DETERMINING RECENT SEDIMENTATION RATES OF THE NUECES RIVER SYSTEM, TEXAS

by

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CONTENTS

Figures

Tables

vii

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INTRODUCTION

Replacement of wetlands by water and barren flats in the lower alluvial valley and delta of the Nueces River suggests that relative sea-level rise and reductions in sediment supply have rendered the Nueces fluvial-deltaic system incapable of maintaining sufficient elevation to prevent its submergence. The Nueces River system has in the past transported a significant load of suspended sediment (Longley, 1992a), but the construction of upstream dams and reservoirs has greatly reduced the volume of sediment reaching deltaic marshes and other wetland habitats. Still, losses in deltaic environments along the Nueces River have been smaller than in other deltas of the Texas coast (White and Calnan, 1991), so there remains a potential for the Nueces River to deliver enough sediment to offset subsidence and submergence.

Objectives

The principal objectives of this study were to determine past rates of sedimentation and relative sea-level rise for a fluvially dominated area along the Nueces River upstream from the delta. This information will be used by the Texas Water Development Board to determine the frequency, duration, and magnitude of river flooding necessary to offset submergence of wetlands (Longley, 1992b). Sedimentation rates are based on activities of ^{210}Pb measured in 11 cores collected in the study area (fig. 1). Rates of relative sea-level rise are based on National Ocean Service (NOS) benchmark releveling surveys, USGS reports, NOS tide gauge data, and data on relative sea-level rise presented by Paine (1993).

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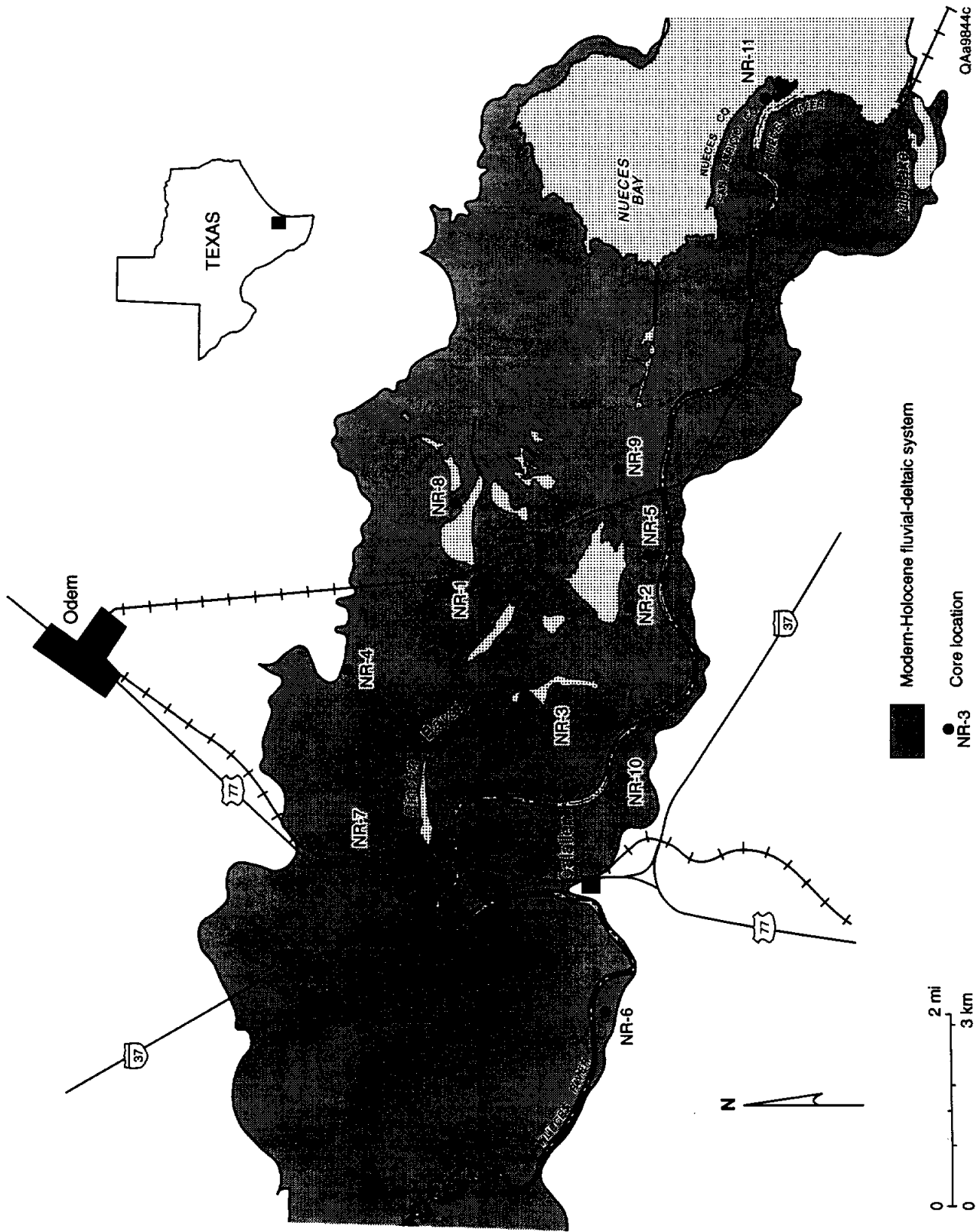
Figure 1. Index map of study area showing locations of coring sites.

2

Natural Environments in the Study Area

Natural environments of the Nueces River system and alluvial valley in the study area (fig. 1) consist of salt, brackish, and fresh marshes; transitional areas; flats; open water (including lakes and abandoned river channels); fluvial woodlands, and uplands (White and others, 1983). These habitats have developed on alluvial valley fill within the entrenched valley. Inland parts of the alluvial valley are dominated by fluvial processes in contrast to deltaic areas where estuarine processes are more influential.

Average monthly median salinities in the upper part of Nueces Bay fluctuate around 21.7 ppt (Texas Department of Water Resources, 1981). However, depending on fresh-water inflows, salinities can drop to less than 1 ppt or exceed 40 ppt (Holland and others, 1975).

The Nueces River delta is generally characterized by salt marshes with salinities decreasing up the valley. In the study area, marshes are reflective primarily of salt to brackish conditions. Upstream from Interstate Highway 37, fresh marshes occur.

Modern–Holocene Valley-Fill Deposits

Sediments in the Nueces River valley fill near Interstate Highway 37 are dominated by thick fluvial sand deposits, locally exceeding 12 m, which are overlain by thin flood basin mud deposits that vary in thickness from 1.2 to 3 m (fig. 2). The depth of the modern river channel is slightly greater than the thickness of the mud deposits; consequently, the channel is floored by sandy sediments and bars.

Human Modifications Potentially Affecting Sedimentation

Among major human modifications in the Nueces River alluvial valley are two Missouri-Pacific (MOPAC) railroad embankments (completed before 1930), State Highway 9 (completed in 1933, preceding IH-37), Interstate Highway 37 (constructed in the late 1950s—early 1960s) (fig. 1), and Lake Corpus Christi (created originally in 1929, Mathis Dam, and enlarged in 1958, Seale Dam). Lake Corpus Christi is

3
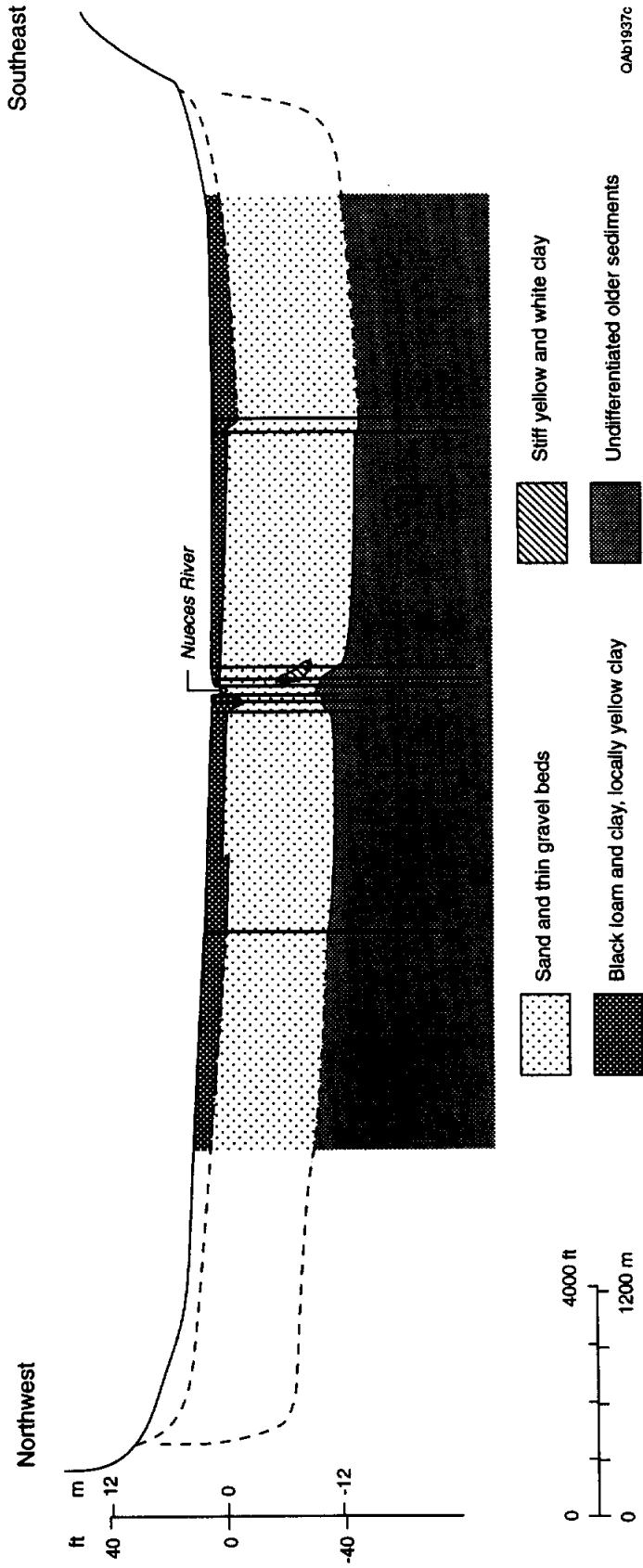
Figure 2. Cross section of Holocene sediments in the Nueces River entrenched valley at U.S. Highway 77. The lithology and thickness of sediments are based on geotechnical surveys made by the Texas Department of Transportation.

4

approximately 50 km upstream from the mouth of the Nueces River. Major alterations caused by MOPAC railroads include approximately 3.7 linear km of fill for the westernmost tracks near U.S. Highway 77 where the valley is about 4.3 km wide and 5.3 km of fill along the easternmost tracks where the valley is about 5.9 km wide (fig. 1). Bridge openings totaling approximately 0.6 km in length are at the Nueces River, Rincon Bayou, and narrow drainages to the north. About 90 percent of the valley is effectively dammed by the railroad fill. At IH-37, approximately 85 percent (4.35 linear km) of the valley is dammed by road fill for the highway.

The effects of human modifications in the study area on marsh sedimentation are not fully understood. It is obvious that flow patterns during flood events have been altered substantially by the MOPAC railroads and highway crossings, which extend across the valley diverting flow through bridge openings. Intuitively, one would expect sedimentation rates to be slightly higher upstream of the railroads and highway due to the partial damming effect. During floods the flow barriers may locally reduce currents and elevate water levels for longer periods of time allowing more sediments to settle upstream. However, variations in sedimentation rates, which are minimal, seem to be influenced more by the geomorphic setting and relationship of a site to the river and relict channels, rather than by location upstream or downstream of the road embankment. There is also the possibility that sediment deposition during hurricane storm surge flooding may compensate for reductions in sediment supplied to downstream sites during river flooding.

Among other artificial changes in the Nueces River valley is a 2.5-km-long navigation channel dredged for oil and gas exploration and production before the 1950s. The channel extends from the bay shoreline westward through marshes north of the river. Dredged material was deposited on mounds on the south side of the channel. No coring sites are near the channel.

Another modification to deltaic marshes is a marsh creation project that was begun in the late 1980s under the direction of the Port of Corpus Christi Authority and the U.S. Army Corps of Engineers. Approximately 80 ha was excavated in a high salt marsh (Spartina spartinae) to create an area of approximately 36 ha of intertidal marsh (Nicolau, 1995). Planted emergent vegetation consisted primarily

5

of *Spartina alterniflora*. The marsh is a mitigation project for developing a spoil disposal area near the Corpus Christi Ship Channel. The initial effort to establish *Spartina alterniflora* at the site was a failure because of incorrect elevation and slope of designated areas and higher than optimal salinity for *Spartina alterniflora* growth (Ruth, 1990; Nicolau and Adams, 1993; Nicolau, 1995). Core NR-9 is about 75 m from the edge of the site. In April of 1995, when cores were taken, the marsh restoration site was characterized primarily by open water.

Historical Wetland Losses

In the Nueces River valley, more than 122 ha of marsh habitat was lost between the 1930s and 1979 (White and Calnan, 1990). The losses were a result of the transformation of emergent vegetation to open water and barren flats, primarily in the delta near Nueces Bay (fig. 3). Progradation ended sometime between 1930 and 1959 (Morton and Paine, 1984). Among the probable causes for the losses in wetlands are reductions in the volume of fluvial sediments reaching the delta and relative sea-level rise.

Suspended fluvial sediment reaching Nueces Bay has been reduced from 750,000 tons/yr during the first half of this century to approximately 40,000 tons/yr from 1970 to 1980 (Morton and Paine, 1984). This large reduction in sediment is caused primarily by Lake Corpus Christi.

Compounding the problem of reduced sediment supply is a rise in relative sea level. Rates of relative sea-level rise at benchmarks in the Nueces River valley along MOPAC near U.S. Highway 77 locally exceed 6 mm/yr, which is approximately three to five times higher than regional and eustatic sea-level rise (Gornitz and Lebedeff, 1987). A more detailed discussion of subsidence and sea-level rise rates is presented in the section titled "Relative Sea-Level Rise."
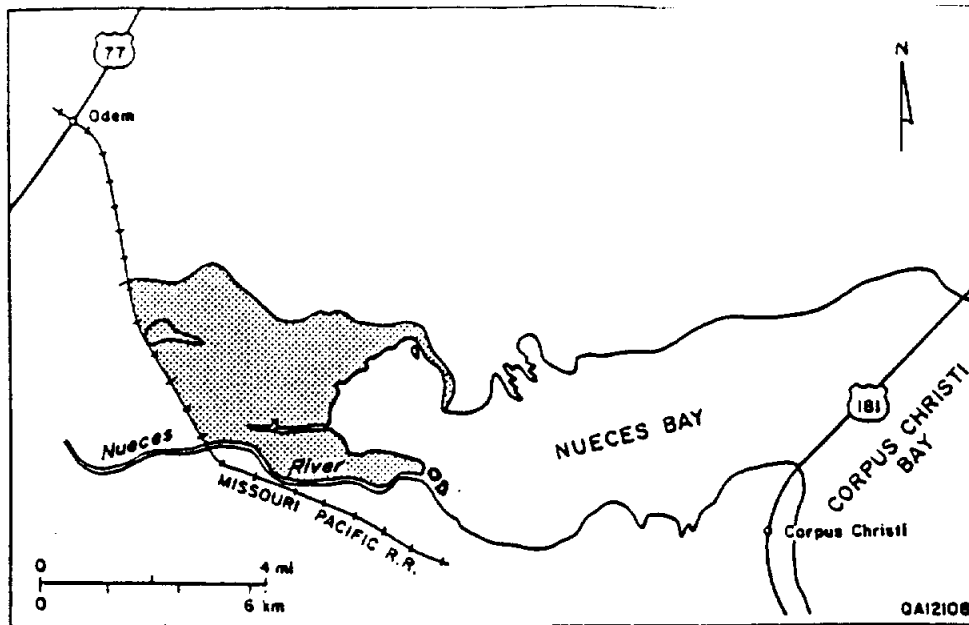
Nueces River delta index map and historical sequence of vegetated areas (in black) for the years 1930, 1959, 1975, and 1979.
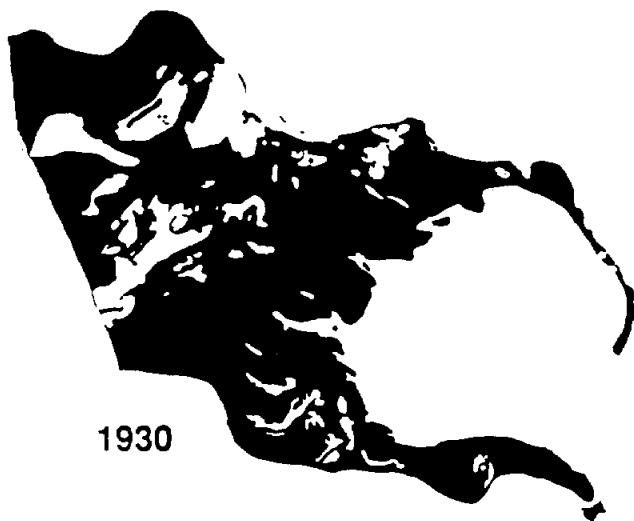
1930

1959

1975

1979

Figure 3. Historical changes in the distribution of vegetated areas (primarily marshes) in the Nueces River delta. From White and Calnan (1990).

7

METHODS

Field Methods

Site Selection

Eleven sites were selected for coring in the Nueces River alluvial valley (fig. 1). Criteria used in selecting sites included location with respect to the modern Nueces River channel and abandoned channels such as Rincon Bayou; location with respect to the estuarine system, relative elevations, susceptibility to flooding, and types of wetland vegetation; and location with respect to existing human modifications. The approach was to sample several different wetland environments but avoid local human alterations that may have affected sedimentation rates.

Coring sites were located throughout the alluvial valley. Ten sites are located downstream from IH-37 and one is located upstream (fig. 1). Four sites are within 300 m of the river; others are at distances of about 500, 700, and 1,200 m. The remaining four core sites are north of Rincon Bayou at distances of about 200, 400, 800, and 1,900 m from the bayou. One site is near the mouth of the Nueces River at the edge of Nueces Bay, but all other sites are more than 3 km upstream from the bay shoreline, which places them in wetland areas thought to be influenced more by riverine sedimentary processes than by estuarine processes.

