Superfund Records Center
SITE: Centredale
BREAK: 3.6
OTHER: 206725

Geomorphic Assessment of the Woonasquatucket River, RI

Engineer Research and Development Center
Waterways Experiment Station
Vicksburg, MS

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SDMS DocID 206725

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1.0 Introduction

The Woonasquatucket River was once typical of most New England rivers - narrow, slightly sinuous, and fast flowing. With this plentiful supply of energy, textile mills located along the river's banks sought to harness the streamflow to drive machinery. According to McConeghy (1995), from 1790 until 1860 more than 45 mills operated along the Woonasquatucket River.

The identification of geomorphic features, combined with sediment age dating tools, provides a means of locating contaminated sites for optimal remediation and mitigation. For example, contamination is usually found in organic material and fine-grained sediment. By locating geomorphic features with this type of material or sediment, contamination in the subsurface can be targeted.

2.0 Study Objective

The U. S. Army Corps of Engineers, Engineer Research and Development Center at the Waterways Experiment Station (ERDC WES), Vicksburg, MS, conducted a study of the geomorphic evolution of the Woonasquatucket River in North Providence, RI. This investigation supports the feasibility study for the Centredale[1] Manor Restoration Project Superfund Site under the direction of the U. S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineer, New England District.

Elevated levels of dioxin, produced from industries operating at a Superfund Site along the Woonasquatucket River, have been detected in sediments sampled along sections of the river in North Providence, RI. The objectives of this study are to provide geomorphic data for spatial and temporal definition of dioxin contamination of the Woonasquatucket River and to offer support for remediation methods.

[1] Until 1893, the official spelling of the town was Centredale. In 1893, the Post Office Department required that the Post Office use Centerdale but local government continues to use Centredale. The name that appears on United States Geological Survey topographic maps is Centerdale.

3.0 Description of Study Area

The area of study includes two mill dams and locations of three former woolen and textile mills: Lyman Mill, Centredale Worsted Mill, and Allendale Mill. A chemical company and a drum reclamation plant occupied the site of the Centredale Worsted Mill after a fire claimed the mill. The geomorphic investigation extends from the former site of the Centredale Worsted Mill to the Lyman Mill Dam (also referred to as Lymansville Dam) (Fig. 1).

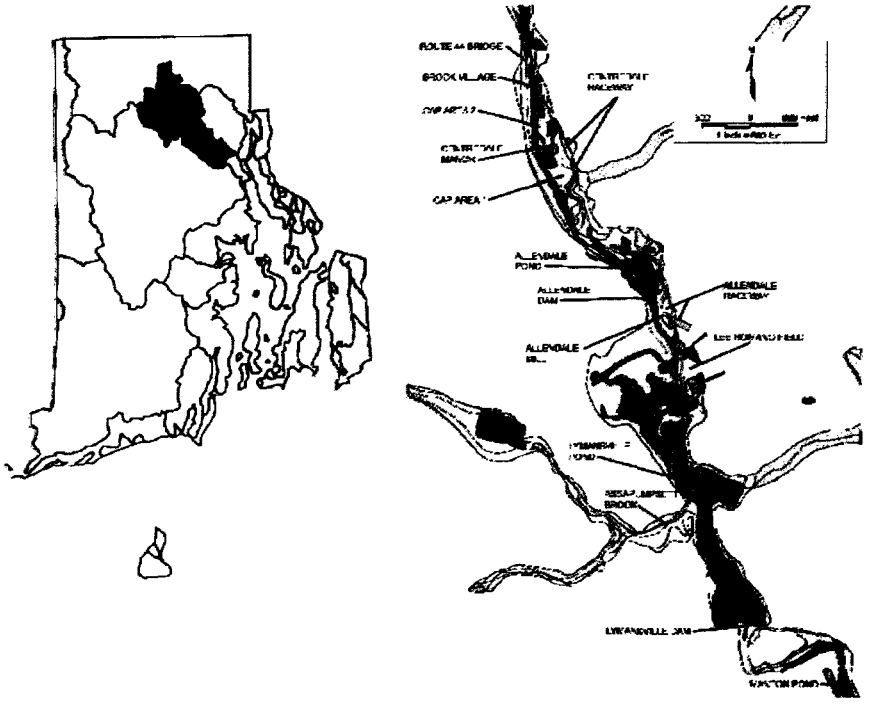

Fig. 1. Location map of the Centredale Manor Restoration Project Superfund site (modified ITT (original reference not cited)).

Mills along the river relied on water to power the machinery, so during times of drought the mills became idle. In 1822, a group of Woonasquatucket Valley mill owners formed a corporation to ensure an adequate supply of water through the construction of

reservoirs (Rhode Island Historical Preservation Commission 1992). The corporation obtained a charter, the first one awarded in the United States for making reservoirs for hydraulic purposes, to construct ponds for retaining floodwaters to operate machinery during times of drought. Dams were set in place to pond water near the headrace, a canal where water flows through a water wheel to power mill machinery. Ponds formed by the dams at Allendale and Lymansville are referred to as Allendale Pond and Lyman Mill Pond, respectively. The river has a fall of about 2.5 m at Centredale and at Allendale, and about 3 m at Lymansville (Bayles 1891). These man-made alterations of the river channel greatly influenced the river morphology and sediment regime.

4.0 Local Geology

The only known surficial geologic mapping in this area conducted prior to this study is by Krinsley (1949) for his Master's thesis in the Department of Geology at Brown University, Providence, RI. His work, along with that of Mr. J. Hiram Smith, was used by the USGS to complete the surficial mapping of the Providence USGS 7.5 min quadrangle, which was published in 1956 as Geologic Quadrangle 84 (GQ 84).

Dr. Jon Boothroyd, professor at the University of Rhode Island, Kingston, RI, and also State Geologist of Rhode Island, is currently mapping Quaternary deposits in the Providence USGS 7.5 min quadrangle but the information has not been released. ERDC contacted the USGS District Office in Rhode Island (275 Promenade St., Suite 150, Providence, RI, 02908, phone, (401) 331-9050) to determine if the agency had conducted other studies along the Woonasquatucket River or if there are plans for future geologic studies in this area. USGS has not directed geologic studies along the Woonasquatucket River and at this time there are no planned studies by the USGS to assess the geology surrounding the Woonasquatucket River.

Surficial deposits in this area are predominantly of glacial origin and can be classified broadly as glacial till or stratified drift (Fig. 2).

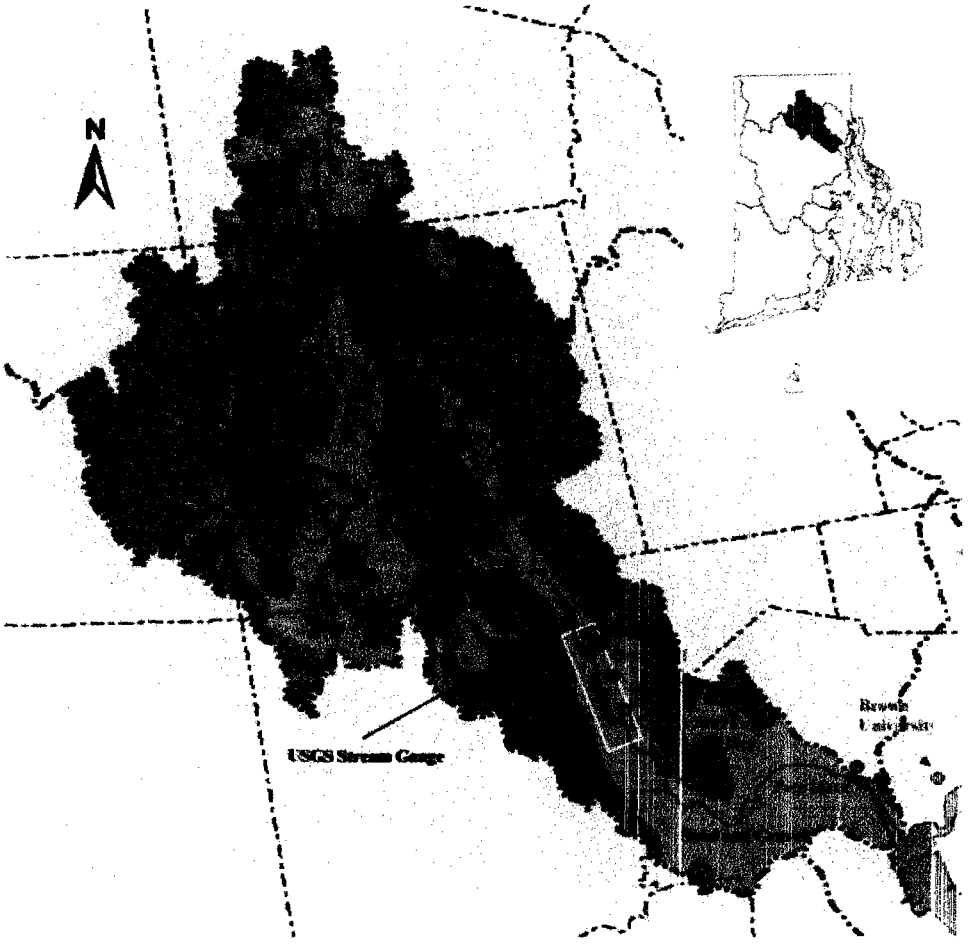

Fig. 2. Surficial geology of the Woonasquatucket River Watershed, not to scale. Study area is indicated by the yellow box. (modified U. S. Geological Survey 2003).

At higher altitudes, glacial till is exposed as ground moraine. In low-lying areas, stratified drift dominates the morphologic features. Glacial till, mapped by Smith (1956) and Krinsley (1949) as ground moraine, is from either of two sources depending on the bedrock from which it was derived - one consisting primarily as material derived from sedimentary rocks of Pennsylvanian age and the other consisting of crystalline rock. According to Smith (1956), the stratified drift exists as outwash plains, kame terraces, kame plains, kames, and ice-channel fillings. The remainder of the surficial deposits along the Woonasquatucket River is alluvium deposited when the river overtops its banks. The alluvium, mapped as floodplain or alluvial deposits, is reworked glacial

outwash and river terrace. The river terraces are former floodplain deposits and are therefore considered depositional features.

The bedrock underlying the surficial deposits consists of Pennsylvanian sandstone, shale, and conglomerate of the Narragansett Basin and older igneous and metamorphic rocks surrounding the basin (Smith 1956). Most of the bedrock is crystalline rock, exposed after uplift and erosion removed the softer rocks of the Narragansett Basin (Fig. 3).

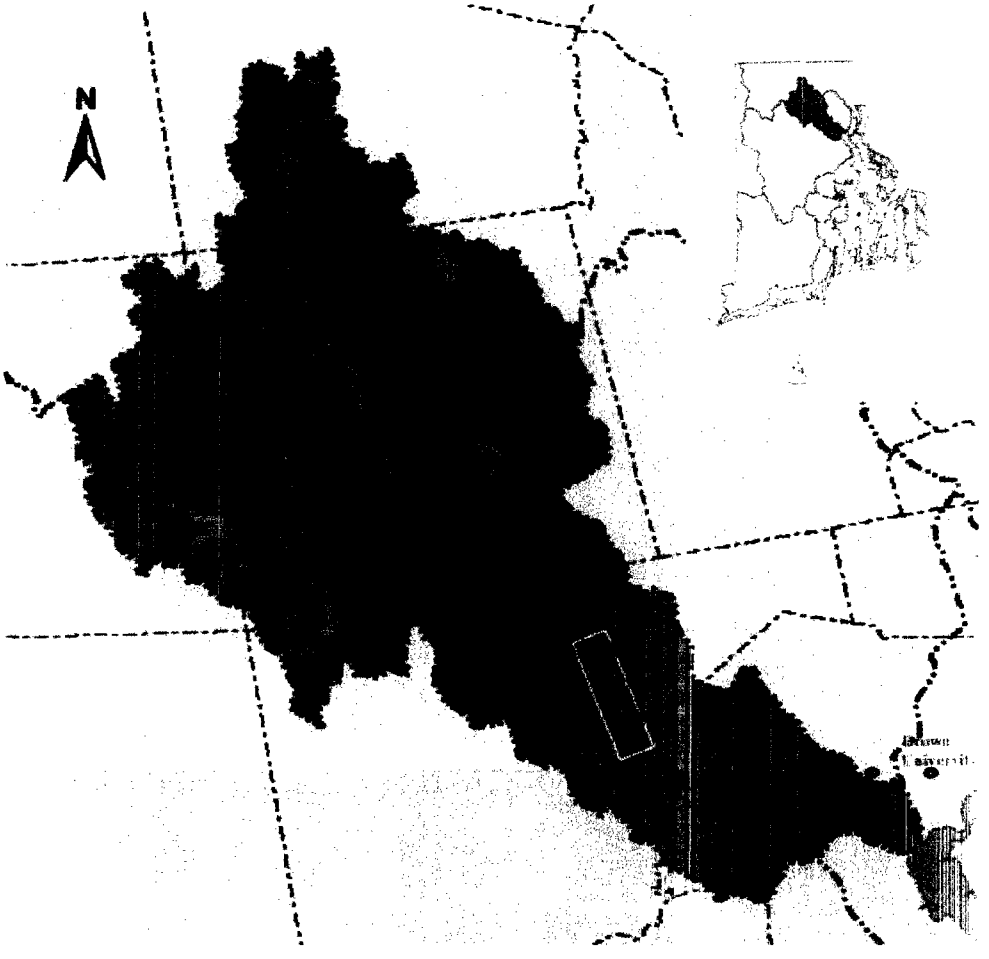

Fig. 3. Bedrock geology of the Woonasquatucket River Watershed, not to scale Study area is indicated by yellow box (modified U. S. Geological Survey 2003).

