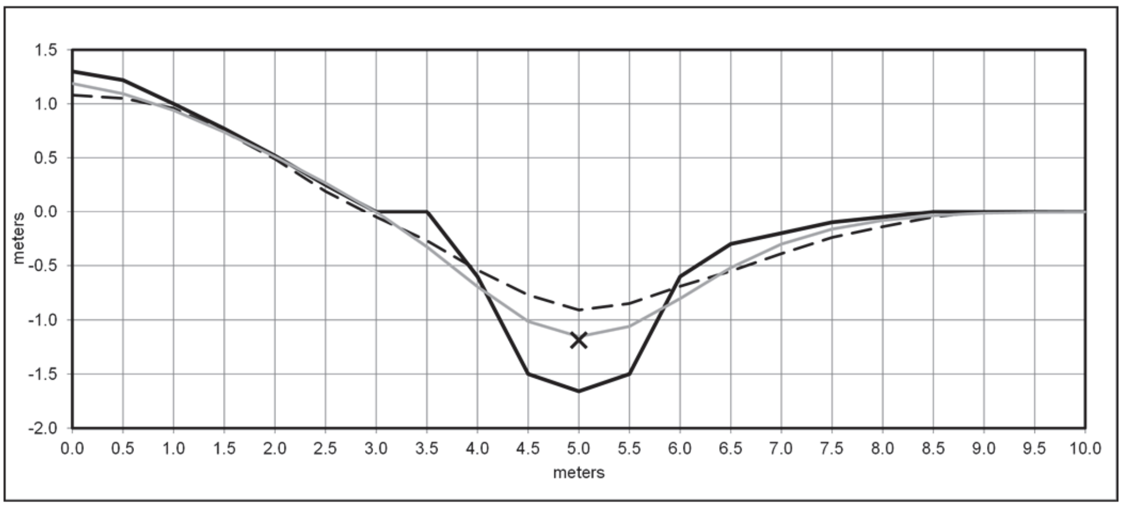

Figure 19: Graph incorporating the 100-yr chronostratigraphic marker determined by $^{210}Pb_{ex}$ dating (black X) into the diffusion model for Profile B at Fort Point, with an estimated initial fort profile (black line), a modeled profile after 100 yrs (gray line), and the actual current topography from TLS data (black dashed line).

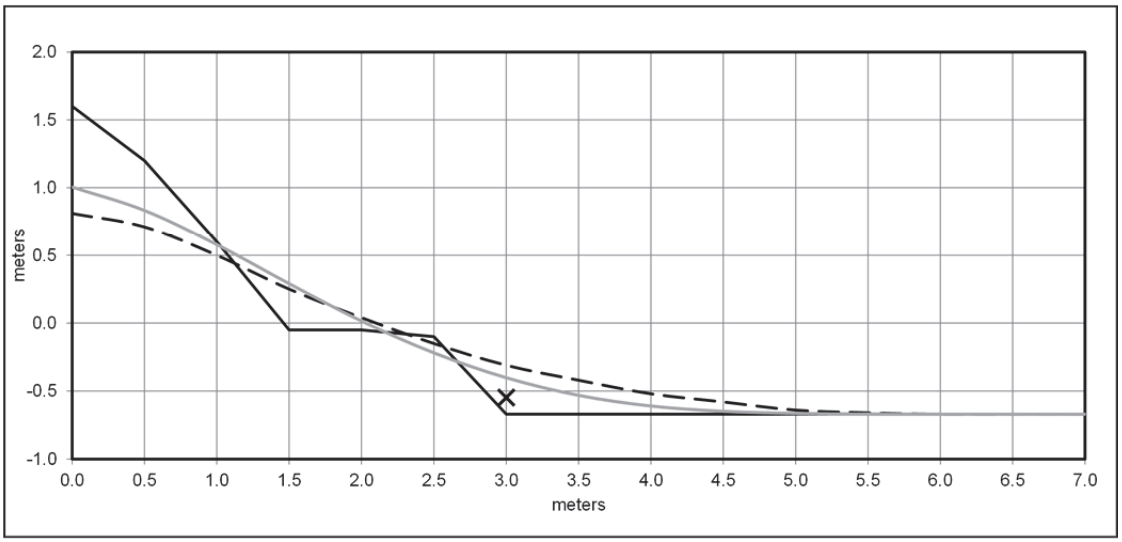

Figure 20: Graph incorporating the 100-yr chronostratigraphic marker determined by $^{210}Pb_{ex}$ dating (black X) into the diffusion model for Profile D at Fort Point, with an estimated initial fort profile (black line), a modeled profile after 100 yrs (gray line), and the actual current topography from TLS data (black dashed line).