Site Description

Wetland coring sites include salt-water marshes characterized by assemblages of *Spartina alterniflora* and *Salicornia-monanthochloe-Suaeda*; brackish-water marshes characterized by *Spartina spartinae, Borrichia frutescens,* and *Distichlis spicata*; and fresh to brackish assemblages of *Scirpus californicus, Typha, Scirpus maritimus,* and *Eleocharis* (table 1). Estimated elevations range from approximately 1.2 m to less than 0.3 m. Coring sites NR-1 and NR-7 had the highest estimated elevations, and site NR-11 had the lowest (table 1). Sites in high marshes and transitional areas, characterized by *Spartina spartinae* and *Borrichia frutescens,* were generally at higher elevations and were the most difficult to core because of dry soils and increasing stiffness of clay with depth. Low marshes composed

8

Table 1. Date of collection, core lenths, elevation, and vegetation at Nueces River coring sites.

Core number	Date cored	Core tube length (cm)	Measured core length (cm)	Estimated elevation (m)	Predominant species	Other species nearby
NR-1	4/25/95	101.2	53.3	1.2	Spartina spartinae, local eleocharis	
NR-2	4/24/95	100.9	64.5	0.6 to 0.9	Scirpus Californicus, Typha sp.	Distichlis, Borrichia, Batis, Salicornia, Monanthochloe
NR-3	4/24/95	100.7	57	0.6 to 0.9	Eleocharis sp.	Borrichia, Sesbania, Spartina spartinae, Distichlis or Paspalum
NR-4	4/25/95	101.5	48.5	0.9	Distichlis spicata, scattered S. maritimus	
NR-5	4/25/95	101.5	42	0.9 to 1.2	Salicornia, Monanthochloe, scattered Sueada	
NR-6	4/25/95	100.8	39	0.9 to 1.2	Typha sp., Scirpus maritimus	
NR-7	4/24/95	100.0	50.0	1.2	Spartina spartinae	
NR-8	4/26/95	100.8	76	0.9	Monanthochloe littoralis	Salicornia, Batis
NR-9	4/26/95	100.7	62	0.9	Monanthochloe, Salicornia	
NR-10	4/27/95	98.5	53.5	1.2	Borrichia frutescens	Salicornia, Spartina spartinae
NR-11	4/27/95	101.2	71	0.15 to 0.3	Spartina alterniflora	Borrichia, Scirpus maritimus

predominantly of *Spartina alterniflora, Scirpus californicus, Typha, and Distichlis spicata* were less difficult to core because of softer and less compacted sediments. Sites were cored near the end of April 1995, when soils were very dry. In some cases, alternate sites, rather than those preselected on aerial photographs, were cored because of extremely dry conditions. When possible, cores were taken at sites with no evidence of surface disturbance such as burrows and cattle trails. However, effects of cattle tracks were difficult to avoid in most areas because grazing is widespread inland from the eastern MOPAC crossing.

Coring Methods

Cores of the marsh substrate were taken by twisting and, where necessary, driving a thin-walled, sharpened metal tube, approximately 1 m long and 11.5 cm in diameter. Lengths of sediment recovered varied depending on the difficulty of penetrating the substrate and the amount of shortening. Some sediment bypassing and thinning occurred in deeper sections of cores where stiff clayey sediments were encountered, especially in transitional area levee-flank environments. Cores were dug out of the marsh soils to minimize loss of material during extraction from the substrate. The end of each core was covered with rubber caps that were tightened down with ring clamps and taped. The cores were transported to the BEG Core Research Center for processing.

Core Shortening

The volume of unconsolidated sediments normally decreases with depth as a result of physical compaction, dewatering, and loss of organic matter. For some depth-dependent relationships, the natural compaction is taken into account and the data are normalized to equate values near the top of the core with those near the bottom of the core. Physical properties affected by natural compaction, such as water content and bulk density, are used to remove the effect of compaction so that data throughout the core can be compared on a postcompaction basis.

In the wetland literature, few references are made to artificial compaction or thinning of wetland sediments caused by the coring operation. Some reports do not address the issue of artificial compaction, and others give only vague qualitative descriptions such as minor compaction. Few studies actually attempt to quantify the

magnitude of artificial compaction and to adjust those depth-dependent parameters derived from the core.

In this report we distinguish between natural compaction and artificial compaction by referring to artificial compaction as "shortening." Shortening commonly results during coring even if steps are taken to minimize it. Adjusting the stratigraphy of the core to remove the effects of shortening is necessary because any vertical displacement of the cored sediments with respect to their natural position will result in the calculation of inaccurate sedimentation rates. Sedimentation rates calculated from shortened cores will underestimate the actual rates of sedimentation.

Penetration of the core barrel into unconsolidated sediments typically causes some minor shortening of the sediments. The amount of shortening depends on the composition and textures of the sediments, their water content, and other physical properties such as bedding. Some muds are susceptible to high shortening, whereas well-sorted, water-saturated sands are essentially incompressible. The observed shortening can occur in one of two forms. The simplest form of shortening is the physical foreshortening of the sediment column as the water and void space are reduced. For this type of shortening all the strata are represented, and the stratigraphy of the core and surrounding undisturbed sediments is the same except that the strata within the shortened intervals are closer together. The most complex type of shortening involves drag along the core barrel and expulsion of sediment so that some strata are bypassed and are not recovered in the core barrel. This type of shortening can occur where stiff sediments overlie a zone of soft sediment, and the soft sediments are driven aside as the core barrel is shoved into the ground. Drag and bypassing of sediments are observed as distorted strata in the cores. The amount of distortion observed in the core and in the x-radiographs of the core reflects the degree of sediment shortening.

Shortening of each core from the Lavaca River was anticipated because the wetland sediments are composed predominantly of mud. As the core barrel was driven into the ground, the amount of sediment shortening was estimated by periodically measuring the distance to the sediment surface on the outside and inside of the core barrel (fig. 4). By making these two measurements and by knowing the length of the core barrel, total penetration of the core barrel, and core length, the
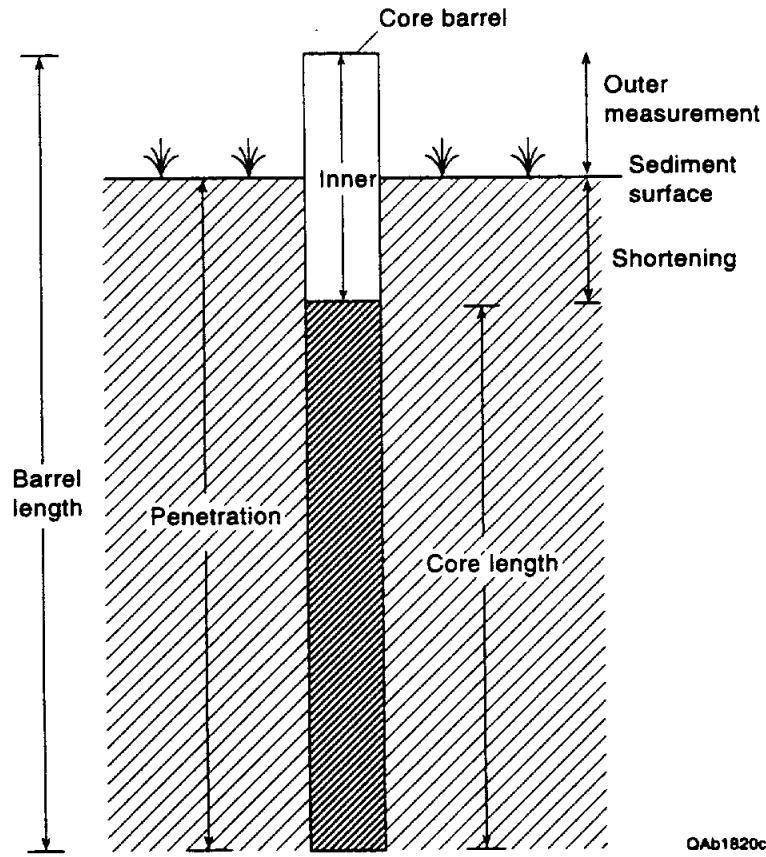
Figure 4. Illustration showing core shortening that may occur during coring.

amount of sediment shortening can be calculated (table 2 and Appendix A). The interval thickness and the amount of shortening for each interval also can be derived from these measurements (table 2) and used to illustrate the percent shortening and the depths at which it occurs. The field measurements and derived data also can be used to reconstruct the interval thickness before shortening and to calculate restored depths that are corrected for shortening (Appendix A). The depth corrections are used to adjust the core depths so that the lengths of the shortened intervals are restored to their unshortened lengths. This is done by calculating the amount of shortening (C_i) for each interval (i), calculating the amount of shortening for each one centimeter depth increment in the interval being corrected, and adding the fractional proportion of shortening to each depth increment. This procedure assumes that the shortening is uniformly distributed throughout the interval. The corrected depths have the numerical effect of "stretching" the core to its unshortened length.

The depth correction equation is given by:
$$D_c = P_{i-1} + (D_u - D_{u,i-1})(1 + (C_i - C_{i-1})/(D_{u,i} - D_{u,i-1})$$
where

D_c = corrected depth

D_u = uncorrected depth

$C_i = I_i - O_i$ = shortening of interval i

$P_i = O_0 - O_i$ = penetration of interval i

and the uncorrected depth of the lower boundary of the core for which corrections are being made is $D_{u,i} = P_i - C_i$.

Before applying the above equation, the appropriate interval (i) for D_u must be determined so that the proper values for shortening and penetration are used to calculate the correction factor.

Core shortening normally increases with depth, but it is not linear. In fact, the shortening curve for each core is different (Appendix A), and some cores are shortened more in the middle than at the top or the bottom. Although shortening is not linear for the entire core, it is assumed to be linear over the interval being corrected. This assumption is necessary because we do not have any information that would permit a more accurate correction.

Table 2. Total shortening and penetration of Nueces River cores and percent shortening calculated for each interval.

Core interval i	Outer reading O_i (cm)	Inner reading I_i (cm)	Total shortening C_i	Total penetration P_i	Depth of shortened interval $(D_{u,i})$	Interval shortening %
NR-1						
0	101.0	101.0	0.0	0.0	0.0	0.0
1	80.5	80.5	0.0	20.5	20.5	0.0
2	69.4	69.6	0.2	31.6	31.4	1.8
3	59.8	60.0	0.2	41.2	41.0	0.0
4	57.2	57.4	0.2	43.8	43.6	0.0
5	52.6	53.0	0.4	48.4	48.0	4.3
6	49.6	50.0	0.4	51.4	51.0	0.0
7	47.0	47.6	0.6	54.0	53.4	7.7
NR-2						
0	100.9	100.9	0.0	0.0	0.0	0.0
1	83.8	83.8	0.0	17.1	17.1	0.0
2	78.2	78.2	0.0	22.7	22.7	0.0
3	73.8	74.0	0.2	27.1	26.9	4.5
4	71.8	72.0	0.2	29.1	28.9	0.0
5	62.8	63.0	0.2	38.1	37.9	0.0
6	58.0	60.0	2.0	42.9	40.9	37.5
7	56.2	58.4	2.2	44.7	42.5	11.1
8	52.4	54.8	2.4	48.5	46.1	5.3
9	44.8	47.4	2.6	56.1	53.5	2.6
10	43.8	46.4	2.6	57.1	54.5	0.0
11	40.0	42.6	2.6	60.9	58.3	0.0
12	36.4	39.0	2.6	64.5	61.9	0.0
13	32.8	35.8	3.0	68.1	65.1	11.1
NR-3						
0	100.7	100.7	0.0	0.0	0.0	0.0
1	89.6	90.0	0.4	11.1	10.7	3.6
2	76.0	76.4	0.4	24.7	24.3	0.0
3	64.2	64.6	0.4	36.5	36.1	0.0
4	59.6	60.0	0.4	41.1	40.7	0.0
5	51.8	52.2	0.4	48.9	48.5	0.0
6	49.4	49.8	0.4	51.3	50.9	0.0
7	45.0	46.0	1.0	55.7	54.7	13.6
8	41.0	42.6	1.6	59.7	58.1	15.0

14

Table 2 (cont.)

Core interval i	Outer reading Oi (cm)	Inner reading Ii (cm)	Total shortening Ci	Total penetration Pi	Depth of shortened interval (Du,i)	Interval shortening %
			NR-4			
0	101.0	101.0	0.0	0.0	0.0	0.0
1	87.0	87.0	0.0	14.0	14.0	0.0
2	80.0	80.0	0.0	21.0	21.0	0.0
3	74.8	75.0*	0.2	26.2	26.0	3.8
4	70.2	70.4*	0.2	30.8	30.6	0.0
5	54.0	54.2	0.2	47.0	46.8	0.0
6	51.6	51.8	0.2	49.4	49.2	0.0
7	46.0	46.2	0.2	55.0	54.8	0.0
8	42.4	42.6	0.2	58.6	58.4	0.0
9	39.4	40.2	0.8	61.6	60.8	20.0

*Field data modified to avoid negative numbers.

			NR-5			
0	101.2	101.2	0.0	0.0	0.0	0.0
1	87.8	88.2	0.4	13.4	13.0	3.0
2	82.0	82.4*	0.4	19.2	18.8	0.0
3	72.4	72.8*	0.4	28.8	28.4	0.0
4	66.6	67.0	0.4	34.6	34.2	0.0
5	63.2	63.8	0.6	38.0	37.4	5.9
6	61.0	62.6	1.6	40.2	38.6	45.5
7	58.6	60.2	1.6	42.6	41.0	0.0
8	56.6	58.2	1.6	44.6	43.0	0.0

*Field data modified to avoid negative numbers.

			NR-6			
0	100.4	100.4	0.0	0.0	0.0	0.0
1	81.0	81.0	0.0	19.4	19.4	0.0
2	76.0	76.0	0.0	24.4	24.4	0.0
3	72.8	73.0	0.2	27.6	27.4	6.3
4	70.6	70.8	0.2	29.8	29.6	0.0
5	65.0	68.0	3.0	35.4	32.4	50.0
6	57.0	63.0	6.0	43.4	37.4	37.5
7	52.0	61.6	9.6	48.4	38.8	72.0

			NR-7			
0	100.0	100.0	0.0	0.0	0.0	0.0
1	86.0	86.0	0.0	14.0	14.0	0.0
2	81.0	81.0	0.0	19.0	19.0	0.0
3	79.8	79.8	0.0	20.2	20.2	0.0
4	71.8	71.8	0.0	28.2	28.2	0.0
5	66.6	66.6	0.0	33.4	33.4	0.0
6	60.4	60.4	0.0	39.6	39.6	0.0

Table 2 (cont.)

Core interval i	Outer reading Oi (cm)	Inner reading Ii (cm)	Total shortening Ci	Total penetration Pi	Depth of shortened interval (Du,i)	Interval shortening %
7	55.6	55.6	0.0	44.4	44.4	0.0
8	51.2	51.4	0.2	48.8	48.6	4.5
9	48.2	49.4	1.2	51.8	50.6	33.3

NR-8

0	100.6	100.6	0.0	0.0	0.0	0.0
1	89.0	89.0*	0.0	11.6	11.6	0.0
2	82.8	82.8	0.0	17.8	17.8	0.0
3	77.8	78.0	0.2	22.8	22.6	4.0
4	58.6	59.0	0.4	42.0	41.6	1.0
5	44.8	45.6	0.8	55.8	55.0	2.9
6	31.4	32.8	1.4	69.2	67.8	4.5
7	20.0	22.0	2.0	80.6	78.6	5.3

*Field data modified to avoid negative numbers.

NR-9

0	100.3	100.3	0.0	0.0	0.0	0.0
1	87.5	87.5	0.0	12.8	12.8	0.0
2	83.6	83.6	0.0	16.7	16.7	0.0
3	72.0	72.0	0.0	28.3	28.3	0.0
4	62.0	62.0	0.0	38.3	38.3	0.0
5	53.5	53.5	0.0	46.8	46.8	0.0
6	44.5	44.5	0.0	55.8	55.8	0.0
7	37.0	38.0	1.0	63.3	62.3	13.3

NR-10

0	98.5	98.5	0.0	0.0	0.0	0.0
1	79.0	79.0	0.0	19.5	19.5	0.0
2	74.0	74.0	0.0	24.5	24.5	0.0
3	61.0	61.0	0.0	37.5	37.5	0.0
4	55.0	55.0	0.0	43.5	43.5	0.0
5	49.5	50.5	1.0	49.0	48.0	18.2
6	45.0	47.0	2.0	53.5	51.5	22.2
7	42.0	45.0	3.0	56.5	53.5	33.3

NR-11

0	101.2	101.2	0.0	0.0	0.0	0.0
1	79.5	79.5	0.0	21.7	21.7	0.0
2	67.0	67.5	0.5	34.2	33.7	4.0
3	58.0	60.0	2.0	43.2	41.2	16.7
4	51.0	53.0	2.0	50.2	48.2	0.0
5	42.5	44.5	2.0	58.7	56.7	0.0
6	36.5	38.5	2.0	64.7	62.7	0.0
7	32.5	34.5	2.0	68.7	66.7	0.0
8	28.0	30.0	2.0	73.2	71.2	0.0

Most cores from the Nueces River system underwent some shortening, and most of the cores are shortened from 1 to 2 cm (table 2 and Appendix A). Core 1 is the least shortened (0.6 cm), whereas core 6 is the most shortened (9.6 cm). Most of the shortening in core 6 occurred below 30 cm. Core lengths estimated from the shortening and penetration measurements generally agree within 1 cm of the actual core length. Larger discrepancies between the depth of penetration and the length of core recovered suggest that some of the sediment dropped out of the end of the core barrel as it was being retrieved.