The Woonasquatucket River is entrenched in a valley train, a glacial feature described by Smith (1956) as a graded outwash, deposited by glacial streams, which fills a valley bottom from wall to wall. Because of the deep entrenchment, the elevated outwash plain is sometimes mistakenly interpreted as river terraces deposited by fluvial

activity. The valley train is derived primarily from crystalline rock and, because the rock has been transported a considerable distance, consists of well-rounded grains. The outwash plain extends the length of the Woonasquatucket River and diverts the southern part of the river to flow in an eastern direction instead of its normal southeastward course. In the area of the Centredale Manor Site, the river channel is straight. The channel changes to a braided pattern close to the Allendale Dam because of the dam breach and returns to a straight channel south of Allendale.

5.0 Data Sources

5.1 Literature review

An extensive literature review was performed using the Internet, GEOREF/S[1], and on-line library catalogs. Information acquired from the Internet was used only if the source could be verified. In addition to the references cited at the end of this report, a bibliography of literature pertinent to the investigation of the site is listed under subject headings in Appendix A. Copies of each publication listed in the bibliography were obtained and reviewed.

5.2 Aerial photography

Aerial photography is an integral part of a geomorphic investigation. A historical assessment using photography aids the evaluation of river morphology. Although the interpretation is based on surficial deposits, historic changes along the river are useful in locating areas in the subsurface where contaminants are likely to be found (i.e. organic material and fine-grained sediments).

Several sources flew and provided aerial photography obtained for this study and resolution varied accordingly (Table 1). The photography was scanned and saved in a tagged image file format (tif) to import into Environmental Systems Research Institute (ESRI) ArcView 8.3, a geographic information system (GIS), or other image processing programs. Sources of photography are listed below.

[1] GEOREF/S is an electronic database that provides access to the geosciences literature of the world (North America 1785 to present; International 1933 to present)

Table 1. Sources of aerial photography.

Source	Date Flown	Approximate Scale
NAS (not defined on aerial photograph)	10/26/1951	1 in = 1690 ft
NAS (not defined on aerial photograph)	10/26/1951	1 in = 1690 ft
United States Geological Survey (USGS)	5/19/1955	1 in = 2000 ft
United States Geological Survey (USGS)	5/19/1955	1 in = 2000 ft
United States Geological Survey (USGS)	5/19/1955	1 in = 2000 ft
National Ocean Survey (NOS)	5/1/1956	1 in = 2420 ft
National Ocean Survey (NOS)	5/1/1956	1 in = 2420 ft
Aerial Viewpoint (AVPT)	2/7/1962	1 in = 1320 ft
Aerial Viewpoint (AVPT)	2/7/1962	1 in = 1320 ft
Aerial Viewpoint (AVPT)	2/7/1962	1 in = 1320 ft
Aerial Viewpoint (AVPT)	9/2/1963	1 in = 1710 ft
Agricultural Stabilization and Conservation Service (ASCS)	9/2/1963	1 in = 1710 ft
Agricultural Stabilization and Conservation Service (ASCS)	9/2/1963	1 in = 1710 ft
United States Geological Survey (USGS)	3/9/1970	1 in = 2000 ft
United States Geological Survey (USGS)	3/9/1970	1 in = 2000 ft
United States Geological Survey (USGS)	3/9/1970	1 in = 2000 ft
National Ocean Survey (NOS)	9/20/1979	1 in = 2510 ft
National Ocean Survey (NOS)	9/20/1979	1 in = 2510 ft
United States Geological Survey (USGS)	3/18/1981	1 in = 2070 ft
United States Geological Survey (USGS)	3/18/1981	1 in = 2070 ft
National Ocean Survey (NOS)	8/23/1985	1 in = 2480 ft
National Ocean Survey (NOS)	8/23/1985	1 in = 2480 ft
Rhode Island Geographic Information System (RIGIS) (USGS)	1992	1:5000
Rhode Island Geographic Information System (RIGIS) (USGS)	1995	1:5000
Rhode Island Geographic Information System (RIGIS)	1997	1:5000
Col-East, Inc.	5/17/1995	1 in = 530 ft
Col-East, Inc.	5/17/1995	1 in = 530 ft
EarthData International	3/4/2000	1:4800
EarthData International	3/4/2000	1:4800
EarthData International	3/4/2000	1:4800
EarthData International	3/4/2000	1:4800
EarthData International	3/4/2000	1:4800
EarthData International	3/4/2000	1:4800
EarthData International	3/4/2000	1:4800
EarthData International	3/4/2000	1:4800
EarthData International	3/4/2000	1:4800

The images were rectified in the Rhode Island State Plane (U.S. Survey Feet, NAD 83) to 1997 USGS digital orthophotographic quadrangles (DOQs) purchased from the Rhode Island Geographic Information System (RIGIS), a consortium of government

and private organizations employing computer and communications technology to manage and use a collective database of comprehensive geographically related information. The DOQs are used as a base for rectification because of the degree of accuracy in developing them. The relative scale on the ground for the DOQs is 1:5000, giving a map accuracy of 3 to 5 m. However, rectification of the aerial photography to the DOQs proved inaccurate for tracing the river channel when using buildings and roads, landmarks usually used to select coordinates from the DOQs. Instead, more points closer to the river had to be used in order to match the individual images to each other.

Some of the photography could not be used in the study because of poor resolution or rectification problems. Unfortunately, the earliest photography available for this area (1935) is too poor a quality to be used in assessing river changes. The 1970 photography also presents a problem because of poor resolution.

5.3 Topographic quadrangles

Topographic maps are also essential when characterizing changes in the river morphology. Topographic quadrangles available for this site were purchased from the USGS in Reston, VA, and scanned and rectified if pertinent to river evolution (Table 2).

Table 2. Topographic Quadrangles acquired for this research.

Map Name	State	Scale	Survey Year	Revision Year	Publication Year
Burrillville	RI	62K	1888	Not Applicable	1940
Burrillville	RI	62K	1915	Not Applicable	Not Applicable
Georgiaville	RI	24K	1942	Not Applicable	1954
Georgiaville	RI	24K	1942	1970	1972
Georgiaville	RI	24K	1942	1975	1975
Pawtucket	RI	24K	1938	1949	1965
Pawtucket	RI	24K	1938	1970	1973
Pawtucket	RI	31K	1938	Not Applicable	1944
Pawtucket	RI	24K	1949	1975	1977
Providence	RI	62K	1887	Not Applicable	1939
Providence	RI	31K	1935	Not Applicable	1956
Providence	RI	24K	1935	1957	1959
Providence	RI	24K	1935	1970	1972
Providence	RI	24K	1957	1975	1978
Providence	RI	25K	Not Applicable	1981	1987
Providence	RI	100K	Not Applicable	1977	1984

5.4 Rhode Island soil survey

Soils reflect post-glacial development and are important in reconstructing the geochronology of the river. The Soil Survey of Rhode Island (U. S. Department of Agriculture 1977), published prior to the construction of Brook Village and Centredale Manor, was used to assess the soil type and conditions surrounding the sites. A digital soil map that can be downloaded from the Natural Resources Conservation Service web site (http://soils.usda.gov/) is recommended for inclusion in a GIS being maintained for the project by Battelle.

5.5 Vibracores

To estimate the sedimentation rate of the river and verify the spatial and temporal extent of dioxin, thirty subsurface vibracore sediment samples were obtained by USEPA in the river channel. The selected method of extracting the samples is a vibracore described in the scope of work provided by the USEPA Emergency Response Team. Additionally, six hand cores were taken between Allendale and Lyman Mill area.

Because of the noncohesive nature of the material in these cores, they were not slabbed or described.

Selection of sample locations was based on several criteria: a preference for glacial and fluvial deposits (such as kame and alluvial deposits), depositional environment (abandoned channel), river morphology (historic and present), and bathymetry of the river based on geophysical transects. Other factors, such as previous chemical analyses of soil samples and breaching of the Allendale Dam, were also considered in selecting vibracore sites.

6.0 Methodology

A geomorphic study uses historic aerial photography, U. S. Geological Survey (USGS) topographic quadrangles, published documents, and field investigations to identify morphological features and changes along the river. Interpretation of these data provides a basis for selecting sites for subsurface investigation needed to define the spatial and temporal extent of dioxin and determines areas suitable for application of sediment age dating methods through geochemical analyses. Dioxin sorbs to fine-grained sediment and organics. These deposits represent low flow activity within the ponds and were considered when selecting sample locations. Information gained from the geochemical analyses is coupled with geomorphic interpretation to estimate sedimentation rates and to establish a timeline as to the depth of dioxin contamination. The dates from the ^{210}Pb analyses are included on the core logs in Appendix B.

6.1 Vibracoring

ERDC and USEPA slabbed and described the vibracores in a secured site at the USEPA lab in Narragansett, RI. The EPA lab constructed a box to hold the core in place while using a circular cutoff saw to cut the core in half (Fig. Here of the box and the saw), a process referred to as slabbing. The box was lined with plastic and the plastic was replaced after each core was slabbed. Water was drained from each vibracore prior to slabbing. After the core was slabbed, it was placed on a table lined with paper. The core was measured, described, and photographed. One side of the core was used for

geochemical analyses (^{210}Pb and ^{137}Cs). The other side was used for geotechnical analyses and dioxin analysis.

Plastic utensils were used to remove samples from the core for these analyses and were disposed of after each sample was taken to prevent cross-contamination. Samples were selected based on changes in lithology. If the lithology was consistent throughout the core, the core was sampled in increments.

The samples were placed in glass jars. Labels recording sample number, site, and purpose of sample were placed on the jars and secured with tape. The information on the labels was recorded on a chain of custody form. The samples were stored in coolers and placed in a refrigerated room outside the lab. Battelle transported the samples to their storage facility in May 2003. Samples were then shipped to the appropriate laboratory for analyses.

Lithologic descriptions of the vibracores were entered into LogPlot and are provided in Appendix B. Dioxin concentrations and results from the ^{210}Pb analysis are included in the core descriptions.

6.2 Geochemical analysis

To estimate sedimentation rates, a geochemical analysis using ^{210}Pb and ^{137}Cs was applied to subsamples from selected cores. After receiving the laboratory data from Teledyne Brown (the ^{210}Pb and ^{137}Cs laboratory) , it was decided that ^{137}Cs would not yield reliable estimates of the sedimentation rates, so only ^{210}Pb is used in determining sedimentation rates. The geochemical interpretation is presented in Appendix C. Samples used in this analysis includes organics and fine grained material, sediment where dioxin is thought to be in higher concentration.

7.0 Geomorphic Analysis

Geomorphic analysis includes interpreting and describing data collected during the course of this investigation and outlined in the objectives of this report.

Regional features are identified in Fig. 4. The map was constructed in Surfer 7.0 by presenting a three-dimensional view of a digital elevation model (DEM). In this view, the relief of the terrain is apparent.

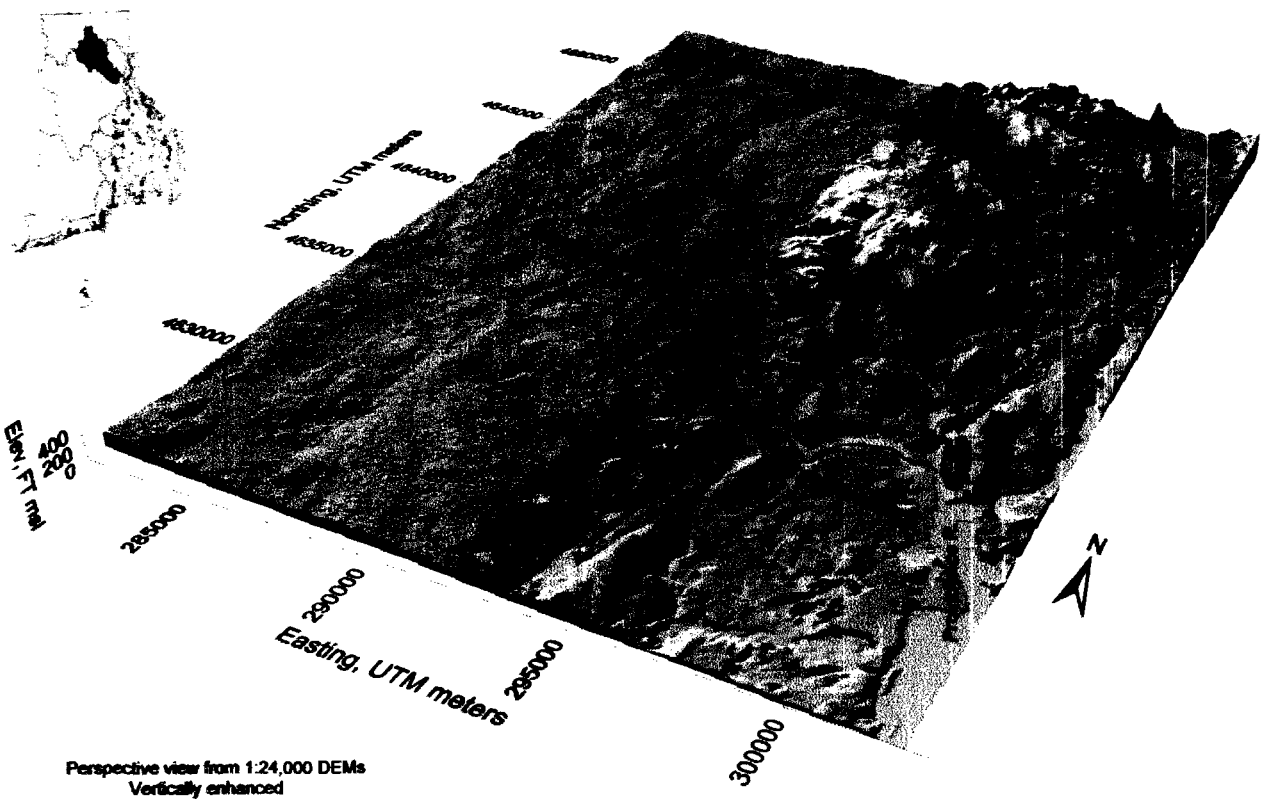

Figure 4. Three-dimensional elevation model of the Woonasquatucket River.