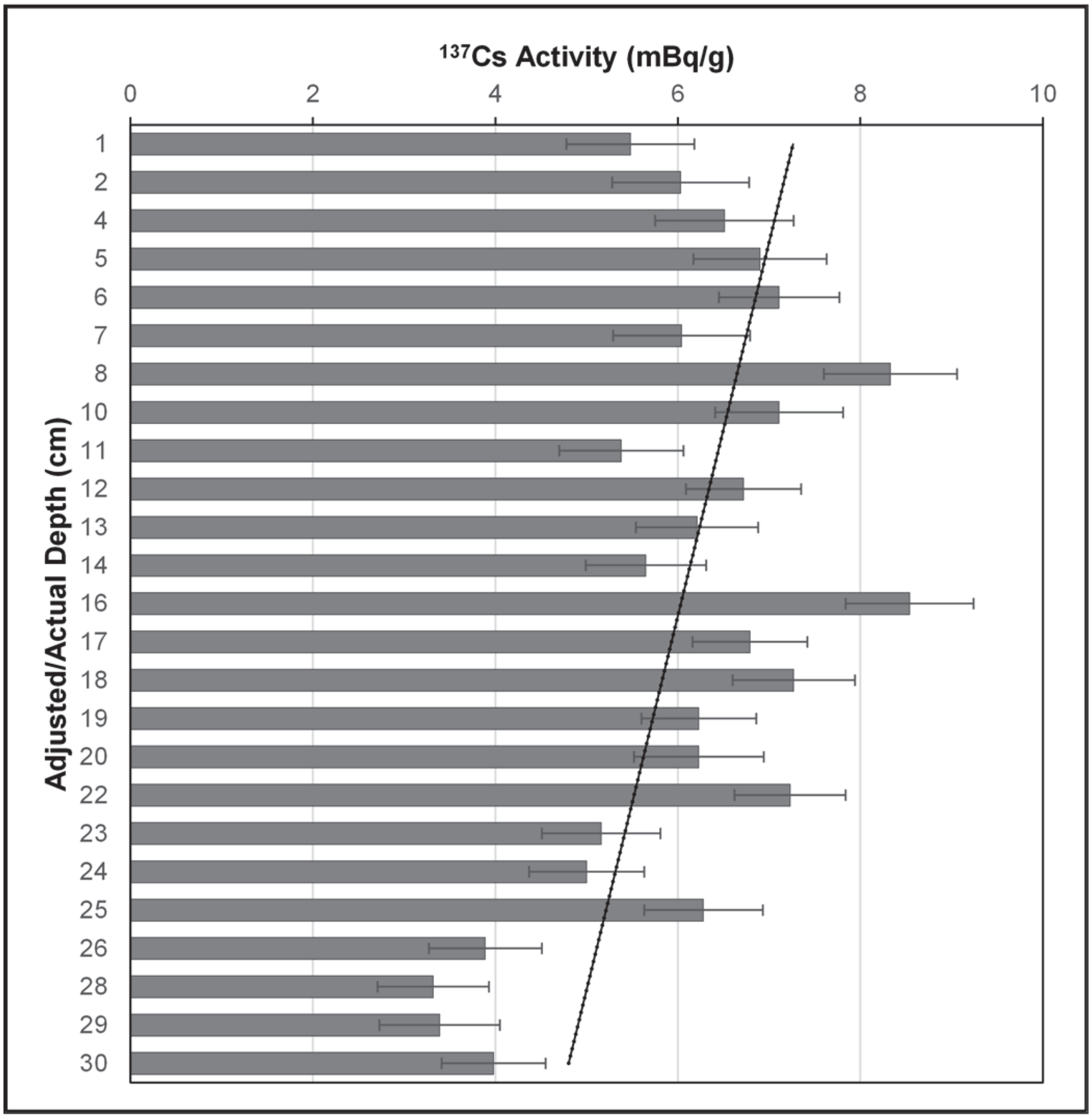

Figure 21: Bar chart displaying ^{137}Cs activity versus depth below ground surface from Core B at Fort Point. These data suggest post-depositional redistribution of ^{137}Cs.