Laboratory Methods

Core Preparation and Handling

Cores were split in half by first cutting horizontally down each side of the metal tube and then by cutting the core in half with a thin wire or band saw. The top section of each core, and in several cases the entire core, was cut with a fine-toothed band saw to limit disturbance of the root-matted zone. The two half cores were then separated, each half retained in the half tube. One half of the core was wrapped in plastic, sealed in an airtight clear plastic liner, and transported to the USGS laboratory in Denver for x-radiography and analysis of ^{210}Pb and ^{226}Ra activity, moisture content, loss on ignition, bulk density, and texture.

The other halves of the cores were archived and retained in the BEG Core Research Center where they were subsampled for other physical and chemical analysis. Immediately after the cores were split, a measured volume of material was collected from near the top, middle, and bottom of each core for analysis of moisture content, chlorinity, and bulk density.

Each half core was trimmed with an osmotic knife and physically described. Information recorded on core description sheets included core depth, sediment color, sediment type (visual description), nature of contacts, textural trends, sedimentary structures, state of oxidation, and presence of accessories (organic material and caliche nodules). The cores were then photographed to produce large-format color prints and 35-mm slides.

17

When not in use, the archived core halves were covered with plastic wrap, placed in labeled boxes, and stored in a climate-controlled room. The archived core half serves as a permanent record of the sediment types encountered and the types of material sampled for textural and geochemical analyses.

Analytical Methods

^{210}Pb **Analysis.** Isotopic analysis of cores (Appendix B) was completed under the supervision of Dr. Charles Holmes of the U.S. Geological Survey using procedures developed by the USGS (Holmes and Martin, 1976; Martin and Rice, 1981), which is a modified version of that described by Flynn (1968) (Appendix C). The specific activity of ^{210}Pb was measured indirectly by determining the activity of the granddaughter isotope ^{210}Po. Samples were analyzed at 1-cm intervals down to a depth of 20 to 21 cm, below which analyses were at 2-cm intervals. Samples were separated by textural composition before isotopic analysis. Only the mud fractions (silt and clay, or particles <62 μm in size) were used in the ^{210}Pb analyses.

^{226}Ra **Analysis.** Isotopic analysis of ^{226}Ra, which is the source of supported ^{210}Pb, was completed under the supervision of Dr. Charles Holmes at the USGS. A representative sample was ground and placed in a counting cup. The cup was placed in a high-resolution planar gamma-ray detector (germanium, lithium-drifted) from which a spectrum was accumulated for 24 h. The resulting value was compared to a standard of known value and reported as disintegrations per minute per gram (dpm/g). The activity of ^{226}Ra was determined by analysis of ^{214}Bi, which has a strong gamma emission and is easy to measure. ^{214}Bi is one of several short-lived intermediate daughters of ^{226}Ra and is assumed to be in equilibrium with it (fig. 5) (Dr. Charles Holmes, personal communication, 1995). This relationship between ^{226}Ra and ^{214}Bi is also reported by Appleby and others (1988) and Brenner and others (1994).

The isotope ^{214}Bi is one of several short-lived intermediate daughters of ^{226}Ra; these daughters decay in a matter of minutes into ^{210}Pb (fig. 5). ^{226}Ra occurs in minerals in the sediments and is the source of the supported ^{210}Pb through the decay chain, including ^{222}Rn, shown in figure 5. The source of the "excess," or unsupported, ^{210}Pb is from ^{222}Rn that has outgassed into the atmosphere from multiple source areas (Robbins, 1978). Although there may be some "leakage" of

U 92	U238 4.6X10^{9}y		U234 2.5X10^{5}y					
Pa 91	α	Pa234 6.7h	α					
Th 90	Th234 24d		Th230 6.7h					
Ac 89			α					
Ra 88			Ra226 1622y					
Fr 87			α					
Rn 86			Rn222 3.8d					
At 85			α	At218 1.3s				
Po 84			Po218 3m	β α	Po214 2x10^{-4}s			Po210 138d
Bi 83			α	Bi214 20m	β α	Bi210 5d	β	α
Pb 82			Pb214 27m	β α	Pb210 22y	β α	■	
Tl 81				Tl210 1.3m	β α	Tl206 4.3m	β	
Hg 80					Hg206 9m	β		
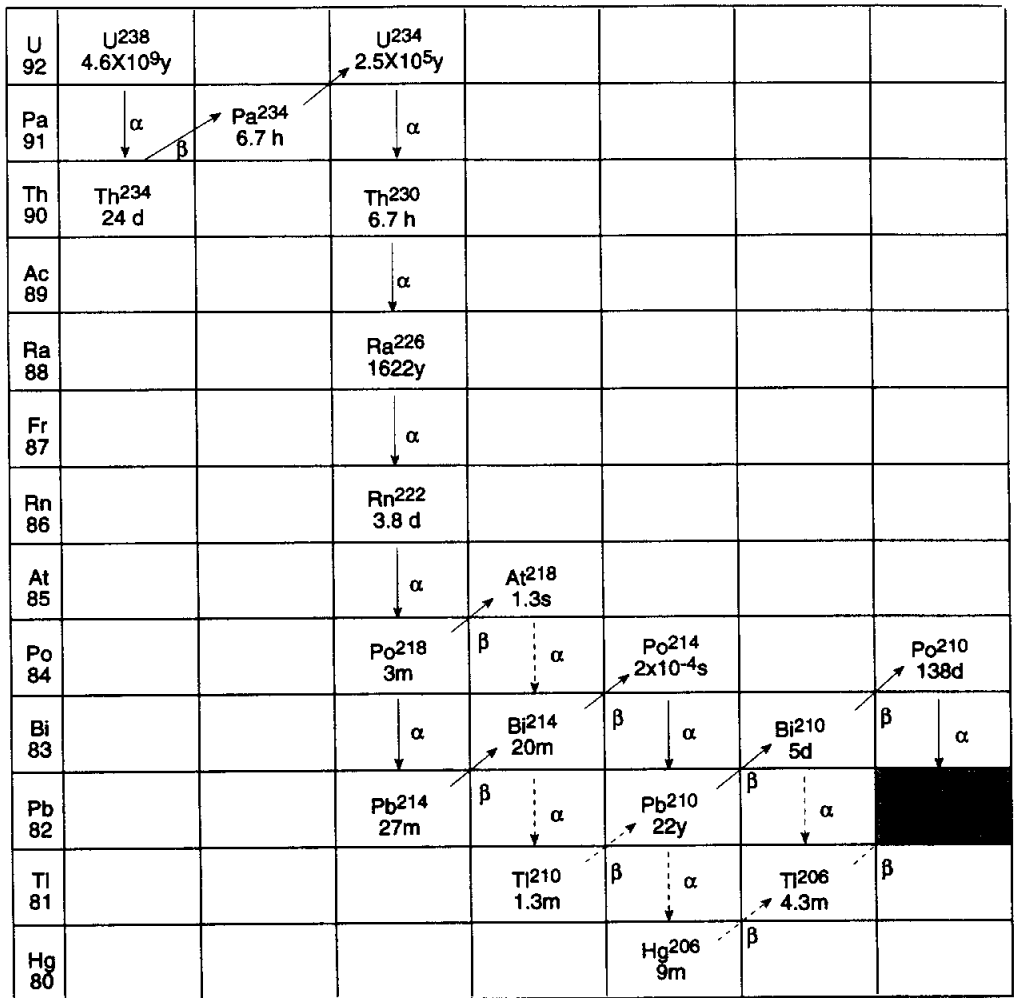
QAa9024c

Figure 5. Relationship between various isotopic elements including ^{226}Ra, ^{214}Bi, and ^{210}Pb. Solid arrows indicate major decay modes. From Robbins (1978).

19

^{222}Rn into the atmosphere from the sediments measured in cores, it is apparently insignificant relative to the entire system. Atmospheric ^{222}Rn decays (as it does in the sediments) through the intermediate daughters including ^{214}Bi (fig. 5), but because of the short half-lives of these isotopes relative to ^{210}Pb, only the ^{210}Pb is effectively deposited from the atmosphere into the sediments, where it constitutes the "excess" or unsupported component of total ^{210}Pb. ^{214}Bi from atmospheric ^{222}Rn does not become a significant part of the sediment and, thus, is not part of the ^{214}Bi measured in the sediment to determine supported ^{210}Pb. A total of 44 samples were analyzed for ^{226}Ra; results are presented in the "Results" section of this report and in Appendix B.

Bulk Density, Moisture Content, and Organic Matter (USGS). Samples were collected by slicing the half core (of measured diameter) into 1- or 2-cm wafers to produce a known volume of sediment for bulk density measurements. The wet sediment wafers were weighed, divided into two samples, one of which was then dried at a temperature of 60°C for 24 h, and reweighed to determine moisture content. The second subsample was separated into its textural components (sand, silt, and clay) as outlined in the "Textural Analysis" section. The mud fraction was analyzed for ^{210}Pb activity using the procedure described in Appendix C. Organic content was determined from weight loss-on-ignition (LOI) by heating the sample to a temperature of 450°C for 6 to 12 h. Wet and dry bulk densities, water content, LOI, and mineral (inorganic) matter are presented in Appendix B. It was assumed that sediments in the cores were carbonate free, but four cores (NR-4, NR-5, NR-7, and NR-10) contain minor concentrations of carbonates in the form of small nodules and tiny fragments of $CaCO_3$, which are most abundant in the lower half of the cores.

Bulk Density (BEG). A measured volume of sediment was obtained by subsampling each half core with a cork borer of known diameter (1.17 cm), and measuring the thickness of the half core, usually about 5 cm. Lengths were based on the thickness of the half core rather than the removed sample plug because of shortening of the plug when it was collected. Three subsamples were taken from each core near the top, middle, and bottom. The subsamples were placed in pre-weighed containers, weighed, then dried at 105°C to constant weight. A total of 33 subsamples were analyzed. From these data, dry bulk density and moisture content were determined (Appendix D).

Textural Analysis. All samples were analyzed for textural composition by the USGS following procedures detailed by Starkey and others (1984). Disaggregated samples were wet sieved through a 230-mesh sieve to separate particles larger than sand size, >62 μm (which included sand, caliche nodules, and gross organics), from silt and clay. The silt and clay fractions were separated by centrifugation, which is essentially a settling technique that operates according to Stoke's law.

Salinity (Chlorinity) (BEG). For sediments with a high salt content, excess ^{210}Pb activities should be determined on a salt-free basis (Church and others, 1981). Total chloride was measured by ion chromatography following BEG procedures (Specific Work Instruction 1.15: Determination of anions by ion chromatography). Three samples from each core (top, middle, and bottom) were analyzed. Chlorinity was converted to salinity using a factor of 1.80655 (Duxbury, 1971).

RESULTS

Results of the ^{210}Pb analysis are presented in Appendix B along with measurements of ^{226}Ra activity, water content, loss on ignition, mineral matter, wet bulk density, and dry bulk density. Bulk density was determined for each sample by the USGS. A few samples from each core were also analyzed for bulk density by BEG. In general, bulk densities measured by the USGS were higher by an average of about 1.5 times than those determined by BEG. The reason for this difference is not clear, but may be related to the variation in methods used to take subsamples of the cores (see "Methods" section). Because USGS measurements were made on every sample that was analyzed for ^{210}Pb, the USGS bulk densities provide the most complete data for analyzing cumulative inorganic mass and for determining dates and sedimentation rates.

^{210}Pb Activity Profiles

The objective of this investigation was to determine sedimentation rates based on ^{210}Pb activity. Accordingly, results of other physical and chemical analyses are discussed primarily in terms of their influence on or relationship with the distribution of ^{210}Pb activity within a core. ^{210}Pb activity profiles were completed

for each core and examined carefully to determine trends and probable causes for variations in trends.

Variations in ^{210}Pb and Probable Causes

Plots of ^{210}Pb activity against depth indicate some scatter and local variations from linear trends for some cores. However, the amount of scatter in Nueces River cores is much less than that found in Lavaca-Navidad River cores (White and Morton, 1995). This reduction in the amount of scatter is attributed to a change in procedures in which only the fine fraction (mud) was analyzed for ^{210}Pb activity. Fluctuations in ^{210}Pb activity in the Lavaca-Navidad River cores were caused partly by variations in sand content in the analyzed samples. Pronounced variations in slope of the plots should define variations in sedimentation rates, which can be correlated with sediment deposition by the Nueces River. But local variations in excess ^{210}Pb activity involving individual samples or a few samples are not fully understood. Some are apparently related to bioturbation and organic properties, presence of carbonates, and other changes in sediment chemistry, and some are possibly due to radioactivity counting errors.

Bioturbation. According to some researchers, for example Nittrouer and others (1979), the relatively uniform ^{210}Pb activity in near surface layers of some cores indicates a zone of bioturbation and mixing of sediments (fig. 6). In most Nueces River cores, distinct evidence of bioturbation was not apparent in either X-rays or dressed and described cores. Below the root zones, cores are homogeneous in appearance and profiles of total ^{210}Pb against depth show that activities generally decline in a relatively linear fashion to depths of about 5 to 20 cm, below which there is a flattening of the profile for most cores. We believe that the flattening occurs as background or supported ^{210}Pb levels are approached and reached at depth. Varying from this general trend is core NR-10, which is nonlinear in the upper 15 cm. The nonlinearity may be a result of bioturbation, physical mixing, variations in organic matter or erosion and deposition during flood events. The specific reason for the "saw-tooth" nature of the ^{210}Pb profile is not totally clear, but may be related to variations in deposition. This site appears to be one of the first sites inundated during floods along the Nueces River.
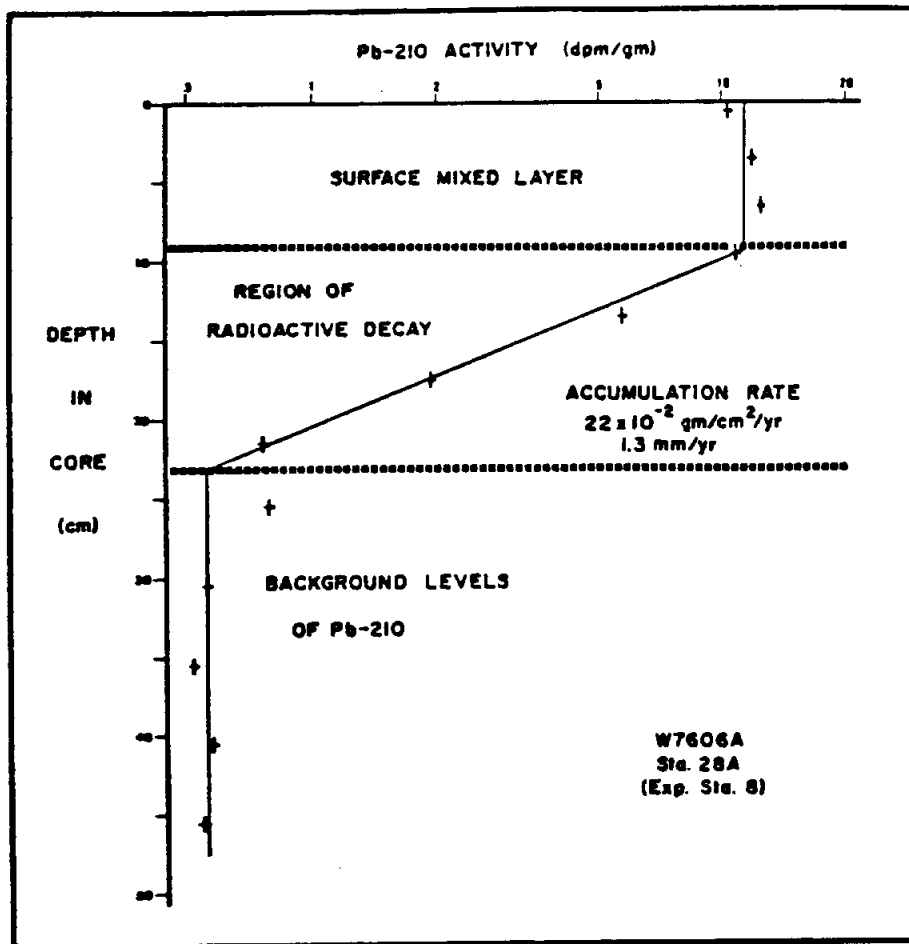
Figure 6. Profile of ^{210}Pb activity of a sediment core from the Washington continental shelf showing the mixed surface layer. Bioturbation in marsh surface layers can produce similar "flat" activities. From Nittrouer and others (1979).

23

Texture. Textural variations can influence excess ^{210}Pb activity (fig. 7). Activity levels are higher in finer sediments, apparently because Pb, like many other metals, is sequestered by fine-grained particles such as clay minerals, organic matter, and Fe-Mn oxides (Nittrouer and others, 1979). Sediment in cores taken in this study consists primarily of homogeneous mud (silt and clay), but sand was higher than expected in some cores. Still, sand is a minor constituent overall (less than 20 percent) (Appendix B) except in core NR-9 where it composes, on average, almost 40 percent of the sediment in samples analyzed (fig. 8).

Because ^{210}Pb activity is affected by sediment texture, exemplified by depressed ^{210}Pb activities in sandy sediments, only the mud fraction was analyzed for ^{210}Pb.

Organics (Weight Loss-On-Ignition). The association between ^{210}Pb activity and organic content, based on weight loss-on-ignition (LOI), varies from core to core, but generally there is a positive correlation. Correlations are especially high for some cores when only the top sections are considered and when one or two anomalous values are excluded. Under these conditions the square of the correlation coefficient (R^2) ranged from 0.746 to 0.945 in eight of the cores, and six of the cores had R^2 of 0.818 or higher. Two of the highest positive correlations between LOI and total ^{210}Pb were in cores NR-1 (fig. 9) and NR-6 (fig. 10). The cores with the lowest correlations were NR-2 and NR-9.