7.1 Historic channel geometry

A valley train, which formed as outwash deposits from a receding glacier, filled the Woonasquatucket River valley bottom. The material deposited by the glacier consists almost entirely of eroded crystalline rock. Subsequently, the headwaters at Primrose Pond entrenched a channel in the outwash to produce the Woonasquatucket River.

Using aerial photography, ERDC traced the outline of the river to identify major changes in the channel (Fig. 5). These outlines show that the river is confined by the

valley train and the ponds and also confirm the channel abandonment between 1970 and 1976 south of the Allendale Dam (orange arrow in Fig. 5).

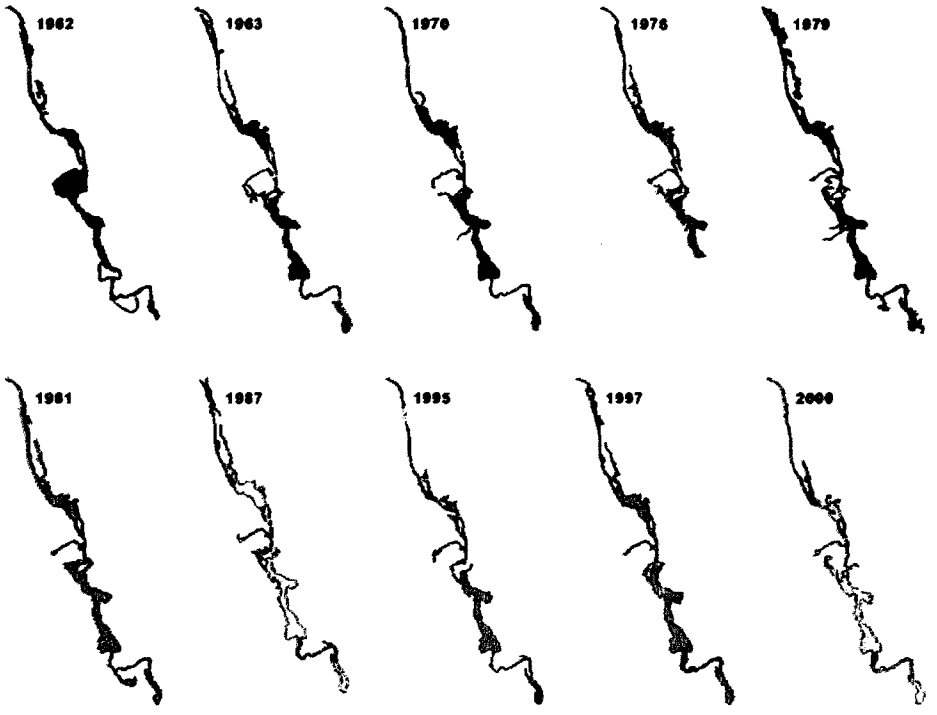

Figure 5. River outlines of the Woonasquatucket River based on aerial photography and topographic maps from 1962 to 2000.

7.2 Geomorphic features

Geomorphic features identified are those typically found in riverine and glacial systems: braid bar, floodplain deposits, river terrace, abandoned channel, kame terrace, ground moraine, and valley train deposits.

A braid bar is indicative of a braided channel and is manifested as an island of sediment within a river channel. The braided pattern of the Woonasquatucket River becomes apparent only after the Allendale Dam breach and does not support classifying the river as a braided system.

Floodplain deposition occurs as sediment is deposited over the riverbanks. These deposits have an abundance of sand with lesser amounts of silt and clay. Plant debris forming organic layers is also present in these deposits as the river moves tree leaves and

other small plant remains originally deposited in the channel. Contaminants are usually present in these organic layers. Organic layers are described in subsurface coring but the spatial extent is often difficult to define.

River terraces are either depositional or erosional in nature. The terrace along the east bank of the Woonasquatucket River is a former floodplain and is therefore classified as a depositional river terrace. Lyman Mill and Allendale Mill are situated on the river terrace above the recent floodplain of the river.

Abandoned channels (channel-fill deposits) are segments of channel abandoned by the river usually because of a river shortening its course by cutoffs. The abandoned channel is slowly filled with alluvium until the previous channel is disconnected from the flow of the river. Clayey sediments and organic matter are deposited until filling is complete. During flooding, overbank deposits may still be introduced into the abandoned channel. These areas are good targets for sediment coring to confirm the existence of contaminated sediments.

For ease of discussion, the Centredale Manor site has been divided into the Allendale Reach, extending north from the tailrace of the former Allendale Mill to the Centredale Manor site, and the Lyman Mill Reach, extending from the southern extent of Lyman Mill Pond to the tailrace of the former Allendale Mill (see Fig. 1).

7.3 Allendale Reach

Meltwater streams deposited sand and gravel between blocks of glacial ice remaining in the valleys and valley walls during glacial retreat. Smith (1956) identified a kame terrace east of the former Centredale Mill site but because of the urbanization in this area and lack of subsurface data, the identification of a kame terrace in this area is based only on Smith's interpretation.

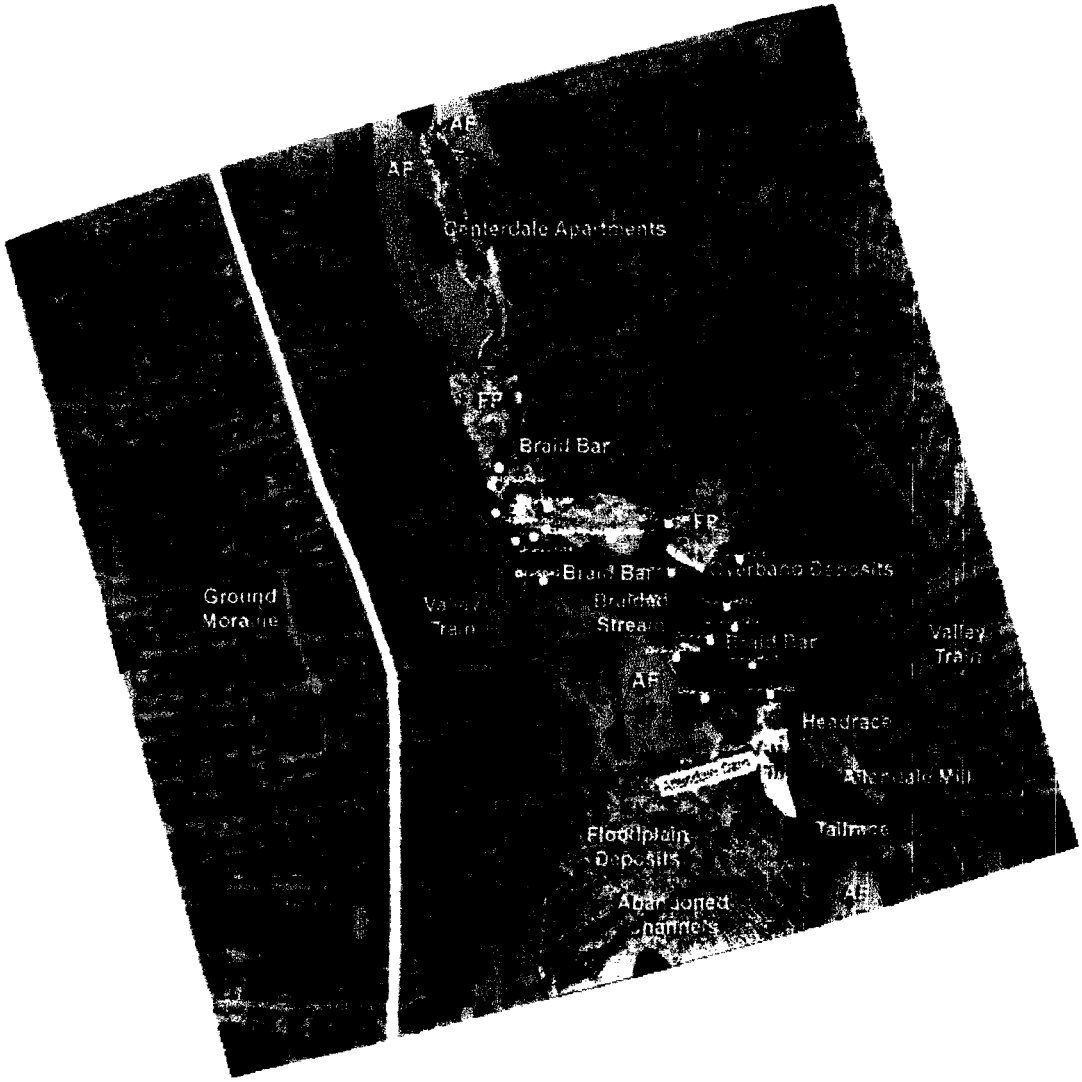

Figure 6. Aerial photography (2000) with geomorphic deposits of the north section of Allendale Reach. Vibracore locations are noted on the photograph.

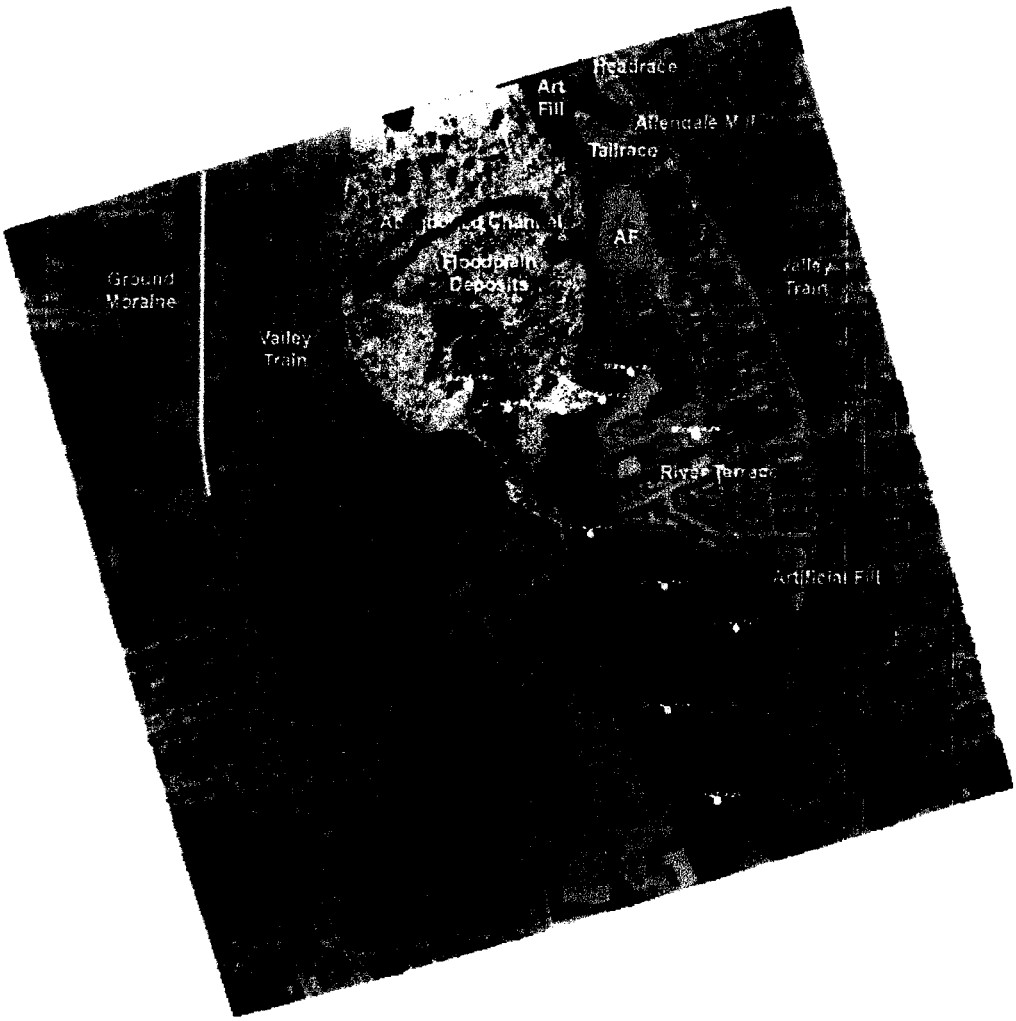

Figure 7. Aerial photograph (2000) of south section of Allendale Reach with geomorphic features. Vibracore locations are shown on the photograph.