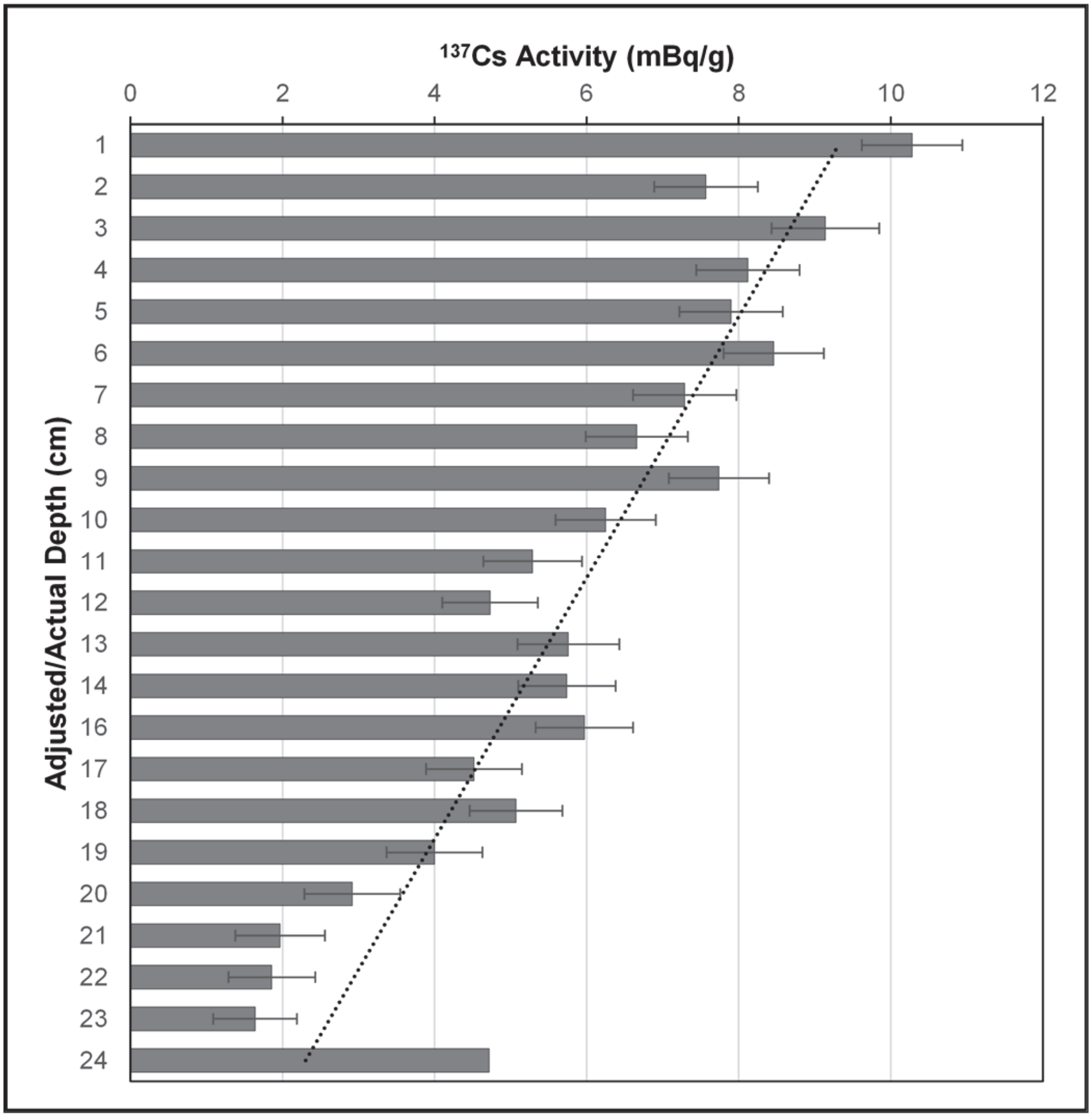

Figure 22: Bar chart displaying ^{137}Cs activity versus depth below ground surface from Core D at Fort Point. These data suggest post-depositional redistribution of ^{137}Cs.

Site	Survey date	Survey stations	Total data points	Data points within fort boundaries	Registration error (cm)	Surface roughness (cm)	Data points representing bare-earth surface
Fort Nonsense	04/18/14	9	10,596,002	10,022,737	1.00	0-3	6,782,955
Fort Point	05/06/14	7	8,520,946	7,556,870	2.15	0-5	5,537,461
Fort Stokes	04/02/14	7	6,092,125	5,761,491	1.24	0-7	3,046,323

Table 1: Summary of TLS survey data for Forts Nonsense, Point, and Stokes.