Calcium Carbonate (Caliche Nodules). Caliche nodules can influence ^{210}Pb activity. Fortunately, large nodules (1–2 cm in diameter) were not found in Nueces River cores. Analysis of nodules from Trinity River cores (White and Morton, 1993) indicated that they can be "hot spots" where ^{210}Pb activity is substantially higher than in surrounding sediments (Dr. Charles Holmes, personal communication, 1993). In Nueces River cores, calcium carbonate specks were observed in the lower portions of a few cores, but there is no obvious evidence that ^{210}Pb activity was affected. Carbonates of sand size or larger would have been separated from the mud fraction before analysis of ^{210}Pb.
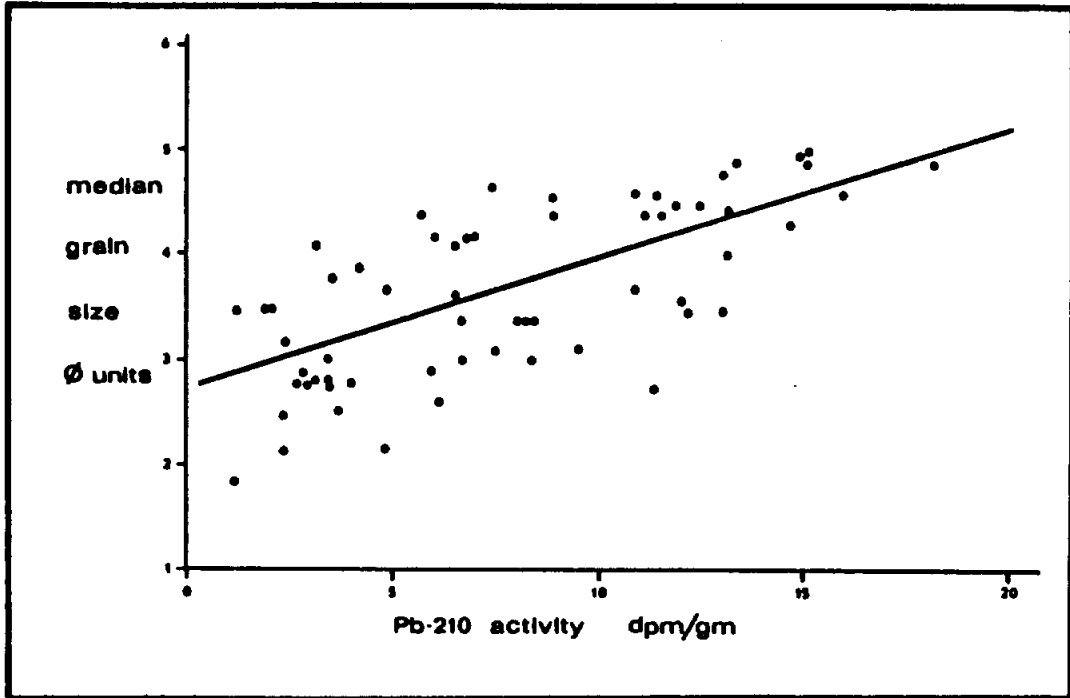
Figure 7. Relationship between grain size and initial ^{210}Pb activity. From Nittrouer and others (1979).

NR-1
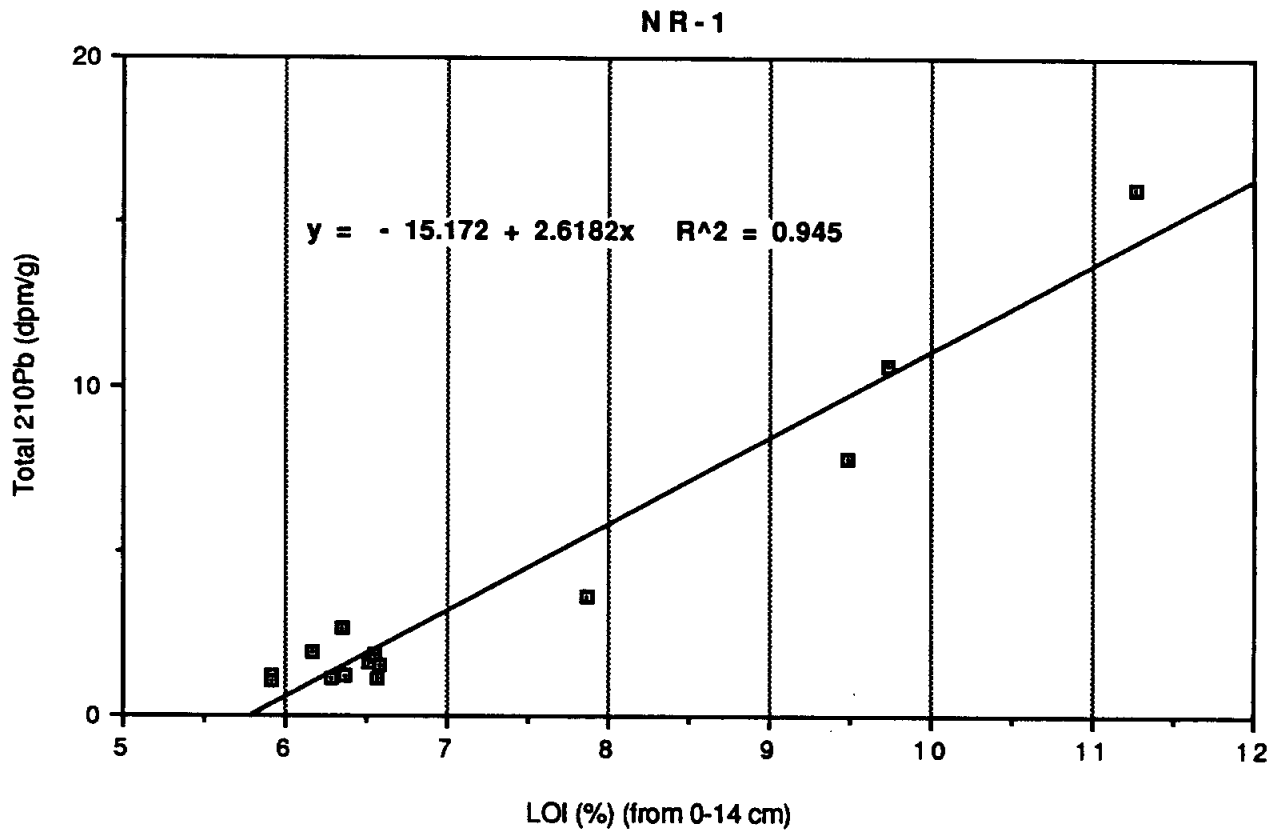

Figure 9. Correlation between percent LOI and total ^{210}Pb activity in core NR-1.

NR-6

$y = -4.8839 + 0.66418x$ $R^2 = 0.914$
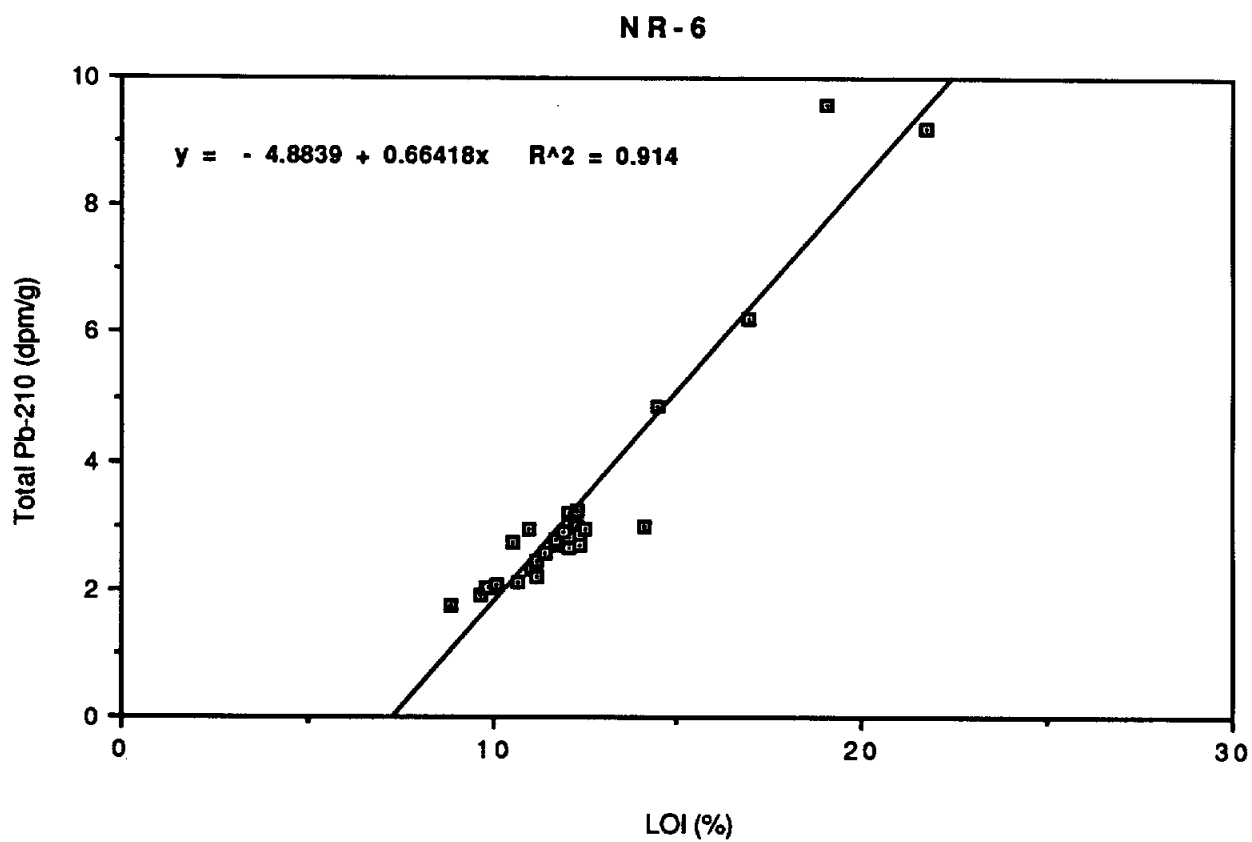
Figure 10. Correlation between percent LOI and total ^{210}Pb activity in core NR-6.

Salinity. Results show that sediments at three core sites, NR-5, NR-8, and NR-9, are the most saline, each exceeding 20,000 ppm (fig. 11). The high salinities in these three cores was expected because they were taken in vegetated "salt" flats where plant species with a high salt tolerance are the dominant vegetation (table 1). The deepest subsample from NR-10 also exceeded 20,000 ppm, which was not expected because the dominant vegetation at the surface was *Borrichia frutescens*. The two sites with the lowest salinities are NR-1 and NR-6. Vegetation at each of these sites indicated low salinities, especially at NR-6, where *Typha* sp. was dominant (table 1). The high salinities at several of the cores suggest that ^{210}Pb should be determined on a salt-free basis for those cores to evaluate whether sedimentation rates are significantly altered.

Nueces River Core Salinities (ppm)
(Cl x 1.80655)
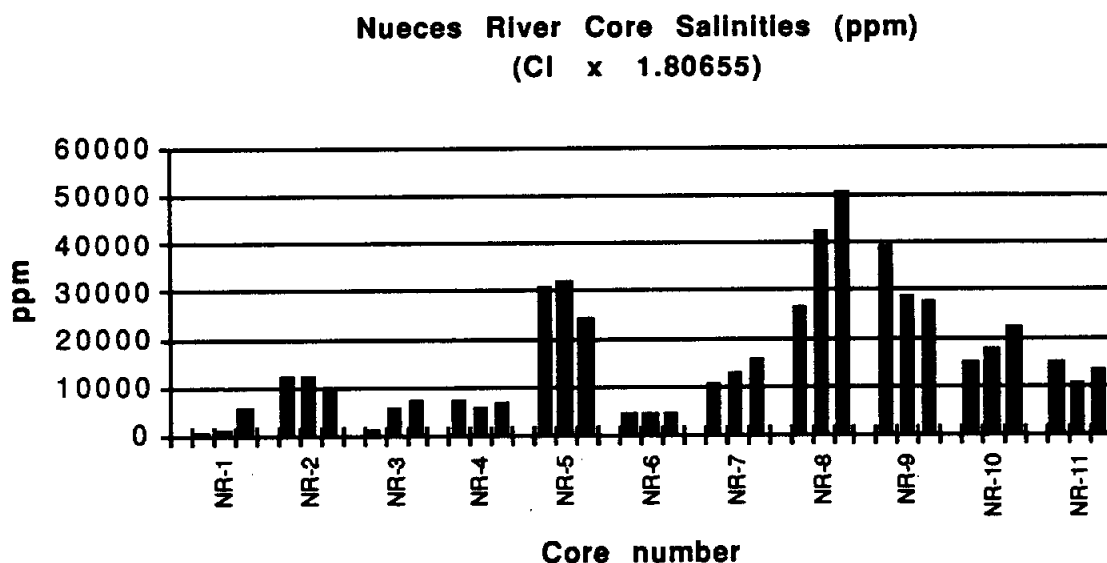
Figure 11. Salinities of sediments subsampled from cores taken in the Nueces River delta and alluvial valley.

Table 3. Salinity of samples analyzed in cores.

Location/ depth (cm)	Cl (mg/kg @105°C)	Salinity (ppm) (Cl × 1.80655)
NRD1/ 5	297	536
NRD1/23	519	938
NRD1/50	2,967	5,359
NRD2/ 5	6,803	12,290
NRD2/35	6,639	11,994
NRD2/62	5,347	9,660
NRD3/ 5	606	1,095
NRD3/33	2,885	5,211
NRD3/54	4,077	7,366
NRD4 / 5	4,044	7,306
NRD4 /25	3,087	5,577
NRD4 /45	3,479	6,284
NRD5/ 5	17,001	30,714
NRD5/24	17,708	31,990
NRD5/39	13,249	23,935
NRD6/11	2,450	4,426
NRD6/22	2,315	4,181
NRD6/36	2,306	4,166
NRD7/11	5,645	10,198
NRD7/25	6,855	12,384
NRD7/44	8,526	15,403
NRD8/12	14,647	26,460
NRD8/42	23,311	42,112
NRD8/72	28,067	50,704
NRD9/ 5	21,663	39,135
NRD9/32	15,870	28,670
NRD9/59	15,216	27,489
NRD10/10	8,298	14,991
NRD10/27	9,753	17,620
NRD10/48	12,209	22,055
NRD11/28	8,335	15,058
NRD11/62	5,691	10,281
NRD11/67	7,256	13,109

Visible Physical and Chemical Variations. Most cores in the Nueces River system were homogeneous in appearance. Variations in appearance occurred in the upper 5–10 cm of most cores where plant roots were abundant. Changes in color generally occurred in deeper portions of the cores, but the color changes did not correspond to changes in ^{210}Pb activities, which were relative "flat" indicating background, or supported, ^{210}Pb levels had been reached. There was little evidence of oxidation in any of the cores. In contrast, almost all cores from the Trinity River system showed evidence of oxidation in the upper halves of the cores.

Accuracy of Analysis at Low ^{210}Pb Concentrations. Some fluctuations in ^{210}Pb activity in the lower part of a core may be a result of low concentrations of ^{210}Pb as background levels are approached. According to Dr. Charles Holmes (USGS), the analytical variance (error bar) for samples with activities below approximately 0.5 dpm/g is larger than for samples with higher concentrations. Therefore some of the sample to sample variations are simply related to counting errors.

Determination of Excess (Unsupported) ^{210}Pb

^{226}Ra. One method used by researchers to determine supported ^{210}Pb activities is to analyze ^{226}Ra from which supported ^{210}Pb is derived and with which it is assumed to be in equilibrium (see "Analytical Methods" section). In some settings, however, ^{226}Ra may be unusable because of possible disequilibrium between ^{226}Ra and ^{210}Pb (Brenner and others, 1994). Still, in many coastal settings ^{226}Ra has been used to estimate supported ^{210}Pb. The USGS analyzed ^{226}Ra in a selected number of samples in all cores (Appendix B). Averages in cores varied from 0.87 to 1.57 dpm/g (table 4).

Table 4. Average activities of ^{226}Ra in selected sediment samples from Nueces River cores.

Core no.	Average ^{226}Ra (dpm/g)	Number of samples
NR-1	0.89	2
NR-2	1.04	3
NR-3	1.29	11
NR-4	1.09	3
NR-5	1.11	3
NR-6	0.87	3
NR-7	0.98	3
NR-8	0.91	3
NR-9	0.99	3
NR-10	1.57	8
NR-11	0.94	2

Supported ^{210}Pb Based on Activity Profiles. The concentration of ^{210}Pb in most Nueces River cores approaches a constant level at depths generally less than 20 cm. Estimates of supported ^{210}Pb concentrations can be made from total ^{210}Pb activity in the lower part of each profile where it becomes "flat" as excess ^{210}Pb approaches zero. Estimates of supported ^{210}Pb levels based on total ^{210}Pb activity profiles are typically higher than those based on ^{226}Ra (table 5). For example, averages are 1.36 and 1.06 dpm/g, respectively, for the activities listed in table 5. In deeper parts of the cores, ^{226}Ra and ^{210}Pb should be in secular equilibrium and activities should be equal. Lower activities of ^{226}Ra compared to ^{210}Pb (table 5) have also been reported by other researchers, for example Robbins and others (1978), who found ^{226}Ra activities to be 10 to 30 percent lower than ^{210}Pb and attributed this difference to small intercalibration errors, to actual departures in secular equilibrium, or to differences in leachability of ^{226}Ra and ^{210}Pb in the analytical process. Generally, activities of ^{226}Ra appear to provide the best estimate of supported ^{210}Pb activities except in a few cases, discussed in the following section.

Table 5. Estimated supported ^{210}Pb levels based on average ^{226}Ra activities, and average, or lowest, activities of total ^{210}Pb near base of cores.

Core Number	Supported ^{210}Pb based on average ^{226}Ra Activity (dpm/g)	Supported ^{210}Pb based on ^{210}Pb activities near base of core (dpm/g)	Cumulative excess ^{210}Pb using average ^{226}Ra for supported ^{210}Pb (dpm/cm^2)
NR-1	0.89	1.09	31.33
NR-2	1.04	1.05	38.13
NR-3	1.29	1.31	33.19
NR-4	1.09	1.60	27.51
NR-5	1.15	1.00	28.46
NR-6	0.87	1.60*	58.88
NR-7	0.98	1.06	40.94
NR-8	0.91	1.70	37.37
NR-9	0.99	0.95	9.31
NR-10	1.57	1.88	25.63
NR-11	0.94	1.60	53.41

* Based in part on ^{226}Ra activity and averages of ^{210}Pb near base of core.