The valley train limits the movement of the pond to the west. As a result, the position of the Woonasquatucket River on the west bank changes very little over time. This area is now the site of a concrete company and is listed as UD (Udorthents-Urban) soil complex.

Ground moraine borders the valley train on the east and west sides of the river (Figs. 6 and 7). The moraine is made up of a thin layer of till that lies primarily on the bedrock.

The Centredale Manor and Brook Village Apartments, formerly the site of the Centredale Worsted Mill, are constructed on the floodplain of the Woonasquatucket River (Fig. 6). Although the site proved efficient in harnessing the waterpower for the mill, the location is not desirable for urban development because of the high probability of flooding.

As expected, the soil under the Brook Village and Centredale Manor development situated on the west and east banks of the Woonasquatucket River is classified as UD soil complex and CB (Canton-Urban soil complex), respectively. Overlap of the two soil complexes is evident on both sides of the river. The soil is moderately well to excessively drained but obviously has been disturbed by construction of the two complexes. The depth of the disturbed soil (fill depth) is approximately 0.6 m (2 ft). Field investigations reveal that the site may now possibly be classified under the Ur (Urban land) category because much of the area consists of buildings, paved roads, and parking lots.

The east bank of the river in this area was developed as a residential area between 1888 and 1935, covering the southern part of the river terrace. Because this area is urbanized, ERDC's geomorphic interpretation relied primarily on historic aerial photography and topographic maps.

Because of the partially breaching of Allendale Dam in 1991 and complete breaching of the dam in 2001, this area has undergone significant changes (Fig. 7). The breach contributed to downstream transportation of contaminated sediment and also altered geomorphic features along the river. As the dam breached and water level subsided, more sediment was exposed along the eastern portion of the river, bordering a residential area. As evident from the 2000 aerial photography, the river assumed the characteristics of a braided channel in response to the dam breach.

The Pp (Podunk) soil is present to the west of Allendale Dam and south of the Centredale Manor site. This series consists of well-drained soils that form in recent alluvium on floodplains. Immediately south of the Pp soil unit, also south of the Brook Village complex, is the Aa (Adrian muck). This soil is poorly drained and, based on the soil description and aerial photography, is indicative of a wetland. Historical aerial photography reveals an abandoned channel in what is now classified as a wetland (Fig.

7). In 1981, the river is shown inundating the wetland, possibly due to higher precipitation than in previous years. This can be seen in the aerial photography from the lack of vegetation and an increase in the river floodplain.

The Pp (Podunk) is present southwest of Allendale Dam and possibly defines the limits of the glacial outwash. The Aa soil occurs again just south of the Pp soil unit . The Pp series are formed in recent alluvium derived mainly from granite, gneiss, and schist, thereby supporting the interpretation of channel migration. Alluvial deposits with a high organic content should be present in the subsurface of the meander loop.

The most prominent textile mill in the study site is the Allendale Mill, designed and constructed by Zachariah Allen in 1822 to manufacture broadcloth, a fabric made entirely of wool. The mill is situated on a river terrace, an ideal setting for the building because of the elevated topography of the terrace. The river was re-directed through the mill to supply power to the looms and although the water wheel was removed in the1960s, the headrace and tailrace still exist. Shortly after the mill began operations, the area suffered a severe drought, resulting in a substantial monetary loss to the mill, which depended on the river for power. Allen devised a plan to impound the water during times of flood through a series of dams and reservoirs, hence Allendale Pond and Lymansville Pond, substantially altering the natural flow of the river.

The Allendale area illustrates the most complex geologic controls on river migration of the study site. In the 1888 USGS 15 min topographic map, the river followed a sharp meander but in the 1935 USGS 7.5 min topographic map, the river abandons the meander loop and follows a straight path. Field mapping revealed three previous channels of the river, likely controlled by glacial outwash and influence of the mill. The most recent meander loop is still in communication with the river during times of high water (as evident in the 1995 aerial photography), thereby allowing a transportation path for dioxin or other contaminants outside of the existing river boundaries.

A large percentage of Allendale Pond bottom is depositional, with very soft and perhaps thicker sediment in much of the channel relative to historic channels. Areas of very thin sediment are apparent on the east side of Allendale Pond (near bedrock outcrops).

This site is unique in that it is highly disturbed by anthropogenic influences as well as by natural glacial and fluvial activities. It is apparent that the river has been straightened at the point where water from the mill enters the river. Spoils from the straightening form a levee covered with cobbles from the river channel. Floodplain deposits were apparent to the west of this ridge during field reconnaissance and are indicative of overbank river flow that occurred prior to construction of the levee.

An abandoned meander seen in topographic maps and aerial photography was verified in a field investigation. This abandoned meander appears to be the response of the river to a man-made cut-off where the river was straightened. The area within the meander should contain fine-grained sediment deposited as the river adjusted to its new man-made path and the meander was cut-off and filled. A few boulders (probably erratics) carried by glacial activity are seen in the area of the meander. A telephone/electrical pole was located close to the abandoned meander and serves as additional evidence that this area has been disturbed. Aerial photos in the 1960s reveal what appears to be a power line running parallel with the river.

7.4 Lyman Mill Reach

Some areas showed a significant number of changes in sediment deposition and channel classification in the years covered by aerial photography. In the southern part of the river (Fig. 8), sediment accumulation showed a substantial increase from 1955 to 1962. However, in 1963, sediment accumulation had decreased similarly to that seen in 1955 photography. The explanation could be very low precipitation in the area during 1961 or 1962 or drawdown of the river.

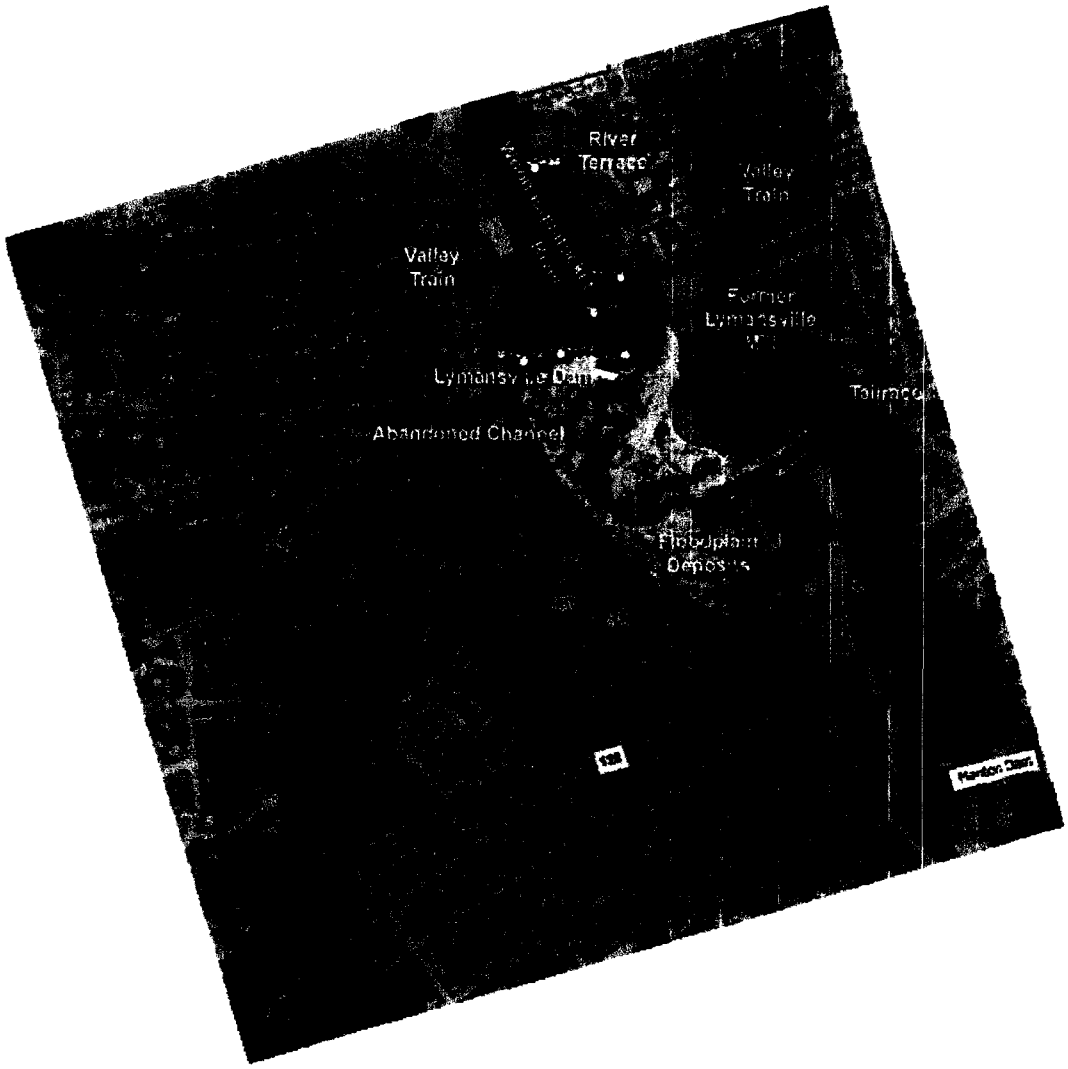

Figure 8. Aerial photography (2000) of the southern extent of the study (Lyman Mill Reach) with vibracore locations.

Two soil types characterized the Lyman Mill Reach. The MU (Merrimac-Urban land complex) borders the UD to the east of the river and continues to the "arm" that extends from the middle of the river. This unit is also present on the west side of the river. As verified in aerial photography, this soil complex represents a river terrace of the Woonasquatucket River (Figs. 7 and 8). Field identification of this soil is difficult because of the intermingling of urban development with the Merrimac soil. A small polygon of HkC (Hinckley gravelly sand loam, rolling) is found within the MU, close to

the UD at the site but still located on the river terrace. It can be differentiated from MU by a higher permeability and sometimes an increased slope.

Continuing south along the west bank of the Woonasquatucket River, the soil is classified as UD and HkC (previously described in this section). South of the HkC soil unit is the Pg (pits, gravel) unit, an area that has been excavated for sand and gravel. The "pit" or quarry can be identified in recent aerial photography (4 Mar 2000). Because of the material being mined, this site is probably situated on a river terrace. What appears to be a scarp, indicative of a change in relief, running parallel to the river is apparent in the same photograph.

The Se (Stissing silt loam) is south of the quarry and is usually found on glacial upland hills or drumlins.[2] This feature does resemble a drumlin in aerial photography. Although this soil is not usually suitable for development, two buildings have been constructed on the southern portion of this unit altering the landscape and geomorphic features. Aerial photography indicates several meander scars in the north portion of this unit. This feature supports an eastern migration of the river at this point.

The eastern bank of the Woonasquatucket River shows greater development. Most of the soils are classified as MU (previously described in this section). A unit of Se is located opposite the MU unit on the west side of the river but has a much smaller spatial extent.

South of the Se unit, a unit of MmB (Merrimac sand loam) soil is present and continues parallel to the river terminating at the Lymansville Dam. This soil is usually found on terraces or outwash plains. The aerial photography supports the interpretation as a terrace based on a higher elevation than what is seen on the western side of the river and by the presence of community development (i.e. communities are more likely to build in areas not prone to flooding).

Like the Allendale site, the southern section of the study area includes a mill dam and pond (Fig. 8). Along the eastern bank, the soil is MU and, as expected, is highly urbanized. This section is part of the river terrace occupied by the Allendale Mill. The HkC soil and the Pg (pits, gravel) unit occupy the west bank of the river. The HkC

[2] A drumlin is a hill of glacial drift with long axis paralleling direction of flow of a former glacier.

covers a kame terrace, an ideal setting for gravel and sand excavation. Three sand and gravel pits in this vicinity were identified by Smith (1956).

Industrialists diverted the river almost due east to accommodate the Lyman Mill. The original path of the river prior to mill construction is difficult to trace but, in addition to the river flowing from the dam, two other channels can be seen on aerial photography. These channels form a "fork" with the tines facing the dam. Cultural debris occupies much of the area south of the dam.

8.0 Distribution of Dioxin Contamination

A correlation of USEPA contaminant sampling and analysis and radioactive dating of the samples provides an approximate timeline of dioxin contamination. Dioxin concentrations correlated with estimated sedimentation rates from ^{210}Pb showed that dioxin levels are considerable higher (>1 ppb) in the top 1 ft of sediment deposited after ~1941 than in sediment deposited before 1941.

The highest dioxin concentration is recorded in core CMS-SD-4213 (124-A). The lithologic description and geomorphic interpretation support this interval as a possible flood event with a considerable amount of organics available for dioxin sorption. This organic layer is approximately 2.5 ft in thickness and is also present in cores north (CMS-SD-4212, 125-A) and south (CMS-SD-4220, 122-A) of CMS-SD-4213 (124-A). Preliminary geophysical assessment identified a previous channel of the river or a scour channel formed by an increase in velocity in this area after construction of the mill raceway. After removal of the mill waterwheel, the velocity of the river is assumed to have been substantially reduced, which allowed for accumulation of dioxin in a stagnant or low flow area.