Core A

Horizon	Depth (cm)	Properties
Cu/A	0-20	Very dark gray (10YR 3/1) silt loam
Cu/AB	20-35	Brown (10YR 5/3) silt loam
Cu/Btg	35-50	Yellowish brown (10YR 5/4) fine sandy loam, slightly gleyed
Cu/Btx	50-68	Yellowish brown (10YR 5/4) fine sandy loam
Cu/Btg	68-75	Yellowish brown (10YR 5/4) fine sandy loam, slightly gleyed
C	75-79+	Yellowish brown (10YR 5/6) medium-coarse sand

Notes: Unconformity between 2Btg and 2C represents historic post-construction surface. "Cu" implies anthropogenicaly manipulated old soils.

Core C

Horizon	Depth (cm)	Properties
A	0-18	Very dark gray (10YR 3/1) silt loam
AB	18-28	Dark grayish brown (10YR 4/2) silt loam
BA	28-36	Brown (10YR 5/3) fine sandy loam
Bt	36-42	Yellowish brown (10YR 5/4) fine sandy loam
Btg	42-45+	Yellowish brown (10YR 5/4) fine sandy clay loam, slightly gleyed

Notes: Unconformity between BA and Bt represents historic post-construction surface.

Table 2: Soil descriptions for Cores A and C collected at Fort Point. Core A was retrieved adjacent to Core B. Core C was retrieved adjacent to Core D. Each member of the pair is useful as a proxy for describing the neighboring core. Depths have been adjusted for compaction.

		Excess ^{210}Pb		^{137}Cs	
Sample interval (cm)	**Actual depth (cm)**	**Activity (mBq/g)**	**Activity error (mBq/g)**	**Activity (mBq/g)**	**Activity error (mBq/g)**
0-1	1.20	56.66	8.43	5.48	0.70
1-2	2.39	51.61	8.66	6.03	0.75
2-3	3.59	43.42	8.52	6.51	0.76
3-4	4.79	48.29	8.04	6.90	0.73
4-5	5.99	35.25	8.07	7.11	0.66
5-6	7.18	37.01	7.93	6.04	0.75
6-7	8.38	31.89	8.25	8.33	0.73
7-8	9.58	27.75	7.78	7.11	0.70
8-9	10.77	26.93	7.55	5.38	0.68
9-10	11.97	11.10	7.67	6.72	0.63
10-11	13.17	26.27	7.77	6.21	0.67
11-12	14.36	19.46	7.42	5.65	0.66
12-13	15.56	20.17	7.81	8.54	0.70
13-14	16.76	24.89	7.42	6.79	0.63
14-15	17.96	8.77	7.58	7.27	0.67
15-16	19.15	18.04	7.36	6.23	0.63
16-17	20.35	23.28	7.70	6.23	0.71
17-18	21.55	9.76	7.20	7.23	0.61
18-19	22.74	9.47	7.06	5.16	0.65
19-20	23.94	13.22	7.02	5.00	0.63
20-21	25.14	8.99	7.33	6.28	0.65
21-22	26.33	4.26	7.16	3.89	0.62
22-23	27.53	-1.83	7.15	3.32	0.61
23-24	28.73	8.85	7.33	3.39	0.66
24-25	29.93	15.65	6.96	3.98	0.57

Table 3: Summary of $^{210}Pb_{ex}$ and ^{137}Cs data from Core B at Fort Point.

		Excess ^{210}Pb		^{137}Cs	
Sample interval (cm)	Actual depth (cm)	Activity (mBq/g)	Activity error (mBq/g)	Activity (mBq/g)	Activity error (mBq/g)
0-1	1.03	42.17	8.13	10.28	0.66
1-2	2.07	28.63	7.26	7.57	0.68
2-3	3.10	25.51	7.90	9.14	0.71
3-4	4.14	24.24	7.26	8.12	0.68
4-5	5.17	16.52	7.38	7.90	0.68
5-6	6.20	30.93	7.16	8.46	0.66
6-7	7.24	27.12	7.47	7.29	0.68
7-8	8.27	23.46	7.63	6.66	0.67
8-9	9.31	27.37	7.53	7.74	0.66
9-10	10.34	19.39	7.53	6.25	0.66
10-11	11.37	6.81	7.50	5.29	0.65
11-12	12.41	10.97	7.19	4.73	0.63
12-13	13.44	7.55	7.49	5.76	0.67
13-14	14.48	5.68	7.70	5.74	0.64
14-15	15.51	10.61	7.39	5.97	0.64
15-16	16.54	8.29	7.56	4.52	0.63
16-17	17.58	3.08	7.53	5.07	0.61
17-18	18.61	5.02	7.60	4.00	0.63
18-19	19.65	10.02	7.57	2.92	0.63
19-20	20.68	15.16	7.26	1.97	0.59
20-21	21.71	0.61	7.21	1.86	0.57
21-22	22.75	7.40	7.29	1.64	0.55
22-23	23.78	-3.96	7.13	4.72	NA