Cumulative Inventories of Excess ^{210}Pb Activity

Estimates of total unsupported residual, or cumulative excess, ^{210}Pb activity for the Nueces River system cores were made using average ^{226}Ra activities as a measure of supported ^{210}Pb (table 5). Based on these data, cumulative inventories of excess ^{210}Pb for all cores range from 9.31 dpm/cm^2 to 58.88 dpm/cm^2. Eight of the cores have cumulative excess Pb inventories ranging from approximately 26 dpm/cm^2 to 41 dpm/cm^2. Core NR-9 has an atypically low cumulative inventory (9.31 dpm/cm^2), apparently because too few samples were analyzed in the upper part of the core to provide sufficient data for calculating the total cumulative inventory (Appendix B). Cores NR-6 and NR-11 have the highest cumulative inventories of 58.88 and 53.41 dpm/cm^2, respectively (table 5). If the higher supported ^{210}Pb activities derived from total ^{210}Pb data are used (table 5), cumulative inventories are reduced to 35.11 dpm/cm^2 in core NR-6 and 29.97 dpm/cm^2 in NR-11. These inventories are more in line with those in other cores.

Sedimentation Rates Based on ^{210}Pb Activities

Sedimentation rates derived from three models CFS (constant flux–constant sedimentation), CRS (constant flux, or constant rate of supply), and CIC (constant initial concentration) (Robbins, 1978; Oldfield and Appleby, 1984) were compared to determine the consistency and utility of the ^{210}Pb data in calculating rates. Using the CFS method, rates at coring sites range from less than 1 mm/yr to more than 5 mm/yr (table 6 and fig. 12). The lowest rate of 0.6 mm/yr at core NR-1 is in agreement with rates determined using the CRS and CIC models (fig. 13) and is supported by a rate based on archeological evidence found at the edge of Rincon Bayou near the coring site. (Best agreement between models for NR-1 was achieved by using a supported ^{210}Pb activity of 1.09 dpm/g from table 5). The archeological evidence, which consists of a thin stratum of shells and faunal bones, was discovered at a depth of 25 cm by Mike Blum (University of Nebraska) and was dated by Bob Ricklis (Archeologist, Corpus Christi) at 500 to 1,000 years B.P. (Before Present). Using the more recent date of 500 years yields an average sedimentation rate of 0.05 cm/yr for the 25 cm of sediment above the archeological horizon. This rate is within 0.01 cm/yr of the rates determined from ^{210}Pb data. The geomorphic setting of coring site NR-1 is consistent with the low sedimentation rate. The site is approximately 3 km north of the Nueces River (fig. 1) and is partially "protected" from flooding by an upland terrace that curves around the western (upstream) side of the site.

Table 6. Average sedimentation rates for given core intervals. Rates are based on a least-squares fit of Ln plots of excess ^{210}Pb against corrected depths (CFS model, Oldfield and Appleby, 1984).

Core no.	Sedimentation rate (CFS model) (cm/yr)	Corrected depth interval used (cm)	R^2	Supported ^{210}Pb (dpm/g)
NR-1	0.06	1-13	0.962	1.09
NR-2	0.55	1-29	0.834	1.04
NR-3	0.20	1-10	0.872	1.29
NR-4	0.20	1-15	0.917	1.09
NR-5	0.13	1-6	0.912	1.15
NR-6	0.10	1-6	0.916	0.87
NR-7	0.16	1-12	0.926	0.98
NR-8	0.13	1-13	0.832	0.91
NR-9	0.10	1-9	0.918	0.99
NR-10	0.32	1-20	0.852	1.57
NR-11	0.45	1-25	0.899	0.94
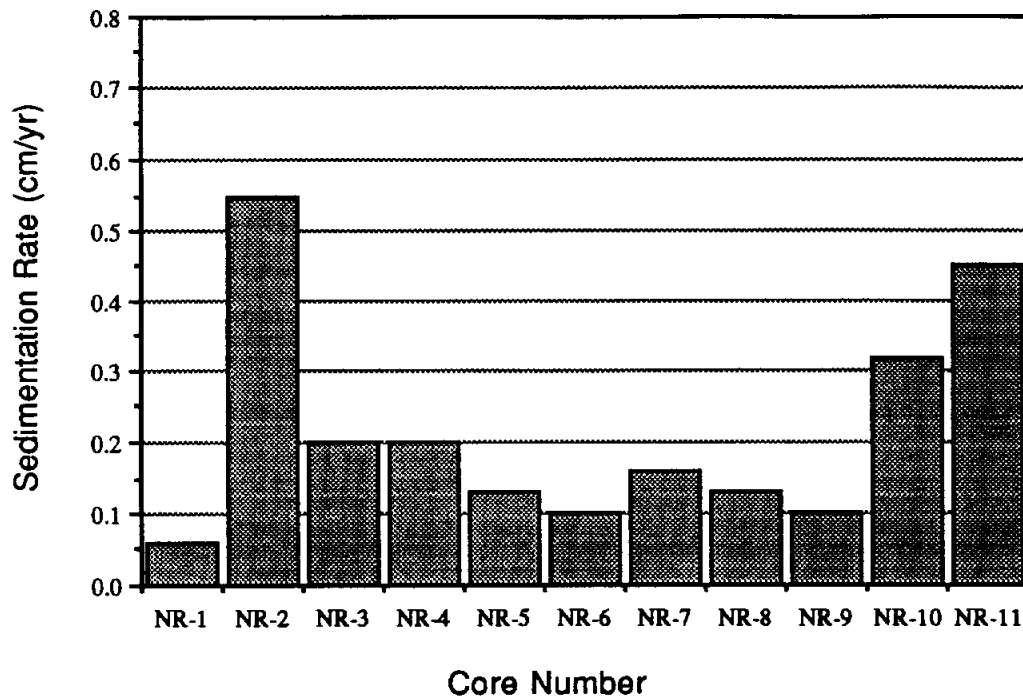
Figure 12. Sedimentation rates of Nueces River cores using CFS model (table 6). Depths are generally less than 15 cm. Supported ^{210}Pb for each core is based on average ^{226}Ra.

The highest sedimentation rates are at coring sites NR-2 and NR-11. Core NR-11 was collected from an intertidal *Spartina alterniflora* marsh that receives sediment from the Nueces River and Nueces Bay (fig. 1). Core NR-2 was collected in a brackish-water marsh that had developed in a depression near the margin of a tidally influenced lake. The average sedimentation rate at the two sites is 0.45 cm/yr for NR-11 (fig. 14) and 0.55 cm/yr for NR-2. The rate at NR-11 is equal to the average rate of relative sea-level rise of 0.45 cm/yr at the Rockport tide gauge for the period from the late 1940s to mid-1980s (fig. 15). Other researchers have also reported a close relationship between rates of relative sea-level rise and rates of estuarine

36

NR-1 (CFS Model)

$y = 3.1533 - 0.49674x \quad R^2 = 0.962$

0.063 cm/yr

NR-1 (CRS Model)

$y = 1.4291 + 6.2403e\text{-}2x \quad R^2 = 0.988$

0.062 cm/yr

NR-1 (CIC Model)

$y = 1.0947 + 6.0182e\text{-}2x \quad R^2 = 0.961$

0.060 cm/yr
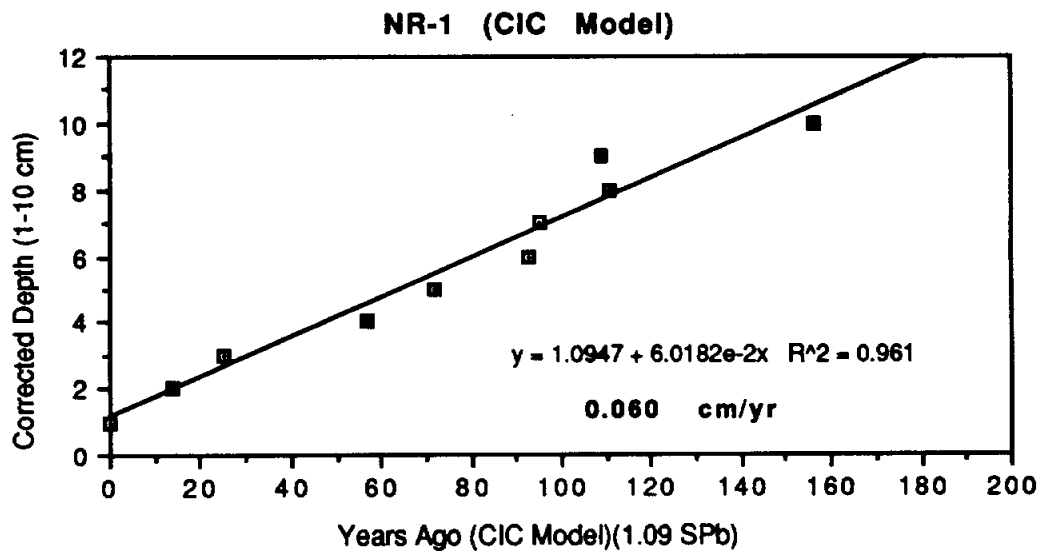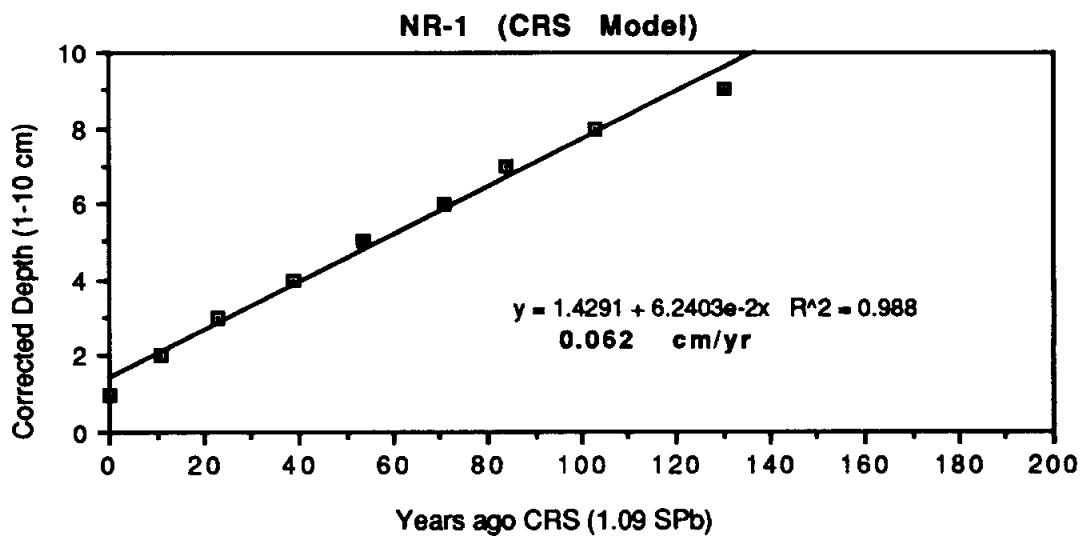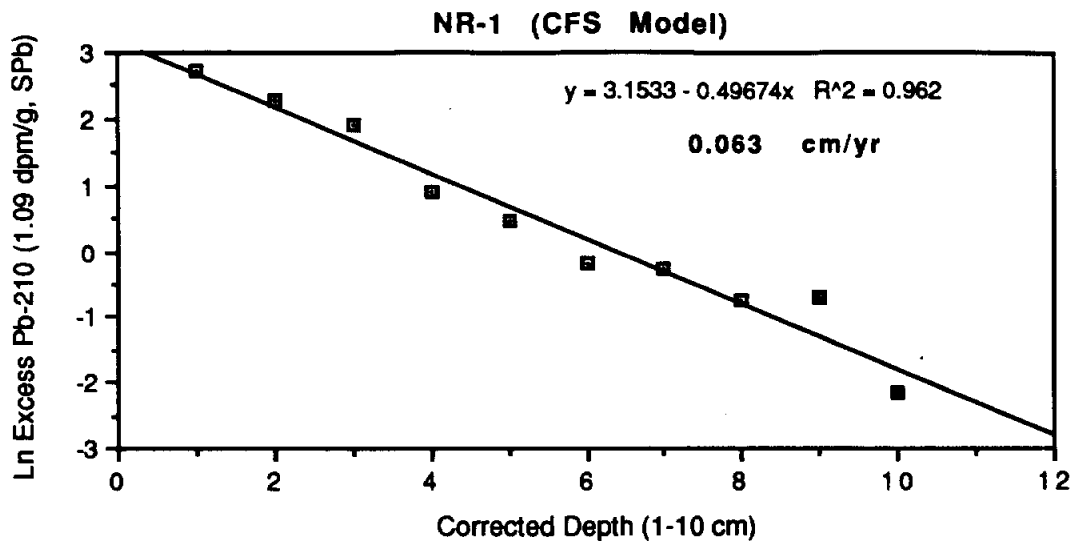
Figure 13. Average sedimentation rates at core site NR-1 based on CFS, CRS, and CIC models.

37
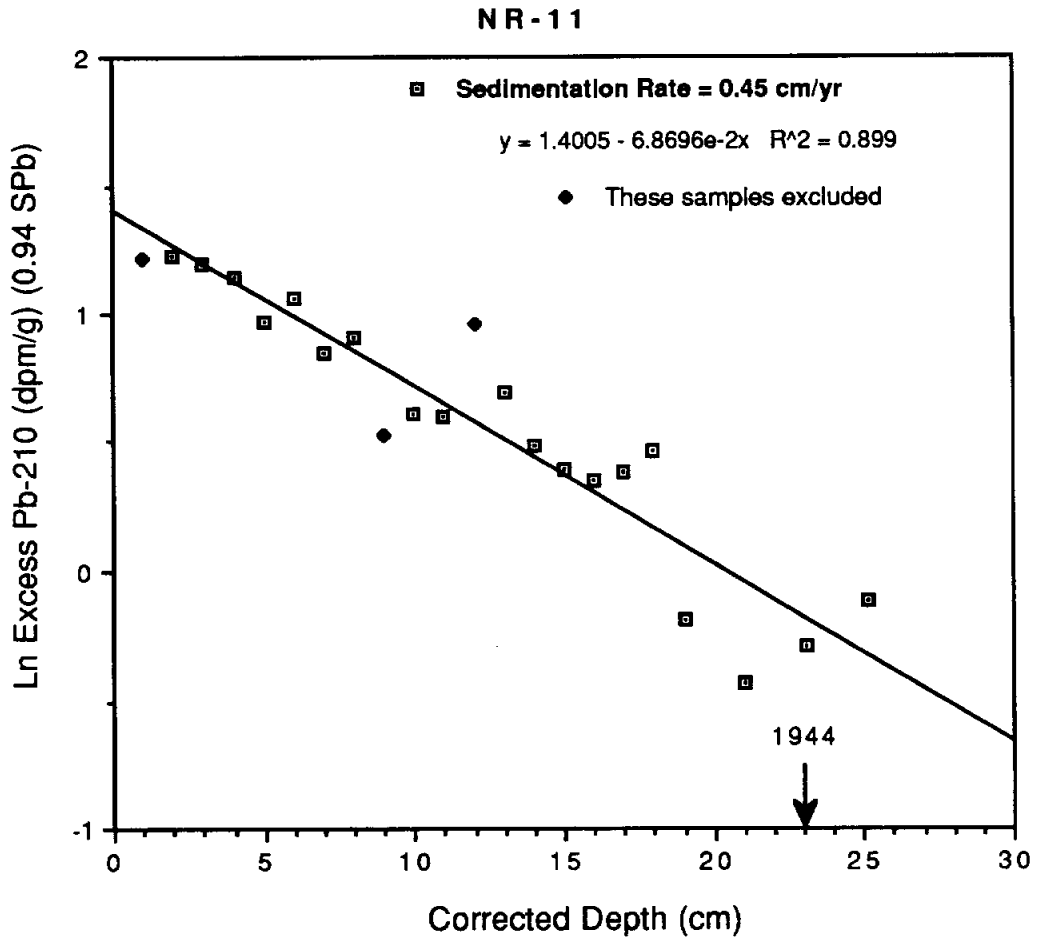
Figure 14. Average sedimentation rate at core site NR-11 based on the CFS model.