Lyman Mill Pond displays a more estuarine environment than what is seen in the Allendale Pond. A layer of muck of 1 to 3 ft in thickness in most of the Lyman Mill vibracores prevented a continuous interpretation of the sedimentation record. The core with the highest dioxin concentration in Lyman Mill Pond is found in LPX-SD-4201. Higher dioxin concentrations are expected in this area because of accumulation of sediment behind Lyman Mill dam.

9.0 Conclusions

1. Measurable levels of dioxin have been detected in sediments in sections of the Woonasquatucket River and artificial ponds within the river from the vicinity of Centredale Manor to Lyman Mill pond.
2. Identification and description of geomorphic features of the Woonasquatucket River valley and surrounding terrain effectively targets likely areas of contamination.
3. Construction of mills and mill ponds in the late 18th and early 19th centuries altered the flow of the Woonasquatucket River and created sites of sediment deposition.
4. Sediments within the Woonasquatucket River valley are of glacial and fluvial origin.
5. Geochemical analysis with ^{210}Pb of vibracore samples collected in the channel and in ponds on the Woonasquatucket yielded reliable data for determining sedimentation rates and approximate age of sediments.
6. The Woonasquatucket River is confined within an entrenched valley. A glacial valley train bordering both sides of the valley limits river migration and sedimentation.
7. The river is free to flood within its narrow valley. Contaminants within the river may be transported onto the floodplain and into abandoned channels during flood.
8. Dioxin concentrations correlated with estimated sedimentation rates from ^{210}Pb showed that dioxin levels are considerable higher (>1 ppb) in the top 1 ft of sediment deposited after ~1941 than in sediment deposited later than 1941.

10.0 Recommendations

The geomorphic interpretation is provided as a framework to support other assessments on the Woonasquatucket River. The following recommendations are suggested to better apply this interpretation in other areas

1. Link geophysics interpretations to geomorphic features.
2. Correlate the organic silt/clay layer in Lyman Mill to the geochemical analysis used in this geomorphic interpretation.
3. Include the geotechnical laboratory analyses with the geomorphic interpretation.

Provide sediment age contour maps to estimate the age distribution of the sediment in both the Allendale Pond and Lyman Mill Pond.

These recommendations are based on further interpretation of existing data and would aid in choosing a remediation method as well as increasing the success of remediation and management.

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Appendix A
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Appendix B
Core Logs - Field Description

PROJECT NAME: Centredale Manor Restoration Project

LOCATION: Woonasquatucket River, North Providence, RI

BORING NUMBER: CMS-SD-4204 136-C

LOCATION (lat/long): 280543.14891 332307.30910

DATE: 5/6/03

TOTAL DEPTH: 2.3'

Depth (ft)	Color	210 Pb / 137 Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]		2.39	12.12		Heavy organics		MH/OH Organic silt, dark yellowish brown															
	[illegible]		1.62	14.83		Strong organics, roots; wood debris @ 1.0'			20.64	70.37	8.24	0.75	0.00	0.00	167	106	61	1.57	237	8.0	68.6	23.3	31.3
-1	[illegible]			7.19		Sandy																	
	[illegible]			2.97		Dark, organic rich																	
-2	[illegible]		881.75	2.81		Sandy, higher clay content than above sandy layer; large piece of gravel @ 2.0', large piece of gravel @ bottom (1/2" size), subrounded.																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/6/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.5'

BORING NUMBER: CMS-SD-4206 161-A

LOCATION (lat/long): 280475.87265 332782.43328

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10Y 4/2		2.74	13.12		Rootlets, wet, no odor, organic		MH/OH Organic silt, dark yellowish brown	50.01	47.11	2.40	0.49	0.00	0.00	174	171	3	1.97	334	5.9	75.7	18.4	24.3
-1			5.45	13.29		Leaf litter, wood																	
			8.216	13.38																			
-2						Gravel																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/6/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.6'

BORING NUMBER: CMS-SD-4207 131-C

LOCATION (Lat/Long): 280423.37268 332555.93756

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0				3.78		Organics, black, strong hydrocarbon odor when cutting core, roots																	
						Pea-sized gravel in sand matrix, root		SM Silty sand, dark yellowish brown	9.50	33.36	22.76	22.72	7.54	4.07									
-1																							
						Large gravel																	
-2						Gravel																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.5'

BORING NUMBER: CMS-SD-4208 131-A

LOCATION (Lat/Long): 280414.49560 332176.23823

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]			1.37		Organics @ top, odor, dark color, broken glass, some coarse gravel, pebbles (subrounded - rounded)			0.18	33.03	3.91	9.48	6.50	79.00									
-1	[illegible]					Coarse sand, subrounded-rounded, quartz pebbles																	
-2																							

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 3.6'

BORING NUMBER: CMS-SD-4209 131-B

LOCATION (Lat/Long): 280423.59283 332248.27325

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10Y 4/2			6.52		Silt, rootlets, organic, moist		MH/OH Organic silt w/sand, dark yellowish brown	15.01	58.40	25.80	0.79	0.00	0.00	58	55	3	2.35	124	8.6	54.4	39.0	45.6
			3.43																				
	10Y 4/2		15.8	21.54		Peat, plastic drink lid @ 0.88'		SM Silty sand, dark yellowish brown	11.90	35.77	50.07	2.26	0.00	0.00	64	61	3	2.09	98	5.8	42.6	51.6	57.2
-1	10Y 2/1																						
				9.70		Organic silt, dark color, hydrocarbon odor, fine-grained sand, wood @ 1.3'																	
	7.5Y 2.5/1		8.91 26	9.22		Organic silt, rootlets, moist, sheen, hydrocarbon odor																	
-2																							
	7.5Y 2.5/1					Organic silt, wood pieces, fine-grained sand																	
	5Y 2.5/1					Silt, wood pieces, odor																	
-3				4.15																			
	7.5Y 2.5/1					Coarse sand, subrounded quartz																	

PROJECT NAME: Centredale Manor Restoration Project **DATE: 5/7/03**

LOCATION: Woonasquatucket River, North Providence, RI **TOTAL DEPTH: 3.4'**

BORING NUMBER: CMS-SD-4210 128-C

LOCATION (lat/long): 280332.09968 333071.61506

Depth (ft)	Color	210-Pb/137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10YR 2/2		1.67	3.54		Odor, black in color		MH/OH Organic silt w/sand, dark yellowish brown	12.68	64.49	17.76	5.07	0.00	0.00	89	73	16	1.57	139	4.6	38.8	56.6	61.2
-1			3.72	3.22																			
				3.57																			
	7.5Y 3/4			1.65		Clay layer, light tan									45	43	2		76				
	7.5Y 3/4					Clay, silt (v. fine grain), heavy organics																	
-2			0.0026	7.19																			
	7.5Y 2/1					3.5" wood debris, organic layer, darkens with depth																	
-3																							

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 3.4'

BORING NUMBER: CMS-SD-4211 128-A

LOCATION (Lat/Long): 280282.82690 332797.98231

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	5Y 4/2			18.95		Organics (grass, rootlets), silt		MH/OH Organic silt, dark yellowish brown	37.84	59.07	1.97	1.12	0.00	0.00	109	103	6	1.97	251	6.3	65.7	28.0	34.3
	5Y 3/1			6.76		Organics, silt																	
-1				2.53																			
	5Y 2/1			1.27		Silt, oil sheen																	
-2	5Y 3/1			0.49		Silt, fine-grained sand, mica flakes																	
	5Y 4/2					Pebbles, rounded gravel clasts (1-3"), coarse, subrounded quartz grains		SP/SM Poorly graded sand w/silt and gravel, dark yellowish brown	1.74	4.40	26.92	34.75	15.93	16.22									
-3																							

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.5'

BORING NUMBER: CMS-SD-4212 125-A

LOCATION (lat/long): 280146.48375 333016.08381

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0			8.95	12.35		Heavy organics, wood debris @ bottom, leaf debris @ top 1.0'		MH/OH Organic silt, dark yellowish brown	25.98	71.83	2.16	0.03	0.00	0.00	147	120	27	2.36	336	6.3	69.3	24.4	30.7
-1			16	8.95																			
			8.151																				
-2																							

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.5'

BORING NUMBER: CMS-SD-4213 124-A

LOCATION (lat/long): 280063.08608 333046.72171

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10YR 3/1		6.57	9.33		Organic, rootlets on top		MH/OH Organic silt, dark yellowish brown	25.42	70.43	5.08	0.08	0.00	0.00	91	79	2	2.04	236	6.87	68.9	24.5	31.1
	10YR 4/2		52.8	14.98		Leaf litter (flood event?)																	
-1	10YR 4/2		8.119	8.57		Organic, wood debris @ 1.7'		MH/OH Organic silt, dark yellowish brown	25.82	63.7	10.39	0.29	0.00	0.00	103	91	12			5.8	66.1	28.1	33.9
-2																							

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.6'

BORING NUMBER: CMS-SD-4214 123-A

LOCATION (Lat/Long): 280007.41814 332950.41781

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]			8.83		Recent sediments - coarse sand, (subrounded, quartz), some organics; about 1/4" gelatinous material on top, hydrocarbon odor		SP	2.29	0.37	19.43	59.82	14.86	3.24									
	[illegible]			12.82		Organics, rootlets mixed with coarse sand, unable to define boundary		SP Poorly graded sand, dark yellowish brown							155	113	42	1.62	168	7.0	60.57	32.5	39.5
-1	[illegible]			7.46		Organics, rootlets, sticky, some root debris																	
-2	[illegible]					Channel lag deposits, gravel clast (1) subrounded, poorly sorted gravel ~ 1.0"																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 4.5'

BORING NUMBER: CMS-SD-4215 12B-D

LOCATION (lat/long): 280251.40151 332284.66623

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10YR 4/2			6.38		Organic silt to peat, rootlets @ top		MH/OH Organic silt, dark yellowish brown	13.27	73.09	13.40	0.24	0.00	0.00	96	84	12	2.00	141	5.2	80.1	34.8	40.0
-1	10YR 2/2n			7.85		Silt, organics, wood fragments, fine grained sand (foil wrapper @1.4')																	
-2	10YR 3/1n			8.37		Poor recovery - gap noticed before core was cut; organics, silt, odor, very moist; foil wrapper @ 2.0'																	
-3	10YR 2/2n					Coarse sand, (1.0 - 2.0" gravel) moist																	
-4	10YR 4/4					Coarse sand, gravel																	

PROJECT NAME: Centredale Manor Restoration Project **DATE: 5/7/03**

LOCATION: Woonasquatucket River, North Providence, RI **TOTAL DEPTH: 3.2'**

BORING NUMBER: CMS-SD-4216 138-A

LOCATION (lat/long): 280629.99966 332075.26407

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10YR 4/2			6.17		Heavy organics, roots at top; Some woody debris at top		MH/OH Sandy organic silt, dark yellowish brown	14.04	53.99	30.71	1.06	0.20	0.00	98	76	22	2.37	114	6.0	52.1	41.9	47.9
-1																							
-2	10YR 5/6			8.79		Clay layer																	
	10YR 4/1			6.24		Sand, coarse, one large clast																	
-3																							

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 3.4'

BORING NUMBER: CMS-SD-4217 136-B

LOCATION (lat/long): 280540.28703 332197.59199

Depth (ft)	Color	210-Pb/137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0				8.33		Leaves, roots, organics		SM Silty sand, dark yellowish brown	8.58	30.77	52.79	7.86	0.00	0.00	82	78	4	2.35	143	6.6	53.0	40.4	47.0
				2.01		Coarse grained		SP Poorly graded sand, dark yellowish brown	2.00	2.87	33.93	55.12	5.11	0.97	163	90	73						
-1				4.92		Organics, silt?																	
				12.31		Clay																	
-2				3.07		Fine-grained sand @ base, 10% mica																	
-3																							

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 4'

BORING NUMBER: CMS-SD-4218 152-A

LOCATION (lat/long): 279946.33100 332813.54899

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10YR 2/2		7.83	7.62		Organics, silt, grass, leaf litter		MH/OH Organic silt, dark yellowish brown	25.37	72.57	2.00	0.07	0.00	0.00	167	101	66	2.33	188	5.9	80.7	33.4	39.3
			5.84																				
-1	1.0Y 2/2N			13.75		Peat, darker color, wood pieces (1.1' - 1.2' odor)																	
	1.0Y 3/6		9.875	9.82		Silt, fine-grained sand																	
-2	10Y 2/N			2.07		Organics, darker color, very moist																	
	10Y 4/1			9.76		Coarse to fine-grained sand (subangular quartz grains), silt, fining-upward sequence																	
-3	10Y 4/1					Coarse-grained sand, pebbles (0.5 - 1.0" size); second fining-upward sequence.																	
-4																							

PROJECT NAME: Centredale Manor Restoration Project

LOCATION: Woonasquatucket River, North Providence, RI

BORING NUMBER: CMS-SD-4219 127-A

LOCATION (lat/long): 280158.17826 332735.66908

DATE: 5/7/03

TOTAL DEPTH: 3.7'

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0				10.37		Organic silt, rootlets, wood, leaf litter @top		MH/OH Organic silt, dark yellowish brown	23.60	62.56	11.28	1.60	0.94	0.00				1.88	204	7.0	63.9	29.1	36.1
-1				5.31		Organics, silt, more moist @ top									86	65	21			4.5	58.7	38.7	43.2
-2				0.34		Fine-grained sand, silt, rootlets, moist		SM	8.66	20.36	43.31	17.96	2.20	7.47									
-3						Fine-grained sand, pebbles, cobble (1.5 - 2.0")																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/7/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.1'