Table 4: Summary of $^{210}Pb_{ex}$ and ^{137}Cs data from Core D at Fort Point.

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Appendix A

COMPLETE RADIOMETRIC ANALYSIS DATA FOR CORE B AT FORT POINT

Dried, milled soil samples were counted for 24 hours in a Canberra well detector (GCW2523). Activity con

* All activites are mBq/g

Core	Depth (cm)	Interval Thickness (cm)	Porosity	Dry bulk density (g/cm3)	Sample mass (g)	**Total Pb-210 (** Net Peak Area	Net Area Uncert	Continuum Counts
B	0.5	1	0.482	1.37	7.47	711	63	1156
B	1.5	1	0.461	1.43	7.18	581	62	1164
B	2.5	1	0.444	1.47	7.25	565	62	1156
B	3.5	1	0.445	1.47	7.6	608	61	1096
B	4.5	1	0.428	1.52	7.61	525	61	1128
B	5.5	1	0.429	1.51	7.74	514	61	1138
B	6.5	1	0.424	1.53	7.58	497	62	1193
B	7.5	1	0.417	1.55	7.9	437	61	1152
B	8.5	1	0.412	1.56	8.04	459	60	1082
B	9.5	1	0.412	1.56	8.01	270	61	1226
B	10.5	1	0.408	1.57	8.04	438	61	1167
B	11.5	1	0.404	1.58	8.08	412	60	1127
B	12.5	1	0.404	1.58	7.81	385	60	1147
B	13.5	1	0.415	1.55	8.18	415	60	1123
B	14.5	1	0.414	1.55	8.2	267	61	1209
B	15.5	1	0.395	1.60	8.24	326	60	1152
B	16.5	1	0.367	1.68	7.98	377	61	1162
B	17.5	1	0.372	1.67	8.32	261	59	1110
B	18.5	1	0.353	1.71	8.48	259	59	1147
B	19.5	1	0.342	1.74	8.47	251	59	1145
B	20.5	1	0.353	1.71	8.22	288	60	1176
B	21.5	1	0.339	1.75	8.58	223	61	1214
B	22.5	1	0.332	1.77	8.48	148	60	1195
B	23.5	1	0.329	1.78	8.32	257	60	1192
B	24.5	1	0.333	1.77	8.55	340	59	1091

centrations were calbriated against NIST SRM4353 activities. Porosity and bulk density were determined gravimet.

46.5 keV)			Pb-214 (295.1 keV)						
ROI Length	Activity	Activity Error	Net Peak Area	Net Area Uncert	Continuum Counts	ROI Length	Activity	Activity Error	Net Peak Area
22	74.06	6.56	444	54	743	27	14.48	1.76	593
22	62.96	6.72	433	53	723	27	14.69	1.8	732
22	60.64	6.65	476	54	734	27	15.99	1.81	809
22	62.25	6.25	425	54	769	27	13.62	1.73	761
22	53.68	6.24	531	53	713	27	17	1.7	841
22	51.67	6.13	421	53	746	27	13.25	1.67	739
22	51.02	6.36	433	54	768	27	13.91	1.73	828
22	43.04	6.01	521	54	723	27	16.06	1.66	777
22	44.42	5.81	581	54	703	27	17.6	1.64	835
22	26.23	5.93	391	55	780	27	11.89	1.67	652
22	42.39	5.9	486	55	772	27	14.72	1.67	860
22	39.68	5.78	600	54	707	27	18.09	1.63	763
22	38.36	5.98	527	54	737	27	16.44	1.68	734
22	39.48	5.71	459	55	799	27	13.67	1.64	841
22	25.34	5.79	477	55	772	27	14.17	1.63	885
22	30.78	5.67	467	54	753	27	13.8	1.6	578
22	36.76	5.95	484	54	734	27	14.77	1.65	636
22	24.41	5.52	459	52	693	27	13.44	1.52	717
22	23.76	5.41	485	55	792	27	13.93	1.58	809
22	23.06	5.42	470	53	711	27	13.52	1.52	667
22	27.26	5.68	550	55	752	27	16.3	1.63	901
22	20.22	5.53	561	55	743	27	15.93	1.56	778
22	13.58	5.51	532	54	727	27	15.28	1.55	809
22	24.03	5.61	531	56	792	27	15.55	1.64	930
22	30.94	5.37	469	55	774	27	13.36	1.57	787