Rockport Gauge: Monthly Mean Staff Height

$y = -700.44 + 0.44761x$ $R^2 = 0.172$

Sea Level Rise = 0.45 cm/yr
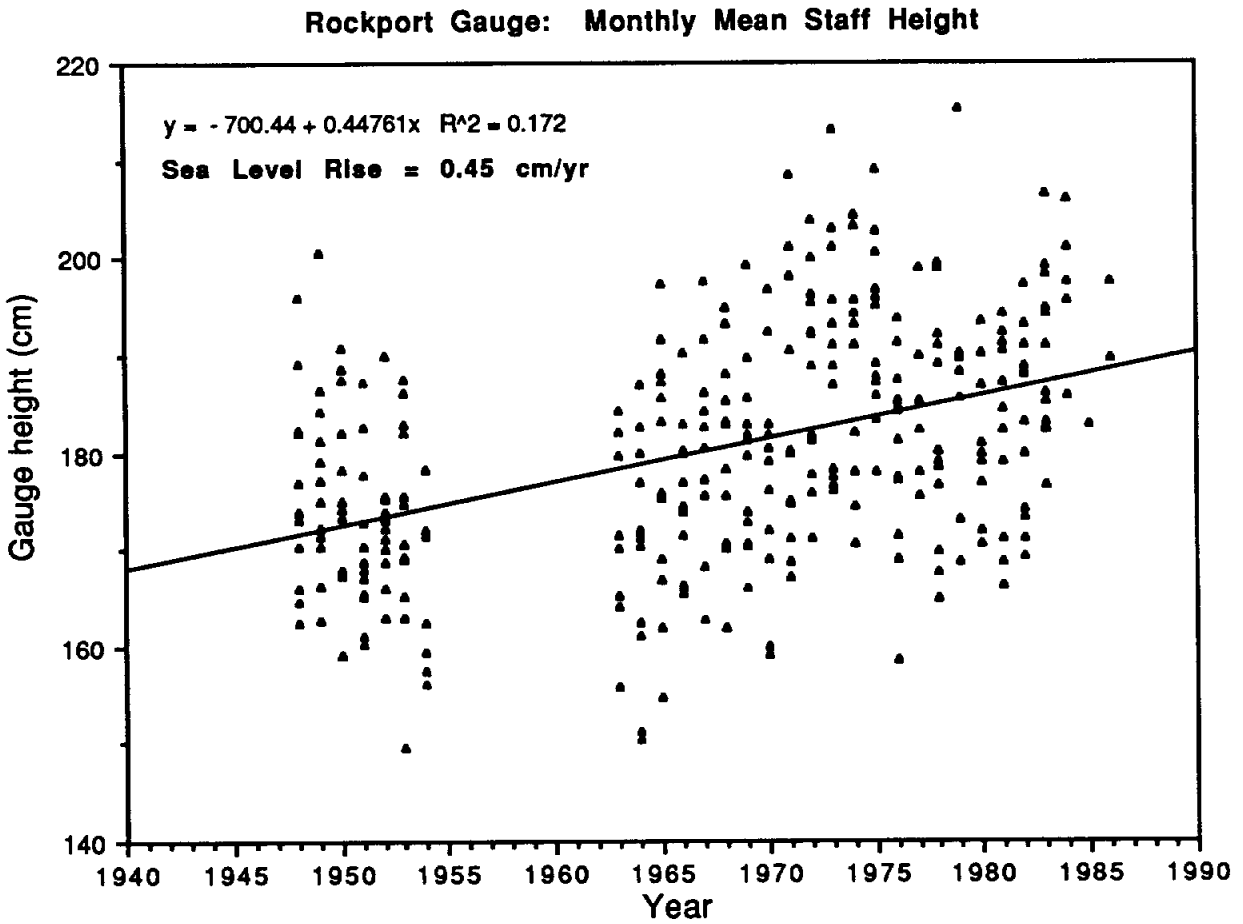
Figure 15. Average rate of sea-level rise at the Rockport tide gauge for the period from the 1940s to mid-1980s. Average monthly tide levels from National Oceanic and Atmospheric Administration (NOAA).

39

salt marsh sediment accumulation (for example, McCaffrey, 1977). Rates indicated by cores from other locations in the Nueces River area are much lower and range from 0.32 cm/yr at NR-10 to $\leq$0.20 cm/yr at the remaining sites (table 6).

Preliminary relationships between sedimentation rates, river suspended sediment loads, dam construction, and relative sea-level rise were investigated for several cores. The results show some interesting and, in some cases, puzzling trends depending on the sedimentation model used. There appears to be a relatively consistent trend using the CFS model and calculating two rates of sedimentation for linear segments of the ^{210}Pb profiles representing the upper and lower parts of cores. Most cores show reductions in sedimentation rates from around the 1930s to present (figs. 16 to 20). The Mathis Dam at Lake Corpus Christi was constructed in 1929 (fig. 21) and is estimated to have trapped 75 percent of the suspended sediment load delivered along the Nueces River (Brune, 1953). The Seale Dam, which flooded the Mathis Dam at Lake Corpus Christi, was completed in 1958 and traps more than 95 percent of the suspended sediment (Liebbrand, 1987).
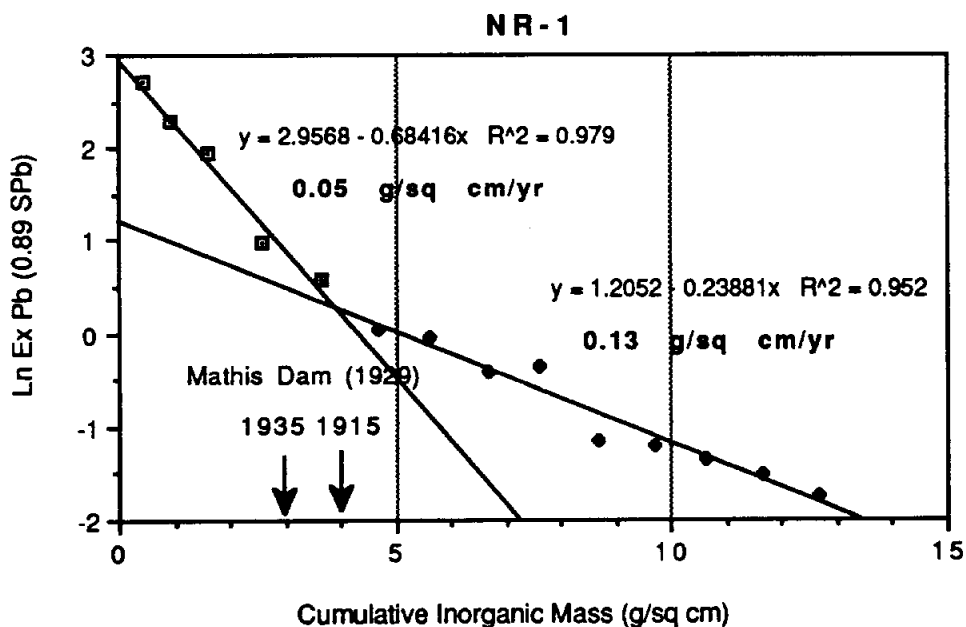
Figure 16. ^{210}Pb profile of core NR-1 showing decreasing rates of sedimentation after approximately 1929 when the Mathis Dam was constructed on Nueces River to form Lake Corpus Christi. Based on the CFS model and cumulative mass.

NR-3
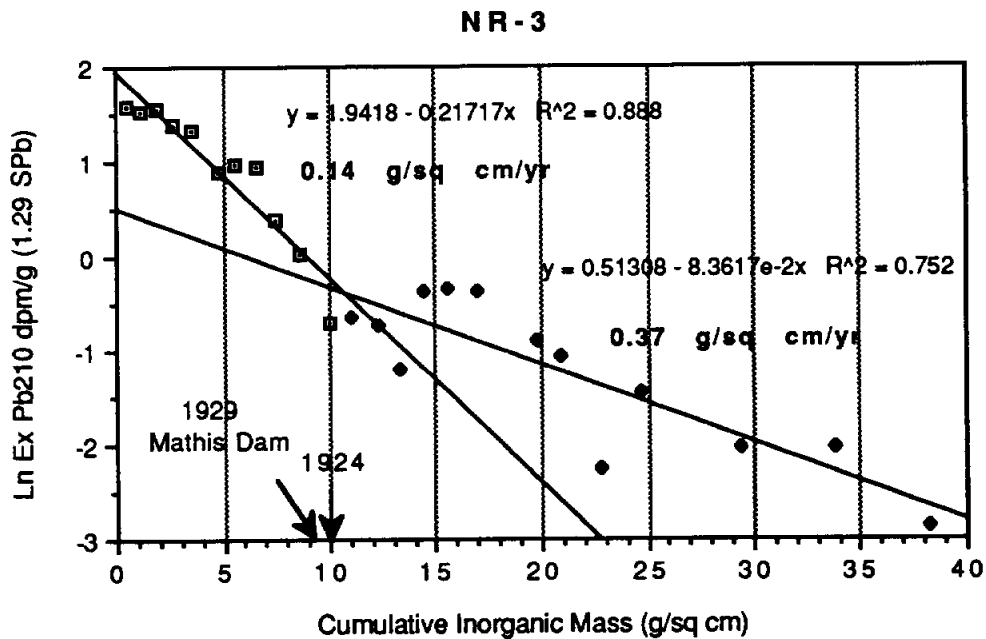
Figure 17. 210Pb profile of core NR-3 showing decreasing rates of sedimentation after the Mathis Dam was constructed on the Nueces River in 1929. Based on CFS model and cumulative mass.

NR-3
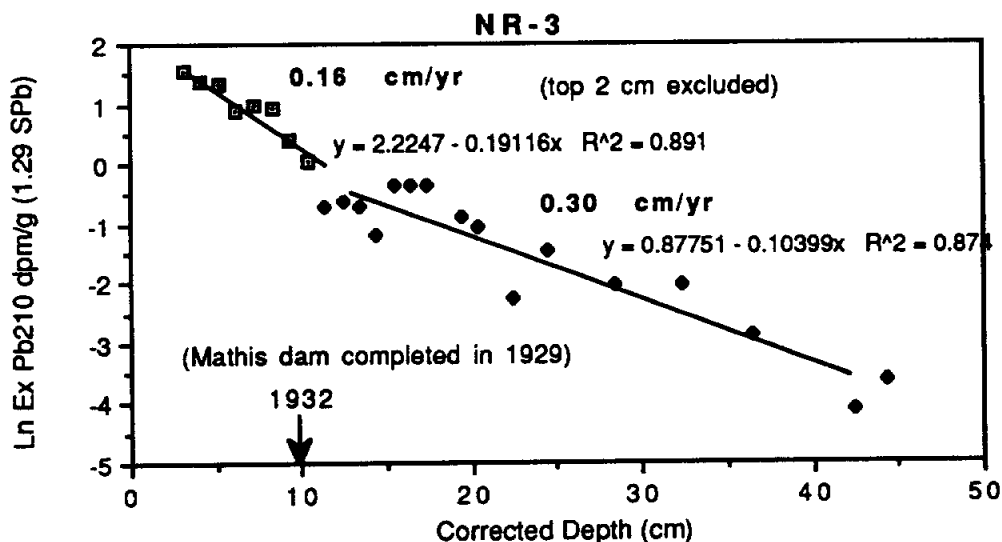
Figure 18. 210Pb profile of core NR-3 showing decreasing rates of sedimentation after the Mathis Dam was constructed on the Nueces River in 1929. Based on CFS model and corrected depth.

41

NR-6
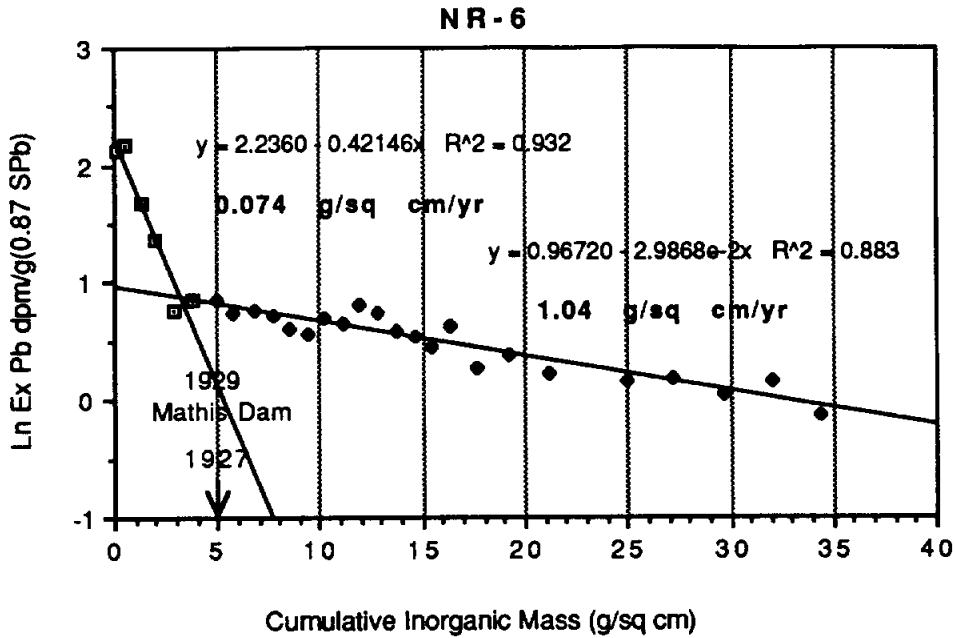
Figure 19. ^{210}Pb profile of core NR-6 showing decreasing rates of sedimentation after the Mathis Dam was constructed on the Nueces River in 1929. Based on CFS model and cumulative mass.

NR-7
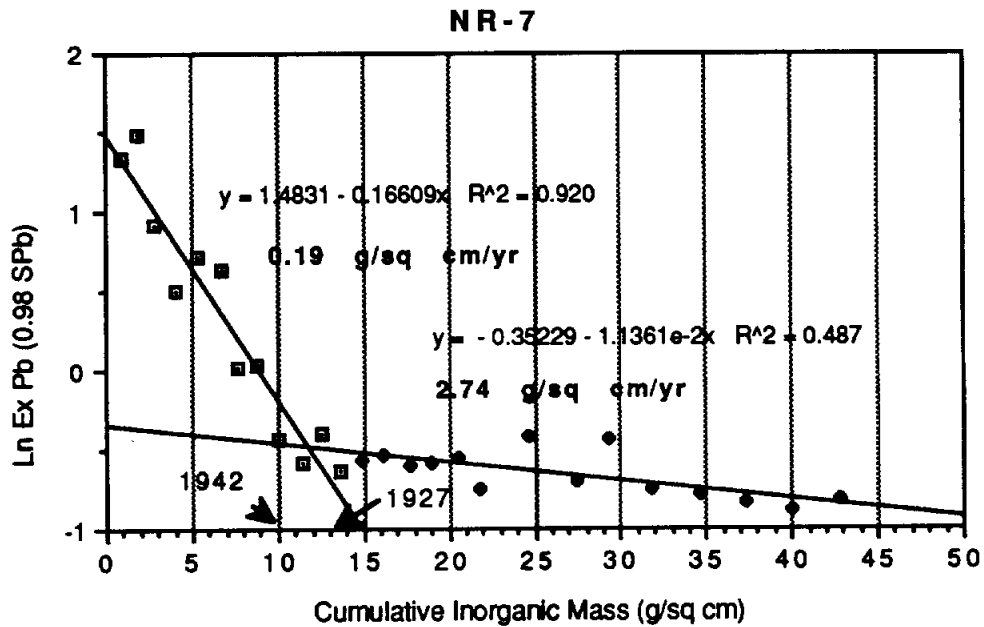
Figure 20. ^{210}Pb profile of core NR-7 showing decreasing rates of sedimentation after the Mathis Dam was constructed on the Nueces River in 1929. Based on CFS model and cumulative mass.

42
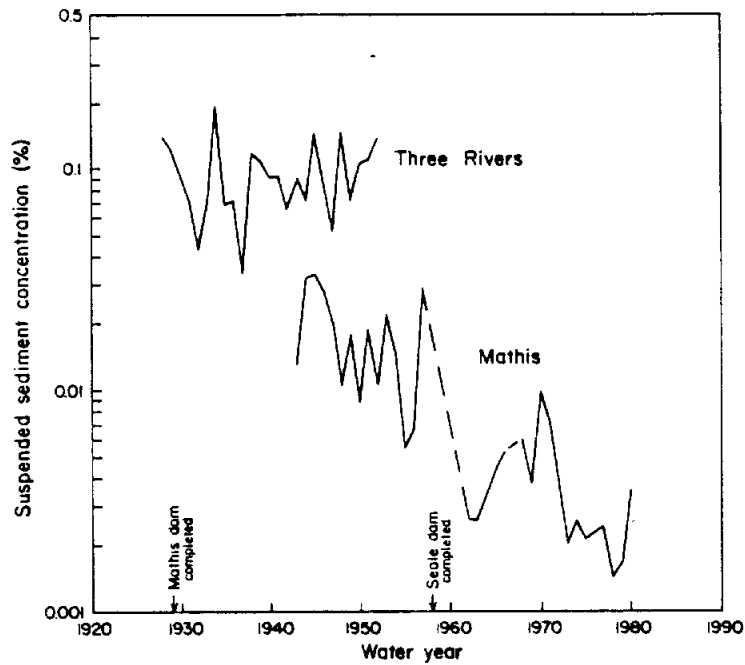
Figure 21. Suspended sediment load (percent by weight) for the Nueces River. The Three Rivers station is upstream from Lake Corpus Christi, and Mathis station is downstream. No data for dashed segments. Note the time of completion of the Mathis and Seale Dams that formed Lake Corpus Christi. From Morton and Paine (1984).

43

Rates of sedimentation derived from the three models show relatively close agreement between average CFS and CIC rates for the upper part of all cores (fig. 22 and table 7). In five cores, there is agreement between rates based on all three models (fig. 22). In the other six cores, however, CRS rates are higher than those based on CFS and CIC. In addition, there is disagreement between the CFS- and CRS-derived sedimentation trends for earlier and later periods. For example, unlike the CFS model, which indicates lower rates after 1930, CRS rates for some cores increased after 1930 (fig. 23).
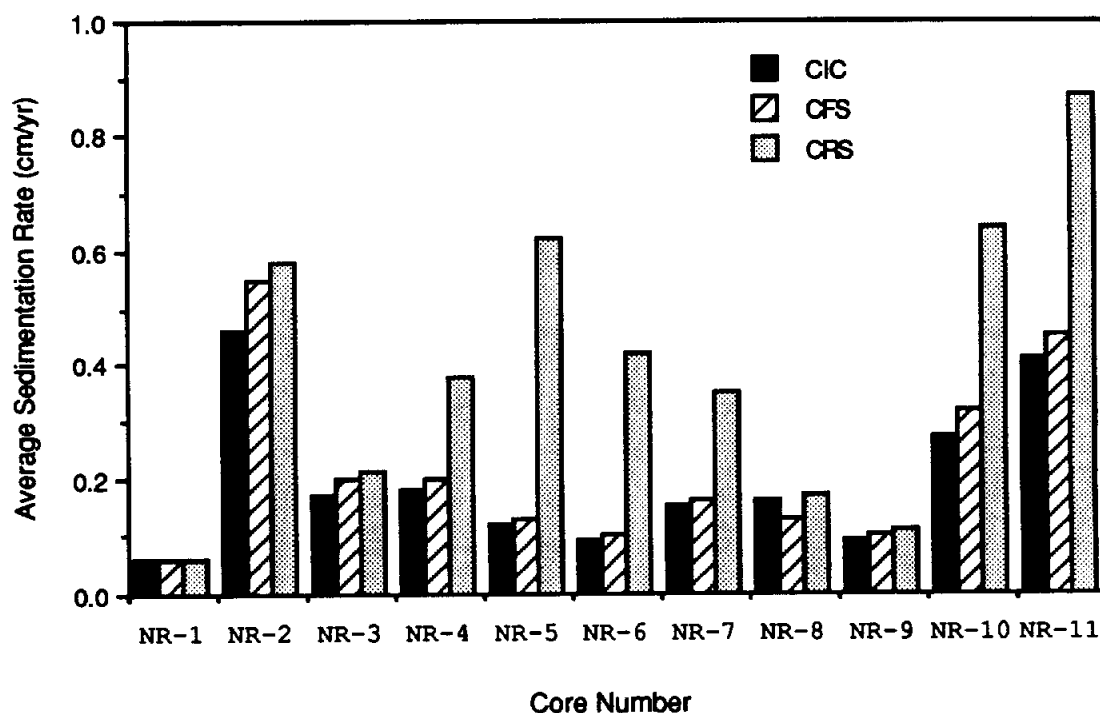
Figure 22. Comparison of sedimentation rates derived from the CFS, CRS, and CIC models. There is relatively close agreement between CFS and CIC rates in all cores and between CFS, CIC, and CRS rates in five cores. See table 7 for core depths on which rates are based.