BORING NUMBER: CMS-SD-4220 122-A

LOCATION (lat/long): 279914.57543 333119.93841

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]		8.37	5.91		Dark organic layer - rootlets on top		MH/OH Sandy organic silt, dark yellowish brown	13.09	43.14	37.38	6.39	0.00	0.00	53	52	1	2.32	152	9.2	42.4	48.4	57.6
			9.653	3.43		Lighter than previous layer																	
-1			9.8334	6.17		Dark organic layer - roots																	
-2						Small, subrounded gravel @ very bottom - interval too small to sample																	

PROJECT NAME: Centredale Manor Restoration Project DATE: 5/8/03

LOCATION: Woonasquatucket River, North Providence, RI TOTAL DEPTH: 3.0'

BORING NUMBER: CMS-SD-4221 167-A

LOCATION (lat/long): 280702.45951 332109.87333

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0				12.31		Organics, rootlets @ top; color change @ 0.6'																	
-1				7.95		Organics (rootlets); woody debris throughout organic layer		MH/OH Organic silt with sand, dark yellowish brown	20.90	56.95	20.90	1.24	0.00	0.00	129	93	36	1.97	142	6.2	60.2	33.6	39.8
-2																							
-3						Cultural debris (plastic) - gravel lag deposits - subrounded																	

PROJECT NAME: Centredale Manor Restoration Project **DATE: 5/8/03**

LOCATION: Woonasquatucket River, North Providence, RI **TOTAL DEPTH: 3.1'**

BORING NUMBER: CMS-SD-4222 120-A

LOCATION (lat/long): 279785.68972 332936.02953

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]		5.62	8.15		Organics, roots		MH/OH Organic silt, dark yellowish brown	24.36	72.91	2.82	0.11	0.00	0.00				2.28	21.2	4.97	67.4	27.7	32.6
	[illegible]		1.85	11.23		Organics, very dark.																	
-1	[illegible]		0.0291	8.65		Organics		MH/OH Organic silt, dark yellowish brown	27.36	65.87	4.83	1.87	0.07	0.00	193	97	96			5.8	67.6	26.6	32.4
-2																							
-3	[illegible]					Did not take sample - coarse sand mixed with this layer of organics - poss. crossing of sediments																	
						Coarse sand, channel																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/8/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 1.2'

BORING NUMBER: CMS-SD-4223 120-B

LOCATION (lat/long): 279796.96218 333191.20672

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0				15.00		Organics, hydrocarbon odor												2.28	310	6.4	72.0	21.6	28.0
						Gap in core																	
-1						Clay layer																	
						Channel lag deposits, subrounded grains																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/8/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 4.4'

BORING NUMBER: LPX-SD-4201 188-A

LOCATION (lat/long): 275592.77104 333892.73874

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0			7.48	8.76		Organics, hydrocarbon odor									190	85	105	2.17	286	4.7	70.6	24.7	29.4
-1			0.0126	23.23		Organics, roots		MH/OH Organic silt, dark yellowish brown	30.11	55.22	13.84	0.71			273	188	105	1.92	222	8.5	71.6	19.9	28.4
-2																							
-3				21.02		Clay									143	90	53						
-4				26.99		Peat, roots Silt (light) Organics, roots Gravel - lag deposits																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/8/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 4.2'

BORING NUMBER: LPX-SD-4202 188-B

LOCATION (lat/long): 275623.92637 334048.48584

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10YR 4/1			0.18		Sand (fine)		SM Silty sand, dark yellowish brown	2.37	24.04	61.76	11.40	0.43	0.00									
	2.5Y 4/1					Sand (med) with organics																	
	2.5Y 4/1					Sand (fine) with gravel clasts throughout, subrounded to rounded																	
-1																							
-2																							
-3																							
	2.5Y 5/6			2.33		Clay (brown)																	
	10YR 2/1					Sand (fine to med)																	
-4				15.33		Organics with mica (<1%)																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/8/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 3.7'

BORING NUMBER: LPX-SD-4203 188-C

LOCATION (lat/long): 275613.70314 334321.18351

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0				9.17		Organics, wet, hydrocarbon odor		MH/OH Organic silt, dark yellowish brown	32.11	62.33	5.42	0.16	0.00	0.00	164	90	74	2.29	216	4.9	67.4	27.7	32.6
-1				5.27		Organics, darker (black) than above interval, wet, hydrocarbon odor																	
-2																							
						Fine sand																	
-3				8.54		Clay																	
				15.21		Organics, rootlets																	

PROJECT NAME: Centredale Manor Restoration Project

LOCATION: Woonasquatucket River, North Providence, RI

BORING NUMBER: LPX-SD-4204 179-A

LOCATION (Lat/long): 275794.91979 334183.99577

DATE: 5/8/03

TOTAL DEPTH: 3.8'

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]			7.94		Organic, hydrocarbon odor		MH/OH Organic silt, dark yellowish brown	32.11	62.37	5.42	0.16	0.00	0.0	164	90	74	2.29	216	4.9	67.4	27.7	
-1																							
-2				5.98		Organics																	
				1.16		Clay																	
						Clay with organics																	
-3						Distinct layering (alt silt, clay?) Mica < 1.0%, minor iron staining																	
				0.33		Fining upwards - med to fine sand																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/8/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 3.5'

BORING NUMBER: LPX-SD-4205 199-A

LOCATION (lat/long): 276413.41998 333939.41415

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]			12.17		Organic, hydrocarbon odor		MH/OH Organic silt, dark yellowish brown	36.36	62.10	1.53	0.00	0.00	0.00	113	90	23	1.91	387	5.0	77.0	18.0	23.0
-1																							
-2	[illegible]			7.02		Organic, hydrocarbon odor, more silt		MH/OH Organic silt, dark yellowish brown	29.78	67.83	2.29	0.12	0.00	0.00	157	96	61	2.26	200	4.9	65.6	29.5	34.4
-3				18.35		Organics, hydrocarbon odor, rootlets																	

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/8/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.3'

BORING NUMBER: LPX-SD-4206 206-A

LOCATION (lat/long): 276809.38726 333726.08198

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]			9.16		Organic, hydrocarbon odor, clay @ 1' - not very consolidated		MH/OH Organic silt, dark yellowish brown	27.26	67.30	4.74	0.45	0.23	0.00	178	85	93	1.87	258	5.3	68.3	26.4	31.7
-1				18.02		Organic wood debris right above gravel, hydrocarbon odor													282	5.8	70.8	23.4	29.2
-2	[illegible]					Gravel, channel lag, subrounded, poorly graded		GP Poorly graded gravel w/sand, dark yellowish	1.23	3.51	6.66	9.98	1.46	77.16									

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/8/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.3'

BORING NUMBER: LPX-SD-4207 217-A

LOCATION (lat/long): 277166.45713 334024.20703

Depth (ft)	Color	210-Pb/137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10YR2/1		3.778	9.96		Organic, color change @ 1.5', hydrocarbon odor, organic debris @ top									106	76	30	2.17	71				
-1			1.41	7.89																			
-2																							

PROJECT NAME: Centredale Manor Restoration Project

DATE: 5/6/03

LOCATION: Woonasquatucket River, North Providence, RI

TOTAL DEPTH: 2.8'

BORING NUMBER: LPX-SD-4208 223-A

LOCATION (lat/long): 277580.65722 333388.51628

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]		4.31	7.89		Organic, wet, hydrocarbon odor		MH/OH Sandy organic silt, dark yellowish brown	18.17	50.26	29.43	1.53	0.60	0.00	79	67	12	2.22	214	5.7	68.6	27.8	33.5
-1	[illegible]		3.75	10.00		Organic, sand lens (1/4')		MH/OH Organic silt with sand, dark yellowish brown	11.74	68.25	19.96	1.89	0.16	0.00	61	54	7	2.10	223	5.2	67.0	27.8	27.8
-2			0.0113																				
						Lag deposits, coarse sand																	

PROJECT NAME: Centredale Manor Restoration Project DATE: 5/9/03

LOCATION: Woonasquatucket River, North Providence, RI TOTAL DEPTH: 3.6'

BORING NUMBER: LPX-SD-4209 219-A

LOCATION (Lat/long): 277346.60111 333709.78901

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	[illegible]		3.17	3.53		Organic - hydrocarbon odor		MH/OH Organic silt, dark yellowish brown	26.42	68.86	4.61	0.03	0.08	0.00				2.42	321	5.17	73.5	21.4	26.5
-1	[illegible]			1.25		Clay (wet) tan									37	35	2			2.7	37.7	59.8	62.3
-2	[illegible]		1.33	3.68		Organic, wood debris		MH/OH Organic silt, dark yellowish brown	18.63	72.66	7.98	0.737	0.00	0.00				1.70	245	6.0	70.4	23.6	29.6
-2	[illegible]			3.88		Clay with some wood debris, very stiff									95	73	22						
	[illegible]					Lag deposits																	

PROJECT NAME: Centredale Manor Restoration Project **DATE: 5/9/03**

LOCATION: Woonasquatucket River, North Providence, RI **TOTAL DEPTH: 2.9'**

BORING NUMBER: LPX-SD-4210 193-A

LOCATION (Lat/long): *275946.78034 334302.89481*

Depth (ft)	Color	210-Pb / 137-Cs 1940 Time Horizon	Dioxin ppb (dry)	TOC (%)	Lithology	Field Description	Interval for Analysis	Lab Description	Clay (%)	Silt (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Gravel (%)	Liquid Limit	Plastic Limit	Plasticity Index	Specific Gravity	Water Content (%)	Ash (%)	Moisture (%)	Organic Matter (%)	Solids (%)
0	10YR 4/2			9.73		Organic, hydrocarbon odor		MH/OH Organic silt, dark yellowish brown	45.21	53.38	1.18	0.26	0.00	0.00				2.29	357	5.3	67.6	27.0	32.3
-1																							
	10YR 2/1			12.11		Organic (possible clay - more cohesive than above), hydrocarbon odor									215	118	97						
-2																							
	10YR 3/1			8.89		Sandy with organics - some wood debris																	
	10YR 5/1					Sand lens (low deposition)																	

Appendix C
Geochemical Interpretation

Preliminary Sedimentation Rate Calculations, and Estimated Age of Dioxin Samples from Woonasquatucket River Floodplain Cores

June E. Mirecki, Ph.D. Environmental Lab
US Army Engineer Research & Development Center, Vicksburg MS

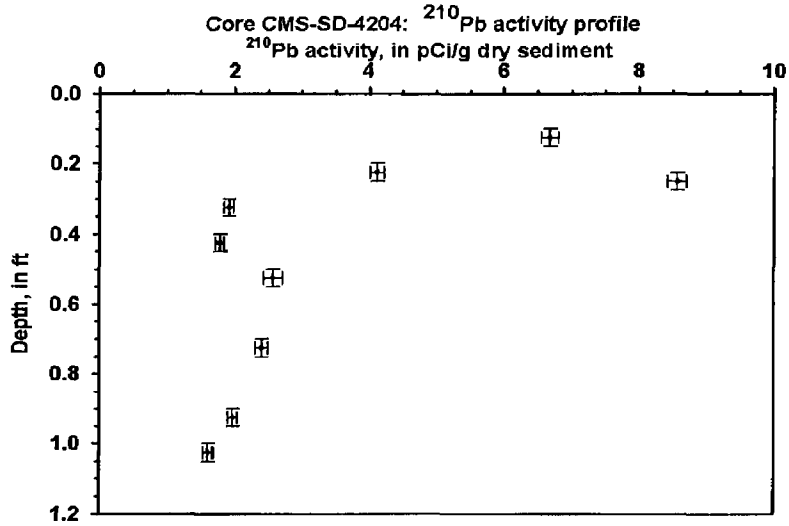
Apparent historical sedimentation rates were estimated in 9 of 10 cores obtained from the Woonasquatucket River floodplain during May, 2003. Core LPX-SD-4209 had insufficient sample data to calculate a sedimentation rate. Sedimentation rates were calculated only from ^{210}Pb data. Cursory inspection of ^{137}Cs data indicated that a large number of samples had activities that were below the minimum detection limit.

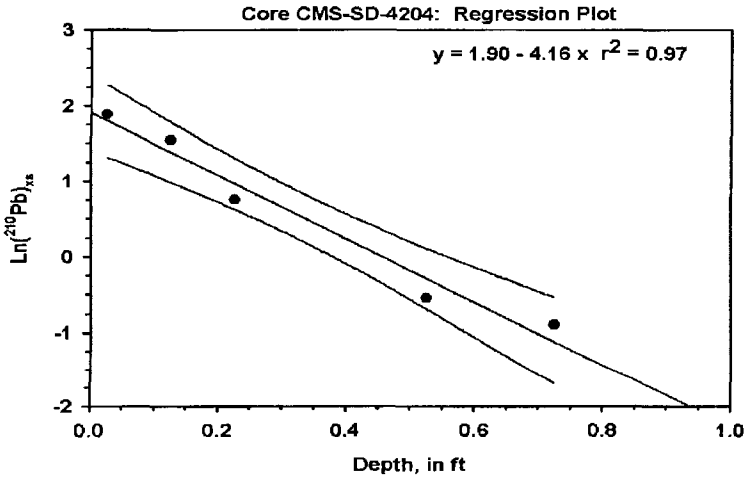
Apparent historical sedimentation rates are similar in each core, ranging from 0.007 to 0.021 ft/yr (0.23 to 0.49 cm/yr). These apparent historical sedimentation rates are generally low but consistent with other regional sedimentation chronologies. Apparent sedimentation rates presented below assume that sedimentation has been constant during the last century, and that there has been no post-depositional modification of floodplain sediment. Both of these assumptions represent and ideal environmental condition, and are unlikely to be fulfilled.