rically assuming 100% mineral solids, 1.0 g/cm3 and 2.65 g/cm3 for water and solids, respectively.

Pb-214 (352.0 keV)					Bi-214 (665.4 keV)			
Net Area Uncert	Continuum Counts	ROI Length	Activity	Activity Error	Net Peak Area	Net Area Uncert	Continuum Counts	ROI Length
54	705	27	13.13	1.2	354	38	340	27
51	557	27	16.86	1.17	222	38	368	27
52	574	27	18.46	1.19	340	37	316	27
51	555	27	16.56	1.11	289	37	326	27
53	587	27	18.28	1.15	382	38	317	27
52	600	27	15.79	1.11	309	38	331	27
53	605	27	18.07	1.16	395	39	339	27
52	584	27	16.27	1.09	329	38	324	27
51	519	27	17.18	1.05	383	38	323	27
51	584	27	13.46	1.05	330	38	333	27
50	502	27	17.69	1.03	353	41	399	27
53	607	27	15.62	1.09	445	36	257	27
56	698	27	15.54	1.19	387	39	343	27
51	531	27	17	1.03	325	38	325	27
51	509	27	17.85	1.03	370	40	356	27
52	630	27	11.6	1.04	286	38	334	27
53	649	27	13.18	1.1	293	38	342	27
51	563	27	14.25	1.01	332	38	326	27
52	574	27	15.78	1.01	330	38	342	27
50	538	27	13.02	0.98	227	37	331	27
55	628	27	18.13	1.11	409	37	284	27
54	636	27	15	1.04	373	38	334	27
52	575	27	15.78	1.01	356	38	319	27
53	559	27	18.49	1.05	344	39	360	27
52	563	27	15.22	1.01	356	37	321	27

Cs-137 (661.6 keV)

Activity	Activity Error	Net Peak Area	Net Area Uncert	Continuum Counts	ROI Length	Activity	Activity Error	Net Peak Area
17.4	1.87	260	33	265	27	5.48	0.7	888
11.35	1.94	275	34	267	27	6.03	0.75	894
17.22	1.87	300	35	271	27	6.51	0.76	947
13.96	1.79	333	35	270	27	6.9	0.73	903
18.43	1.83	344	32	195	27	7.11	0.66	922
14.66	1.8	297	37	299	27	6.04	0.75	933
19.13	1.89	401	35	248	27	8.33	0.73	961
15.29	1.77	357	35	256	27	7.11	0.7	854
17.49	1.74	275	35	287	27	5.38	0.68	854
15.13	1.74	342	32	203	27	6.72	0.63	913
16.12	1.87	317	34	237	27	6.21	0.67	949
20.22	1.64	290	34	261	27	5.65	0.66	927
18.19	1.83	424	35	233	27	8.54	0.7	1035
14.59	1.71	353	33	224	27	6.79	0.63	964
16.57	1.79	379	35	245	27	7.27	0.67	907
12.74	1.69	326	33	232	27	6.23	0.63	931
13.48	1.75	316	36	279	27	6.23	0.71	957
14.65	1.68	382	32	191	27	7.23	0.61	987
14.29	1.65	278	35	273	27	5.16	0.65	945
9.84	1.6	269	34	260	27	5	0.63	857
18.27	1.65	328	34	257	27	6.28	0.65	979
15.96	1.63	212	34	287	27	3.89	0.62	955
15.41	1.64	179	33	264	27	3.32	0.61	945
15.18	1.72	179	35	306	27	3.39	0.66	1007
15.29	1.59	216	31	222	27	3.98	0.57	965

K-40 (1460.8 keV)