44
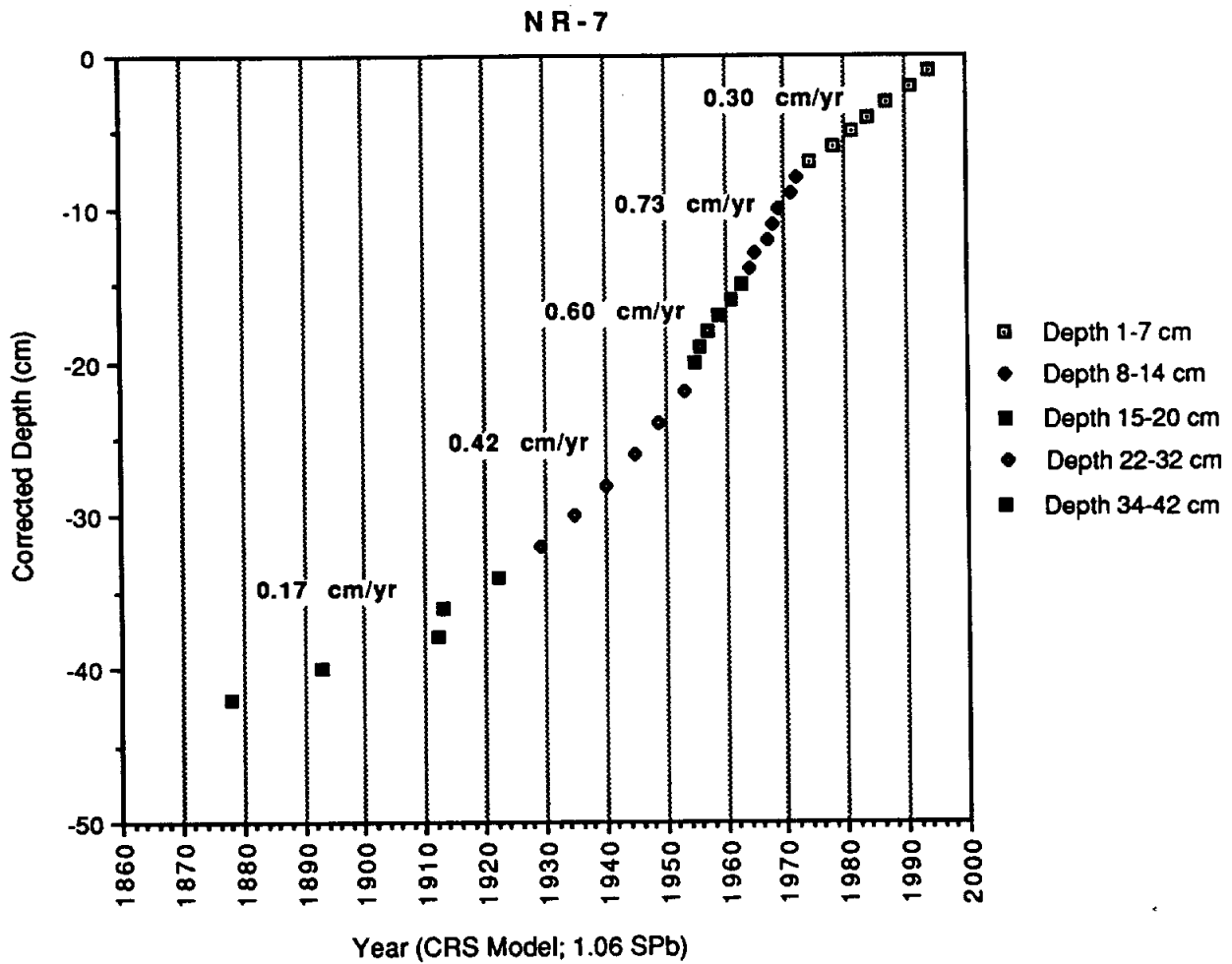
Figure 23. Changes in sedimentation rates through time at core site NR-7, based on the CRS model. Note that rates appear to increase after the 1930s until 1975. The CFS model indicates that rates decreased after 1930 at this site (fig. 20).

The CRS model helps define more recent trends, for example, from the 1950s to present. Changes in relative sea-level (RSL) rise over the past five decades may have influenced sedimentation at some sites. At NR-11, an intertidal site, rates of sedimentation appear to have been highest during the period from 1964 to 1975, when the rate of RSL rise was the highest, and lower from 1975 to the 1990s, when the rate of RSL rise was lower (fig. 24). A few other coring sites also indicate a decline in sedimentation rates during these periods, but these trends can be related to suspended load changes along the Nueces River (figs. 25 and 26).

Although sedimentation can be influenced by changes in streamflow or relative sea-level rise, these two processes are sometimes related. Secular variations in sea level can be caused by climatic factors, such as droughts and periods of higher than normal precipitation and riverine discharge. These short-term sea-level variations produce temporary adjustments in the longer term trends related to eustatic sea-level rise and subsidence. Such variations can apparently affect sedimentation rates as illustrated by the positive correlation between changes in RSL rise rates, streamflow (and suspended sediment load), and sedimentation at least in some cores for the period 1961–1975 (fig. 27). It is possible that Hurricanes Carla (1961), Beulah (1967), and Fern (1971) affected the sedimentation rates for the period 1961–1975. Hurricanes Beulah and Fern caused abnormally high rainfall, which was reflected in high streamflow (and sediment load) along the Nueces River in 1967 and 1971 (fig. 27).

Table 7. Average rates of sedimentation for selected depths in Nueces River cores based on CFS, CIC, and CRS models.

Core no.	CFS rate (cm/yr)	CRS rate (cm/yr)	CIC rate (cm/yr)	Corrected (cm)	Anomalies excluded
NR-1	0.06	0.06	0.06	1-10	
NR-2	0.55	0.58	0.46	1-29	
NR-3	0.20	0.21	0.17	1-10	
NR-4	0.20	0.38	0.18	1-15	1
NR-5	0.13	0.62	0.12	1-6	
NR-6	0.10	0.42	0.09	1-6; 1-12 CRS	
NR-7	0.16	0.35	0.15	1-12; 1-7 CRS	
NR-8	0.13	0.17	0.16	1-13	1
NR-9	0.08	0.10	0.07	1-8; CRS	
NR-10	0.32	0.64	0.27	1-20; 1-11 CRS	3
NR-11	0.45	0.87	0.41	2-25; 1-18 CRS	3

Rockport Tide Gauge

Mean Sea Level (cm)

1.70 cm/yr

0.48 cm/yr

Year (to 1993)

Core NR-11

Corrected Depth (cm)

0.87 cm/yr

1.5 cm/yr

Year (Based on CRS Model; 0.94 dpm/g SPb)

Core NR-11

Corrected Depth (cm)

0.46 cm/yr

0.84 cm/yr   (2 anomalies excluded)

Year (Based on CIC Model; 0.94 dpm/g SPb)
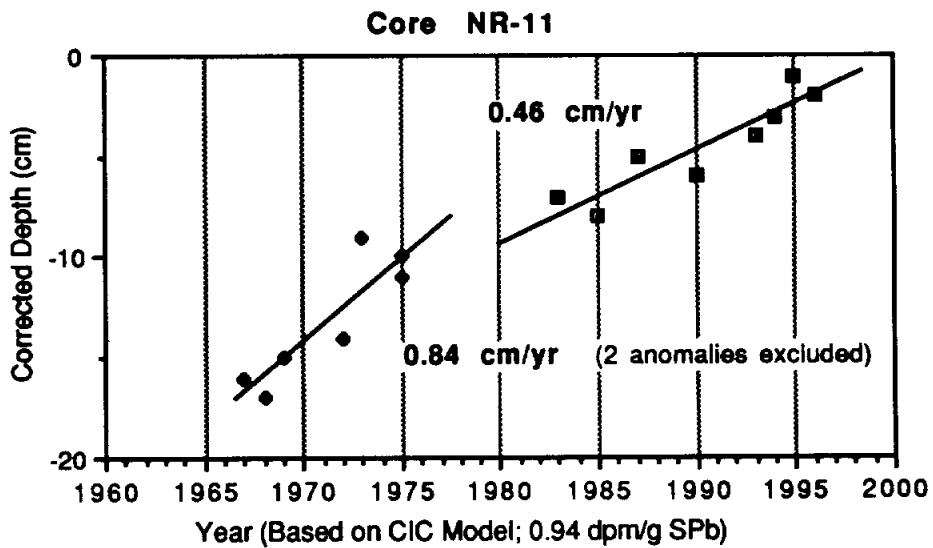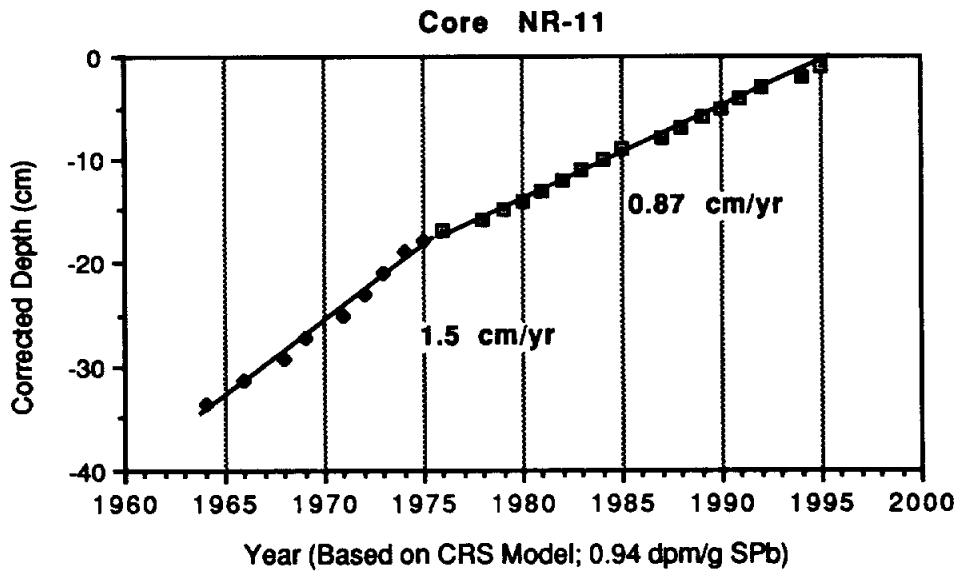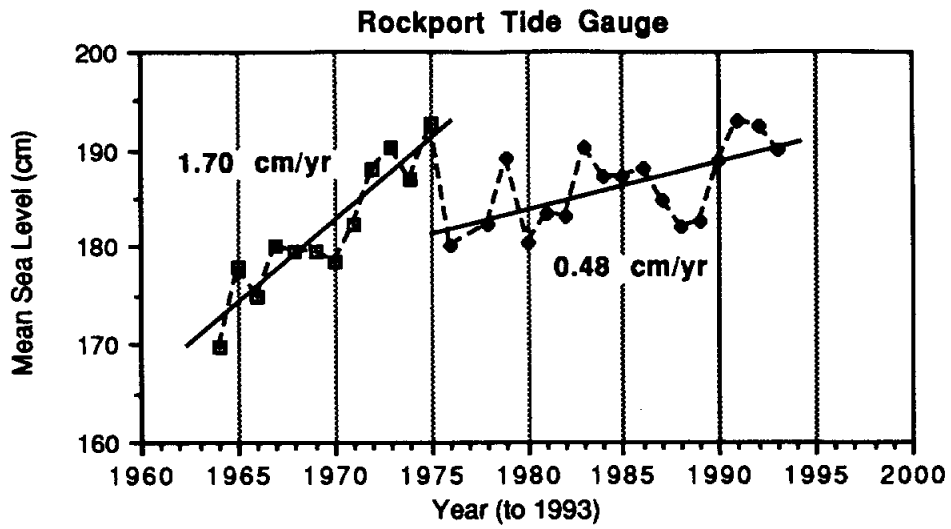
Figure 24. Comparison of changes in rates of relative sea-level rise at the Rockport tide gauge with changes in sedimentation rates at core site NR-11. Tide data from NOAA.

47
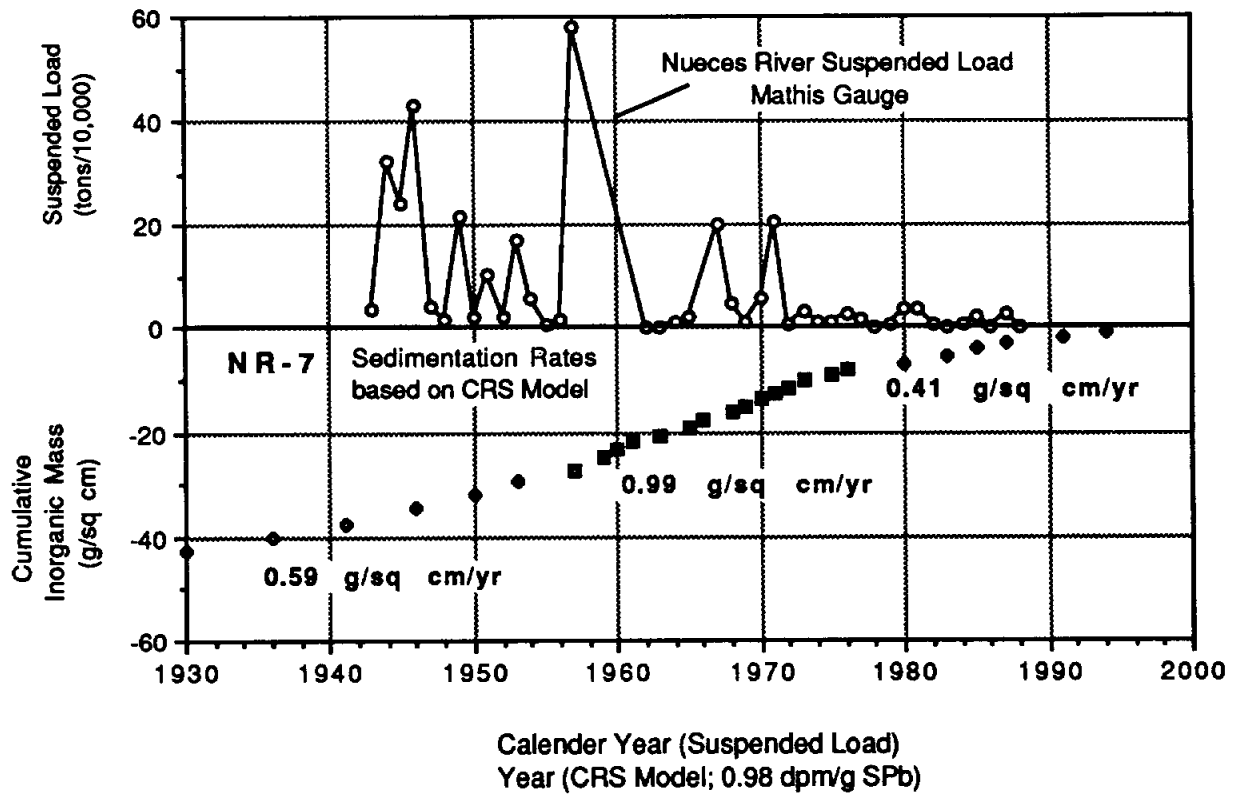
Figure 25. Comparison of changes in suspended load of the Nueces River with changes in sedimentation at core site NR-7. The sedimentation rate decreased in the mid 1970s, which corresponds with a decrease in suspended load. Suspended load data from the Texas Water Development Board (TWDB).