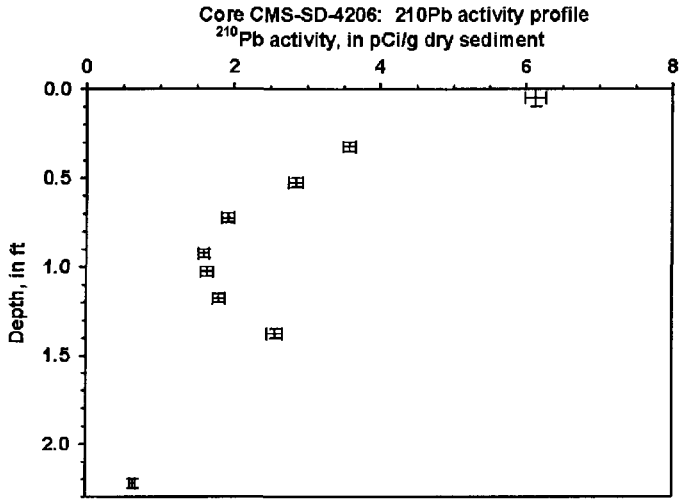
CORE	Surficial ^{210}Pb activity in pCi/g (Depth, ft)	Supported ^{210}Pb activity in pCi/g (No. of samples)	Slope of regression line (m)	Apparent Sedimentation Rate in ft/yr	Apparent Sedimentation Rate in cm/yr
CMS-SD-4204	8.57+/- 0.146 (0.0 – 0.05)	2.00 +/- 0.39 (n=3)	-4.16	0.007	0.23
CMS-SD-4206	6.13 +/- 0.147(0.0 – 0.10)	1.67 +/- 0.97 (n=3)	-3.26	0.010	0.29
CMS-SD-4209	5.57 +/- 0.25 (0.10 – 0.15)	1.16 +/- 0.35 (n=5)	-1.94	0.016	0.49
CMS-SD-4210	4.36 +/- 0.079 (0.10 – 0.15)	1.19 +/- 0.27 (n=3)	-1.47	0.021	0.64
CMS-SD-4212	5.45 +/- 0.538 (0.10 – 0.15)	0.95 +/- 0.33 (n=5)	-2.82	0.011	0.34
CMS-SD-4213	4.18 +/- 0.307 (0.10 – 0.15)	1.28 +/- 0.47 (n=6)	-2.23	0.014	0.43
CMS-SD-4218	8.59 +/- 0.301 (0.10 – 0.15)	1.31 +/- 0.07 (n=3)	-2.36	0.013	0.40
CMS-SD-4219	2.24 +/- 0.064 (0.30 – 0.35)	0.52 +/- 0.02 (n=2)	-2.83	0.011	0.33
CMS-SD-4222	4.35 +/- 0.263 (0.10 – 0.15)	1.10 +/- 0.36 (n=4)	-1.81	0.017	0.52
LPX-SD-4201	3.72+/- 0.292 (0.10 – 0.15)	0.56 +/- 0.13 (n=3)	-2.91	0.011	0.33

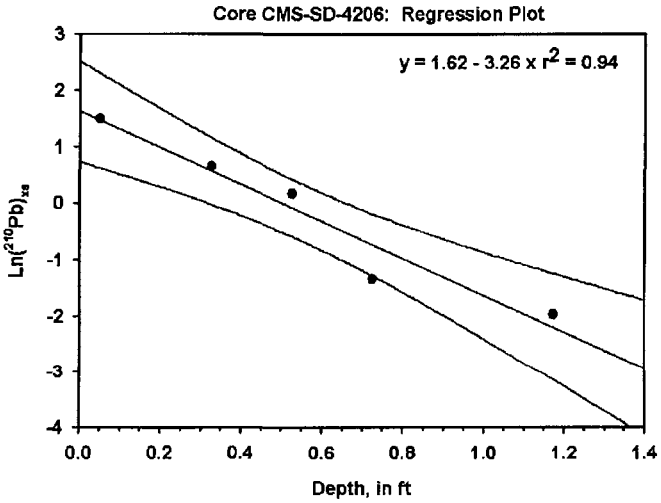
Table 1. Apparent historical sedimentation rates of Woonasquatuket River floodplain cores, calculated from ^{210}Pb isotope data.

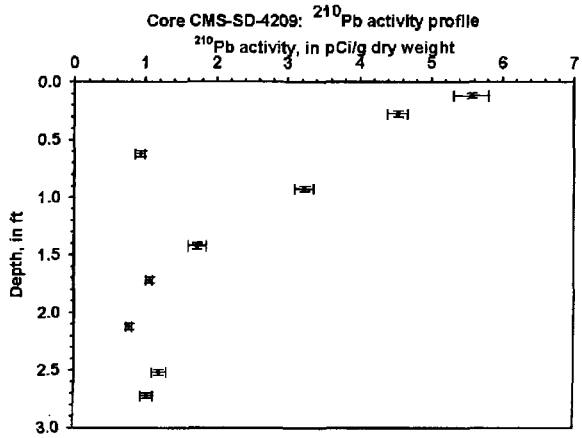
Apparent sedimentation rates combined with the historical information on dioxin deposition will permit selection of appropriate sediment samples for dioxin analysis. For example, assume that dioxin deposition began in the Woonasquatucket River floodplain at 1940, 63 years before present. If sedimentation rate is 0.007 ft/yr, then sediment deposited 63 years ago would be 0.44 ft below the top of the core (0.007 ft/yr * 63 yr = 0.44 ft/yr). Sediment lower than 0.44 ft should be uncontaminated, given no post-depositional disruption.

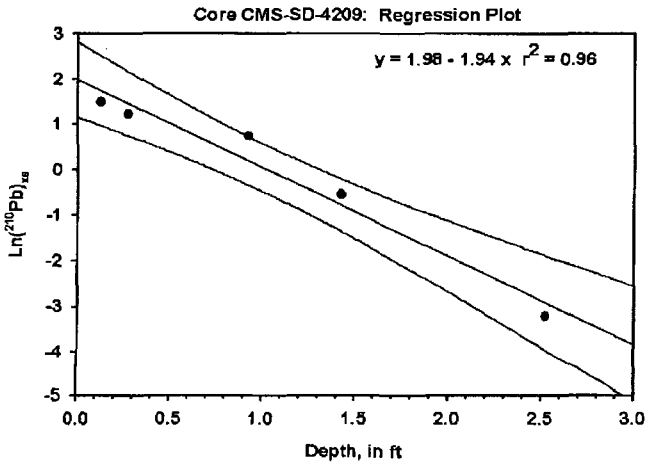

Core CMS-SD-4204: 210Pb activity profile
210Pb activity, in pCi/g dry sediment
0
2
4
6
8
10
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Depth, in ft

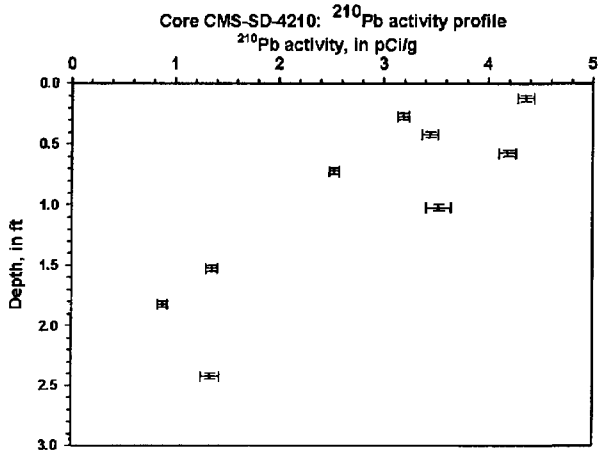

Core CMS-SD-4204: Regression Plot
y = 1.90 - 4.16 x r2 = 0.97
3
2
1
0
-1
-2
Ln(210Pb)xs
0.0
0.2
0.4
0.6
0.8
1.0
Depth, in ft

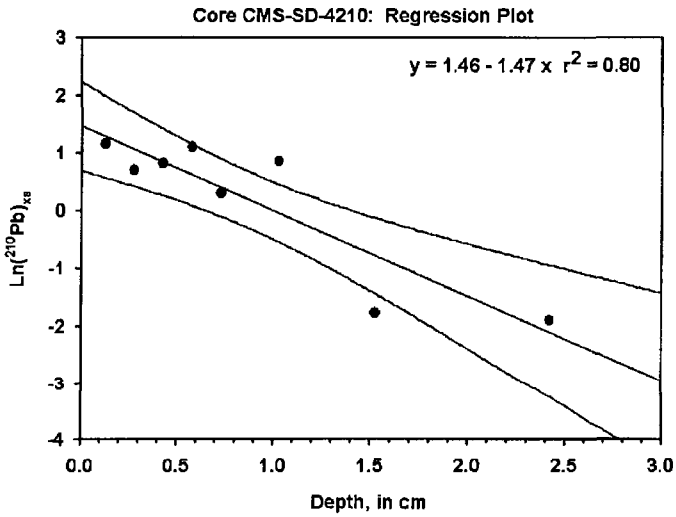

Core CMS-SD-4206: 210Pb activity profile
210Pb activity, in pCi/g dry sediment
0
2
4
6
8
0.0
0.5
1.0
1.5
2.0
Depth, in ft

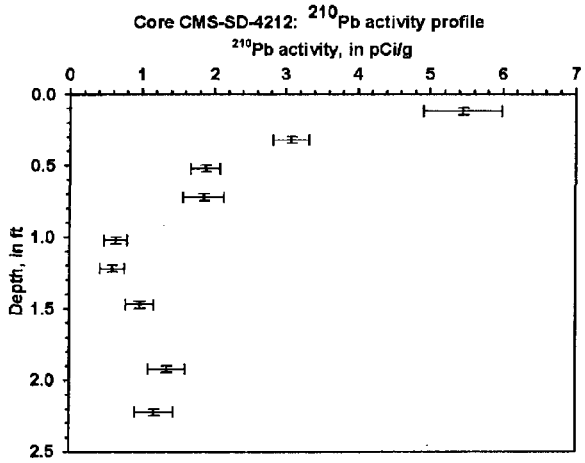

Core CMS-SD-4206: Regression Plot
y = 1.62 - 3.26 x r2 = 0.94
3
2
1
0
-1
-2
-3
-4
Ln(210Pb)xs
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Depth, in ft

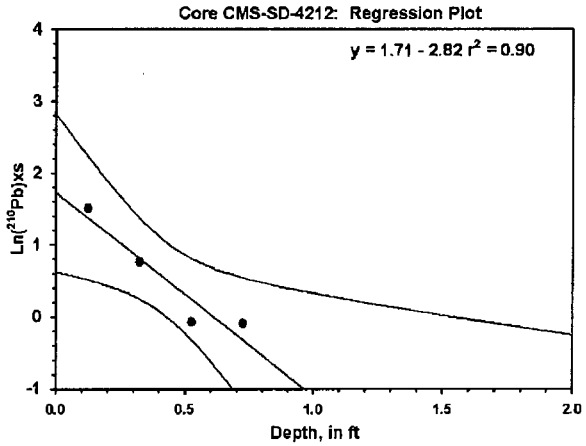

Core CMS-SD-4209: 210Pb activity profile
210Pb activity, in pCi/g dry weight
0
1
2
3
4
5
6
7
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth, in ft

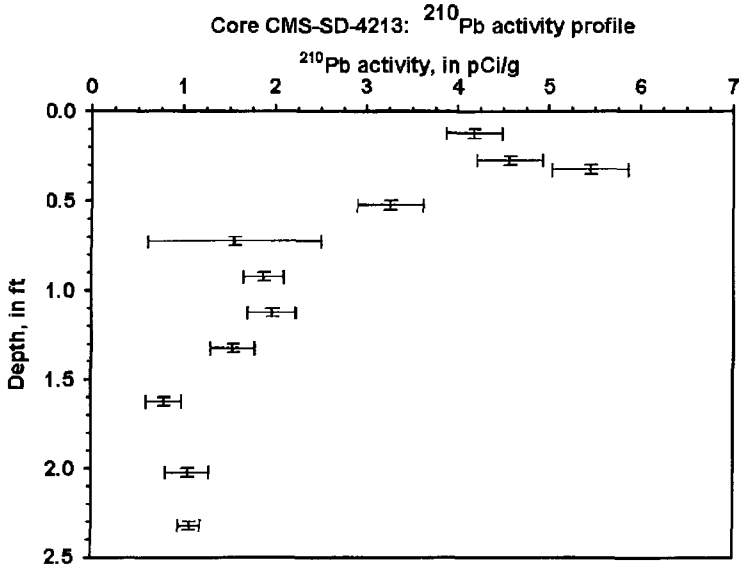

Core CMS-SD-4209: Regression Plot
y = 1.98 - 1.94 x r2 = 0.96
3
2
1
0
-1
-2
-3
-4
-5
Ln(210Pb)xs
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth, in ft