Net Area Uncert	Continuum Counts	ROI Length	Activity	Activity Error
34	89	29	285.24	10.92
34	85	29	298.76	11.36
34	60	29	313.42	11.25
34	89	29	285.09	10.73
34	71	29	290.71	10.72
34	67	29	289.24	10.54
34	62	29	304.2	10.76
34	94	29	259.38	10.33
33	75	29	254.87	9.85
33	65	29	273.5	9.89
33	51	29	283.22	9.85
34	79	29	275.28	10.1
36	75	29	317.98	11.06
34	60	29	282.77	9.97
34	75	29	265.4	9.95
34	76	29	271.1	9.9
35	79	29	287.75	10.52
35	66	29	284.65	10.09
34	64	29	267.39	9.62
35	111	29	242.78	9.92
35	75	29	285.77	10.22
35	86	29	267.07	9.79
34	62	29	267.39	9.62
36	97	29	290.41	10.38
35	81	29	270.82	9.82

Appendix B

COMPLETE RADIOMETRIC ANALYSIS DATA FOR CORE D AT FORT POINT

Dried, milled soil samples were counted for 24 hours in a Canberra well detector (GCW2523). Activity con

* All activites are mBq/g

Core	Depth (cm)	Interval Thickness (cm)	Porosity	Dry bulk density (g/cm3)	Sample mass (g)	Total Pb-210 (		
						Net Peak Area	Net Area Uncert	Continuum Counts
D	0.5	1	0.430	1.51	8.07	586	66	1310
D	1.5	1	0.400	1.59	8.57	489	62	1159
D	2.5	1	0.387	1.63	8.02	448	63	1226
D	3.5	1	0.385	1.63	8.51	428	61	1172
D	4.5	1	0.364	1.69	8.53	358	62	1214
D	5.5	1	0.359	1.70	8.63	537	61	1137
D	6.5	1	0.350	1.72	8.53	496	63	1236
D	7.5	1	0.342	1.74	8.25	439	62	1186
D	8.5	1	0.336	1.76	8.11	458	60	1120
D	9.5	1	0.344	1.74	8.31	385	62	1210
D	10.5	1	0.340	1.75	8.24	260	61	1226
D	11.5	1	0.336	1.76	8.49	334	60	1152
D	12.5	1	0.370	1.67	8.2	307	61	1192
D	13.5	1	0.387	1.62	8.12	232	62	1268
D	14.5	1	0.350	1.72	8.35	321	61	1214
D	15.5	1	0.340	1.75	8.22	250	61	1202
D	16.5	1	0.349	1.73	8.26	221	61	1215
D	17.5	1	0.334	1.76	8.18	208	61	1235
D	18.5	1	0.326	1.78	8.31	301	62	1265
D	19.5	1	0.323	1.79	8.3	343	60	1140
D	20.5	1	0.315	1.81	8.3	216	59	1165
D	21.5	1	0.262	1.96	8.26	248	59	1120
D	22.5	1	0.272	1.93	8.5	172	59	1157

centrations were calbriated against NIST SRM4353 activities. Porosity and bulk density were determined gravimet.

46.5 keV)			Pb-214 (295.1 keV)						
ROI Length	Activity	Activity Error	Net Peak Area	Net Area Uncert	Continuum Counts	ROI Length	Activity	Activity Error	Net Peak Area
22	56.5	6.36	440	57	853	27	13.28	1.72	702
22	44.4	5.63	517	56	792	27	14.69	1.59	860
22	43.46	6.11	460	57	866	27	13.97	1.73	845
22	39.13	5.58	492	54	739	27	14.08	1.55	881
22	32.66	5.66	616	53	681	27	17.59	1.51	804
22	48.42	5.5	563	54	732	27	15.89	1.52	878
22	45.24	5.75	523	58	878	27	14.93	1.66	837
22	41.4	5.85	498	57	836	27	14.7	1.68	941
22	43.94	5.76	481	57	858	27	14.45	1.71	802
22	36.05	5.81	606	55	757	27	17.76	1.61	954
22	24.55	5.76	509	56	806	27	15.05	1.66	905
22	30.61	5.5	486	59	903	27	13.94	1.69	1014
22	29.13	5.79	549	55	765	27	16.31	1.63	923
22	22.23	5.94	638	56	756	27	19.14	1.68	898
22	29.91	5.68	725	55	711	27	21.15	1.6	943
22	23.66	5.77	516	54	734	27	15.29	1.6	827
22	20.82	5.75	629	56	743	27	18.55	1.65	927
22	19.79	5.8	526	57	826	27	15.66	1.7	984
22	28.18	5.8	525	57	823	27	15.39	1.67	996
22	32.15	5.62	552	56	797	27	16.2	1.64	833
22	20.25	5.53	555	56	774	27	16.29	1.64	1001
22	23.36	5.56	550	56	790	27	16.22	1.65	867
22	15.74	5.4	568	57	819	27	16.28	1.63	861

rically assuming 100% mineral solids, 1.0 g/cm3 and 2.65 g/cm3 for water and solids, respectively.

Pb-214 (352.0 keV)					Bi-214 (665.4 keV)			
Net Area Uncert	Continuum Counts	ROI Length	Activity	Activity Error	Net Peak Area	Net Area Uncert	Continuum Counts	ROI Length
55	679	27	14.39	1.13	315	39	359	27
53	577	27	16.6	1.02	368	38	330	27
53	595	27	17.43	1.09	392	39	355	27
53	597	27	17.12	1.03	345	39	361	27
53	594	27	15.59	1.03	375	40	374	27
55	634	27	16.83	1.05	411	39	340	27
55	662	27	16.23	1.07	421	40	349	27
53	571	27	18.86	1.06	403	40	363	27
54	632	27	16.36	1.1	366	39	358	27
55	614	27	18.99	1.09	377	39	345	27
54	608	27	18.16	1.08	398	39	335	27
55	597	27	19.75	1.07	454	39	336	27
56	657	27	18.62	1.13	482	38	289	27
55	638	27	18.29	1.12	366	39	351	27
55	620	27	18.68	1.09	439	39	334	27
54	629	27	16.64	1.09	344	40	361	27
53	584	27	18.56	1.06	399	40	363	27
53	538	27	19.9	1.07	329	40	377	27
53	554	27	19.82	1.05	411	40	363	27
54	626	27	16.6	1.08	384	37	299	27
54	562	27	19.95	1.08	444	38	317	27
54	600	27	17.36	1.08	359	39	357	27
55	649	27	16.75	1.07	456	40	332	27

Cs-137 (661.6 keV)

Activity	Activity Error	Net Peak Area	Net Area Uncert	Continuum Counts	ROI Length	Activity	Activity Error	Net Peak Area
14.33	1.77	527	34	185	27	10.28	0.66	946
15.77	1.63	412	37	278	27	7.57	0.68	1048
17.95	1.79	466	36	253	27	9.14	0.71	987
14.89	1.68	439	37	271	27	8.12	0.68	1010
16.14	1.72	428	37	277	27	7.9	0.68	969
17.49	1.66	464	36	259	27	8.46	0.66	983
18.12	1.72	395	37	299	27	7.29	0.68	969
17.94	1.78	349	35	261	27	6.66	0.67	923
16.57	1.77	399	34	239	27	7.74	0.66	965
16.66	1.72	330	35	266	27	6.25	0.66	952
17.74	1.74	277	34	260	27	5.29	0.65	985
19.64	1.69	255	34	276	27	4.73	0.63	980
21.58	1.7	300	35	263	27	5.76	0.67	915
16.55	1.76	296	33	246	27	5.74	0.64	984
19.3	1.71	317	34	246	27	5.97	0.64	1008
15.37	1.79	236	33	265	27	4.52	0.63	1001
17.74	1.78	266	32	217	27	5.07	0.61	994
14.77	1.8	208	33	260	27	4	0.63	1006
18.16	1.77	154	33	279	27	2.92	0.63	996
16.99	1.64	104	31	257	27	1.97	0.59	961
19.64	1.68	98	30	238	27	1.86	0.57	928
15.96	1.73	86	29	230	27	1.64	0.55	990
19.7	1.73	26	30	272	27	4.72	NA	1047

K-40 (1460.8 keV)

Net Area Uncert	Continuum Counts	ROI Length	Activity	Activity Error
35	95	29	281.27	10.41
36	74	29	293.42	10.08
35	70	29	295.29	10.47
36	84	29	284.78	10.15
35	83	29	272.58	9.85
36	92	29	273.31	10.01
34	66	29	272.58	9.56
34	78	29	268.45	9.89
35	79	29	285.51	10.36
34	75	29	274.88	9.82
35	85	29	286.83	10.19
36	101	29	276.97	10.17
36	117	29	267.74	10.53
35	88	29	290.77	10.34
35	75	29	289.66	10.06
35	80	29	292.2	10.22
36	88	29	288.75	10.46
36	84	29	295.09	10.56
35	85	29	287.59	10.11
36	106	29	277.82	10.41
34	81	29	268.28	9.83
35	75	29	287.59	10.17
36	82	29	295.56	10.16