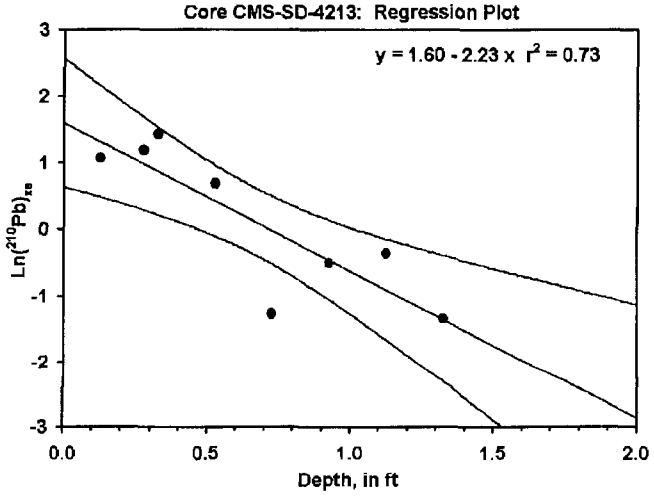

Core CMS-SD-4210: 210Pb activity profile
210Pb activity, in pCi/g
0
1
2
3
4
5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth, in ft

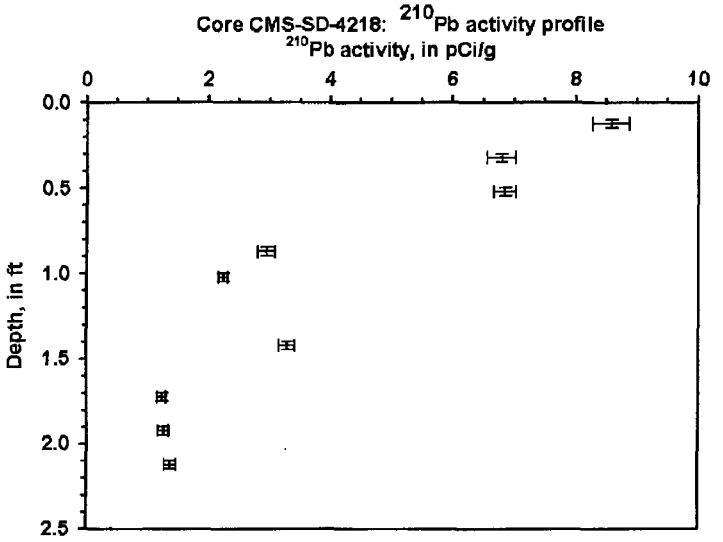

Core CMS-SD-4210: Regression Plot
y = 1.46 - 1.47 x r2 = 0.80
3
2
1
0
-1
-2
-3
-4
Ln(210Pb)xs
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth, in cm

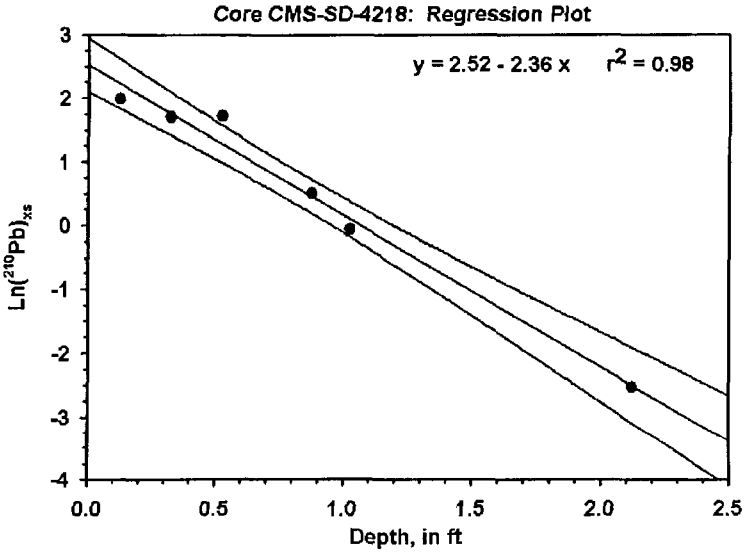

Core CMS-SD-4212: 210Pb activity profile
210Pb activity, in pCi/g
0
1
2
3
4
5
6
7
0.0
0.5
1.0
1.5
2.0
2.5
Depth, in ft

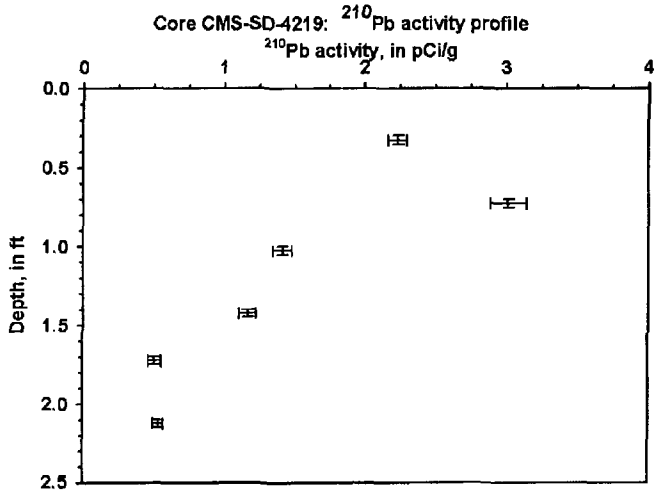

Core CMS-SD-4212: Regression Plot
y = 1.71 - 2.82 r2 = 0.90
4
3
2
1
0
-1
Ln(210Pb)xs
0.0
0.5
1.0
1.5
2.0
Depth, in ft

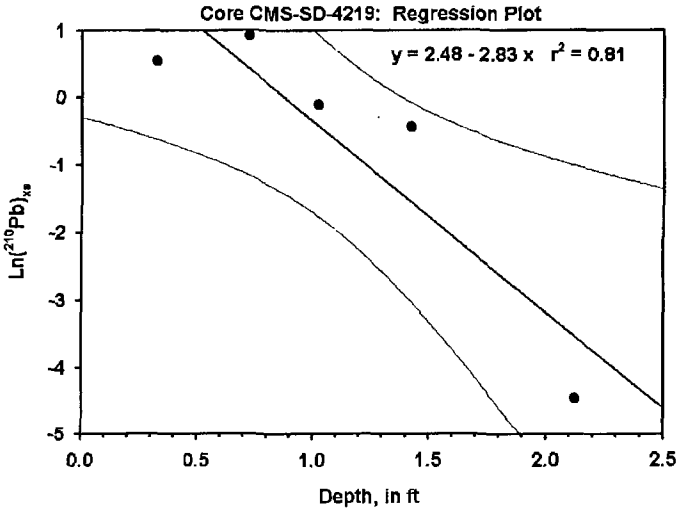

Core CMS-SD-4213: 210Pb activity profile
210Pb activity, in pCi/g
0
1
2
3
4
5
6
7
0.0
0.5
1.0
1.5
2.0
2.5
Depth, in ft

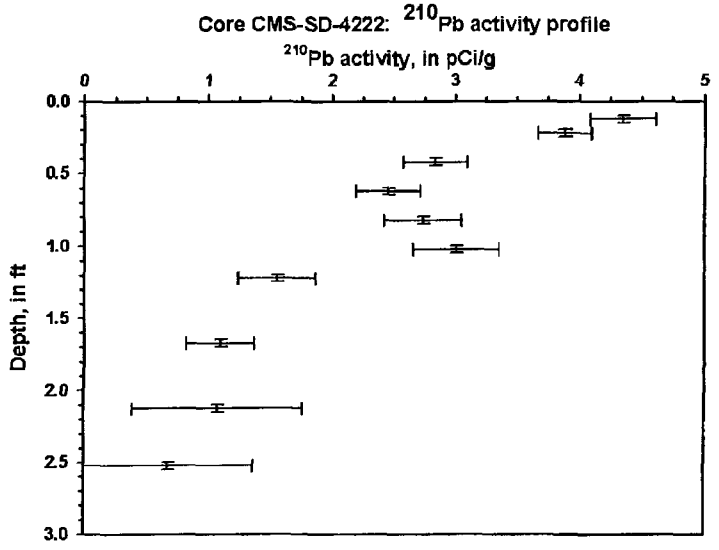

Core CMS-SD-4213: Regression Plot
y = 1.60 - 2.23 x r2 = 0.73
3
2
1
0
-1
-2
-3
Ln(210Pb)xs
0.0
0.5
1.0
1.5
2.0
Depth, in ft

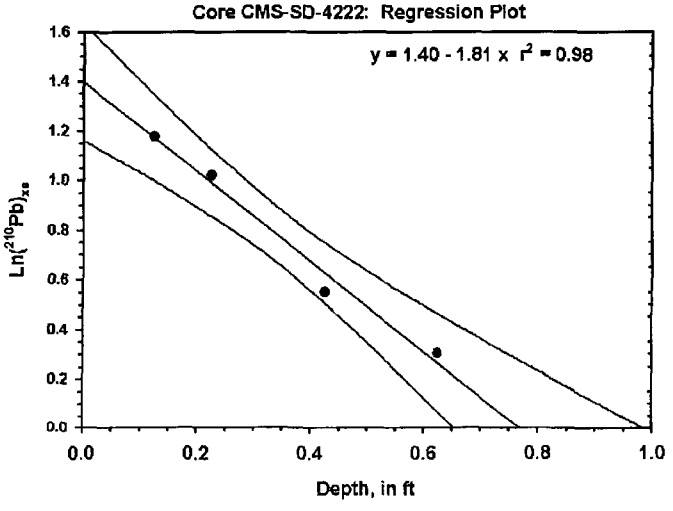

Core CMS-SD-4218: 210Pb activity profile
210Pb activity, in pCi/g
0
2
4
6
8
10
0.0
0.5
1.0
1.5
2.0
2.5
Depth, in ft

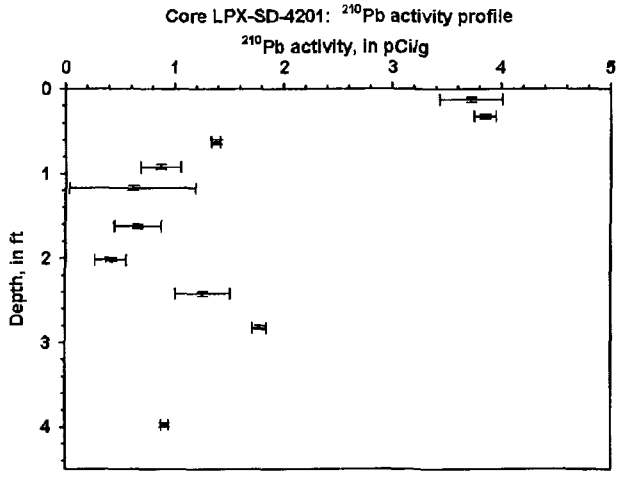

Core CMS-SD-4218: Regression Plot
y = 2.52 - 2.36 x
r2 = 0.98
3
2
1
0
-1
-2
-3
-4
Ln(210Pb)xs
0.0
0.5
1.0
1.5
2.0
2.5
Depth, in ft

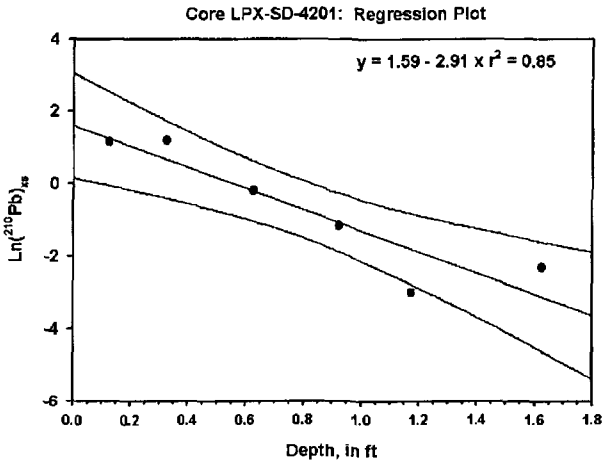

Core CMS-SD-4219: 210Pb activity profile
210Pb activity, in pCi/g
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
Depth, in ft


Core CMS-SD-4219: Regression Plot
y = 2.48 - 2.83 x r2 = 0.81
1
0
-1
-2
-3
-4
-5
Ln(210Pb)xs
0.0
0.5
1.0
1.5
2.0
2.5
Depth, in ft


Core CMS-SD-4222: 210Pb activity profile
210Pb activity, in pCi/g
0
1
2
3
4
5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth, in ft


Core CMS-SD-4222: Regression Plot
y = 1.40 - 1.81 x r2 = 0.98
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Ln(210Pb)xs
0.0
0.2
0.4
0.6
0.8
1.0
Depth, in ft


Core LPX-SD-4201: ^{210}Pb activity profile
^{210}Pb activity, in pCi/g
0
1
2
3
4
5
Depth, in ft
0
1
2
3
4


Core LPX-SD-4201: Regression Plot
y = 1.59 - 2.91 x r^2 = 0.85
Ln(^{210}Pb)$_{xs}$
4
2
0
-2
-4
-6
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Depth, in ft