48
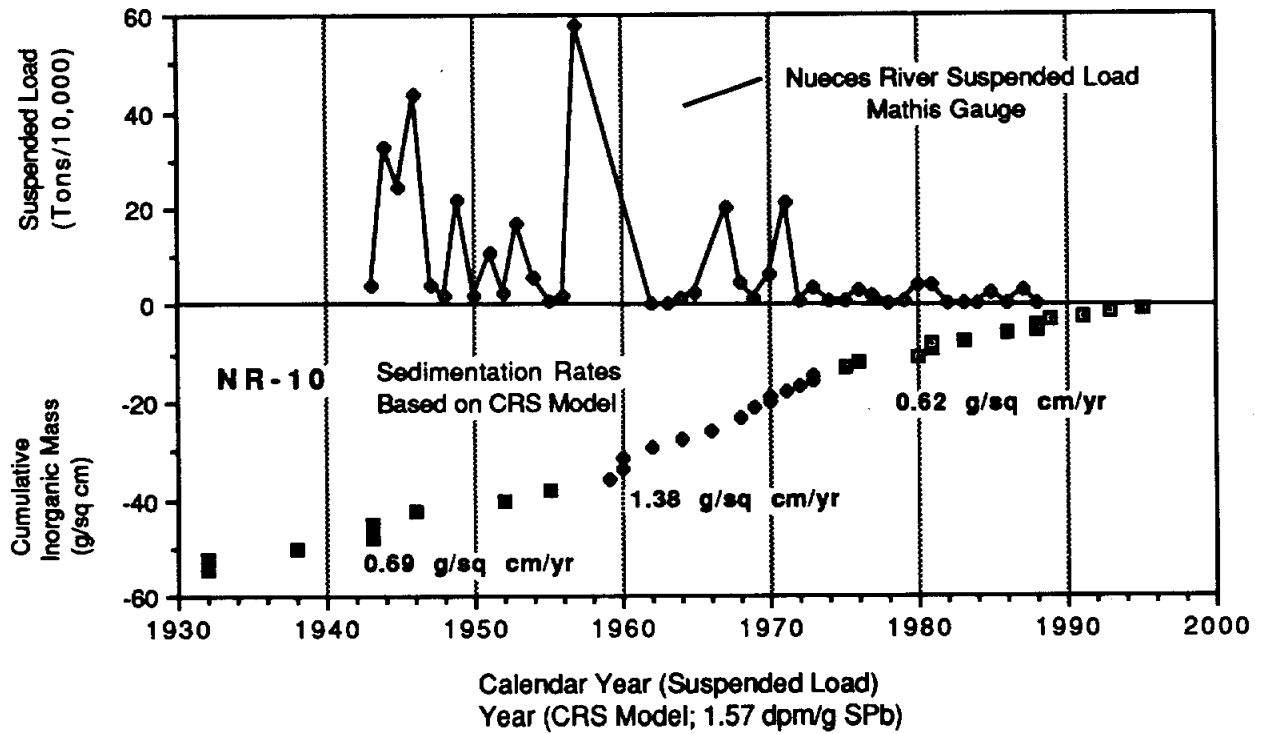
Figure 26. Comparison of decreasing rates of sedimentation at core site NR-10 with a decreasing sediment load along the Nueces River. The rate decreased after the mid-1970s as at core site NR-7 (fig. 25). Suspended load data from TWDB.
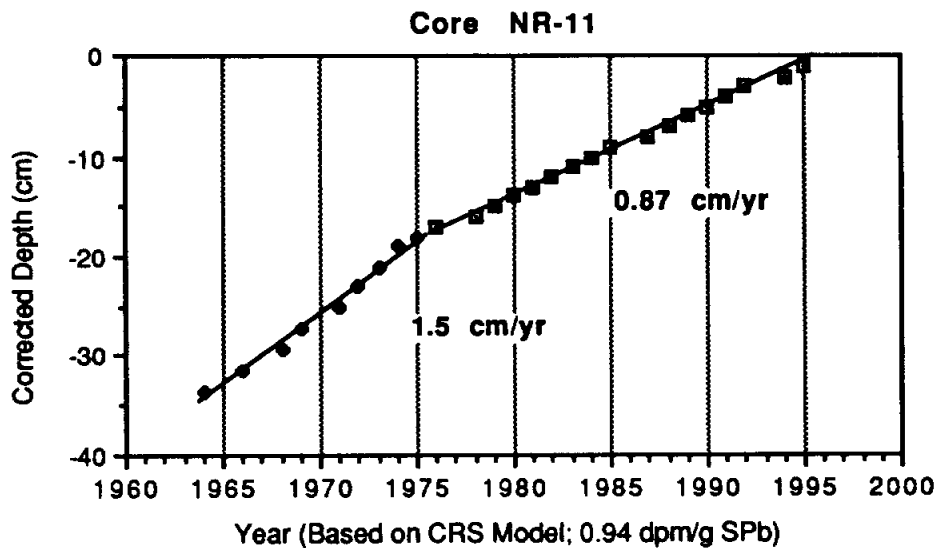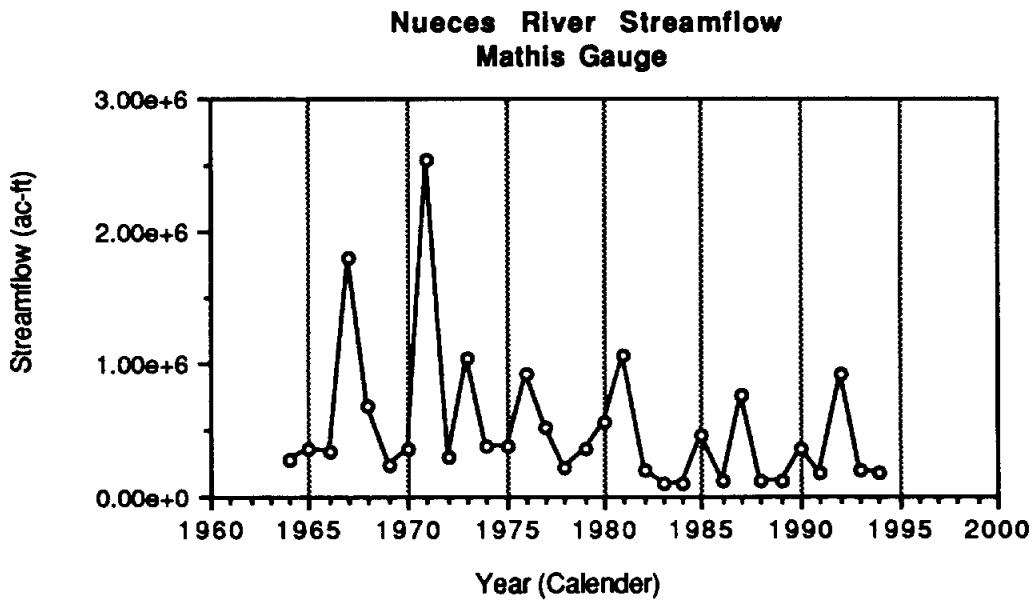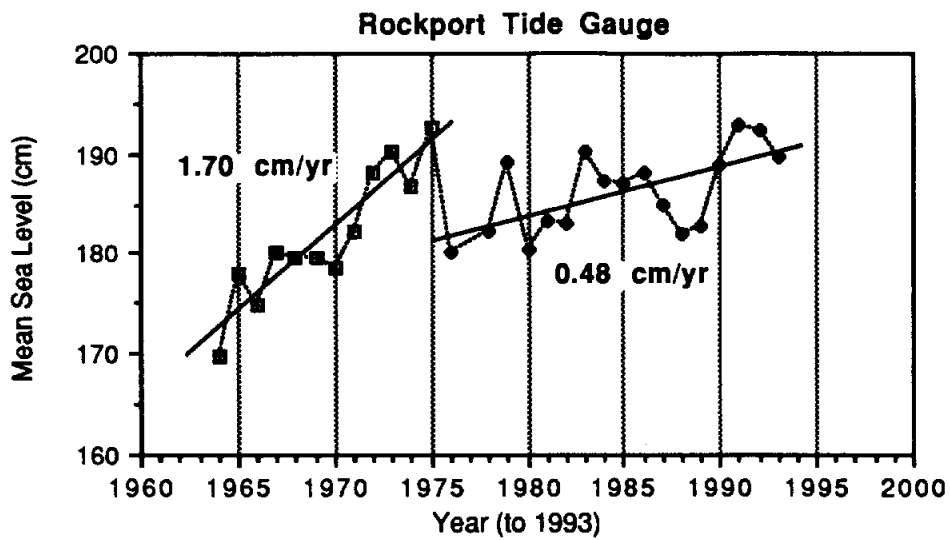
Figure 27. Comparison of rates of sea-level rise at the Rockport gauge, stream-flow at the Mathis station, and sedimentation at core site NR-11. Tide data from NOAA and streamflow data from TWDB.

50

Annotated Plots of Probable Causes for Variance in ^{210}Pb Activity

Depth plots of total ^{210}Pb activity (figs. 28 to 38) are annotated to indicate probable causes of local variations in excess ^{210}Pb activity. The plots were compared with the actual cores, core descriptions, x-radiographs, organic matter (LOI), and textural properties in an effort to explain some of the variations in ^{210}Pb activity. Note that depths used in these illustrations are actual core depths and are not corrected for shortening.
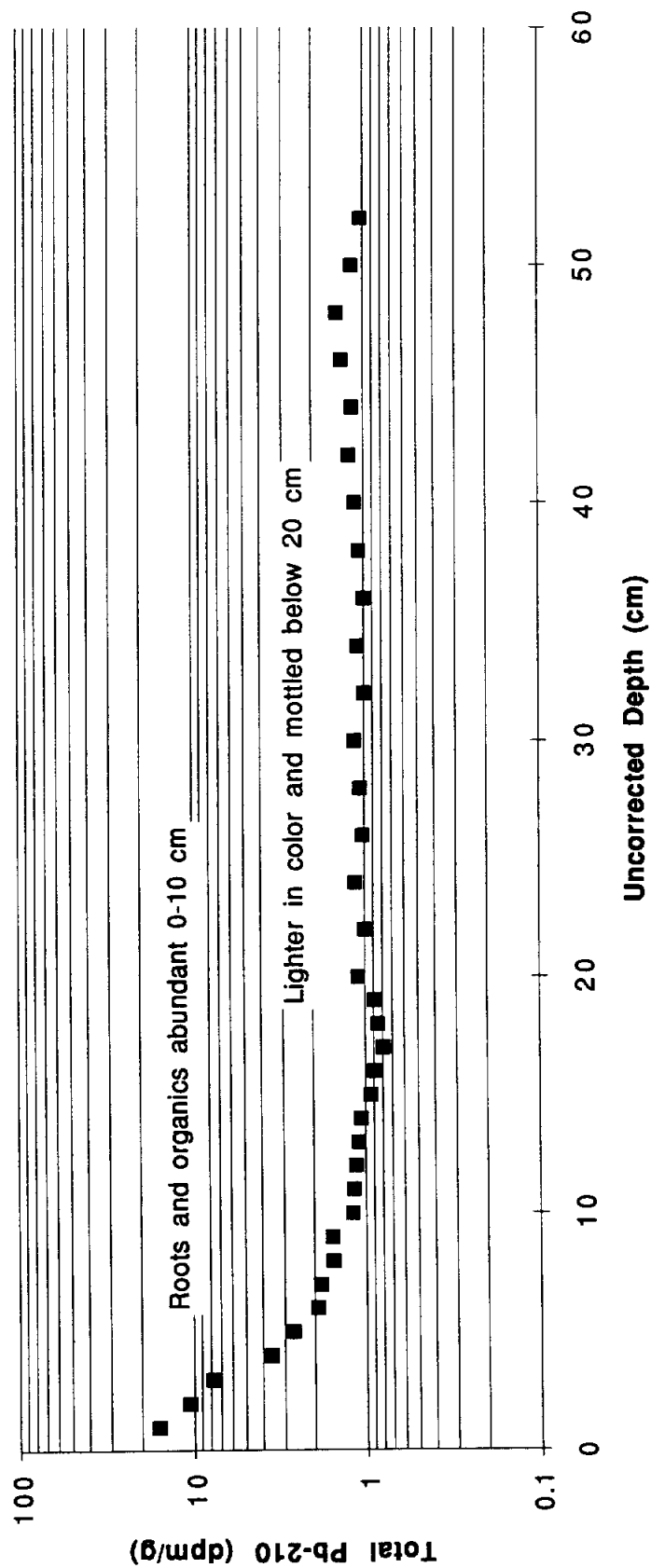
Figure 28. Core NR-1 annotated profile.
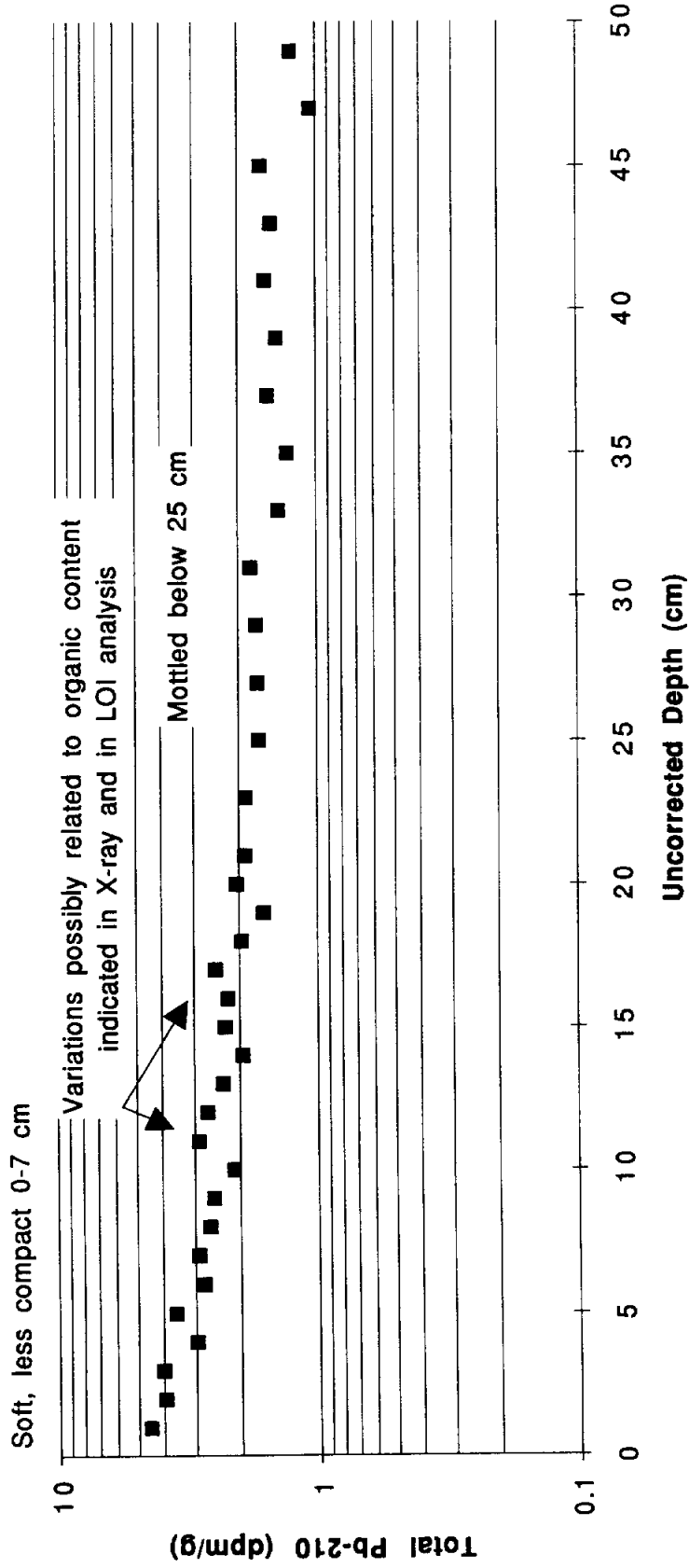
Figure 29. Core NR-2 annotated profile.
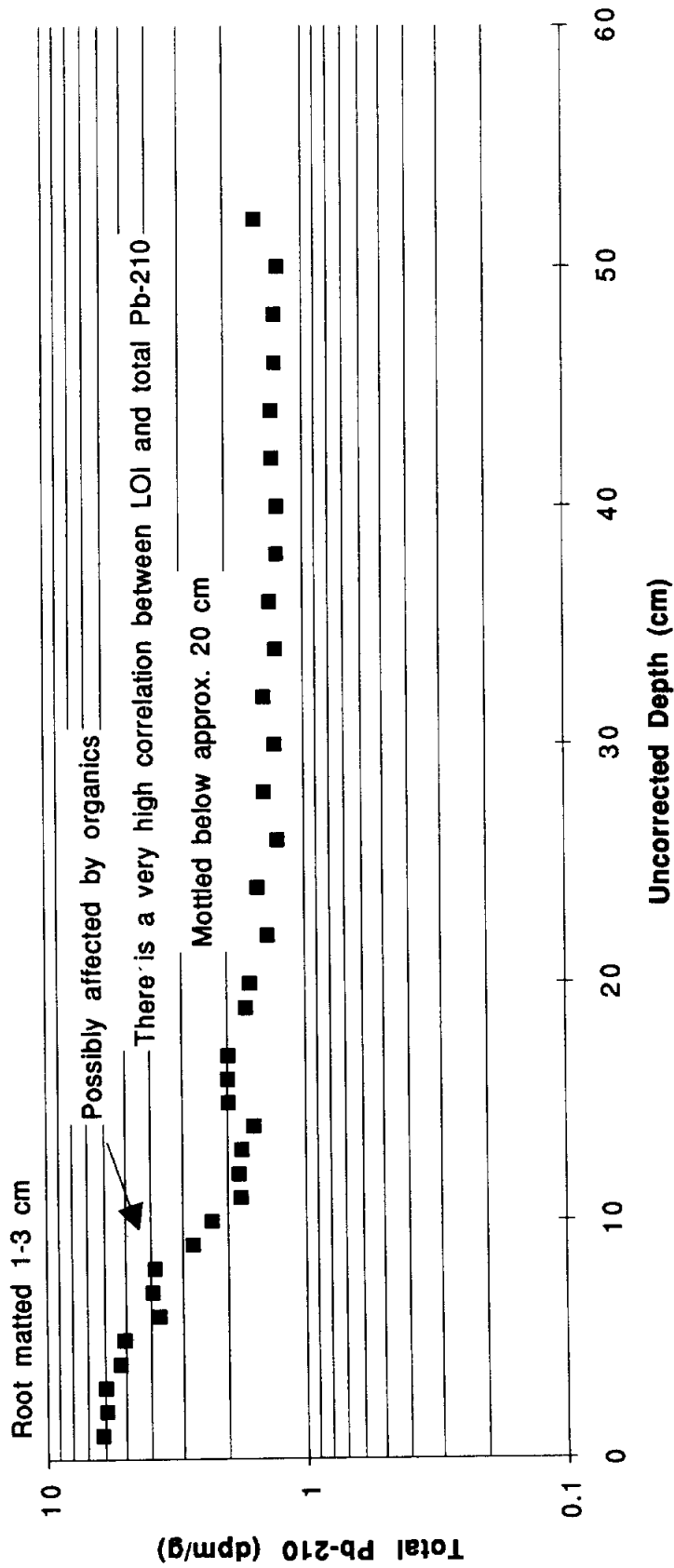
Figure 30. Core NR-3 annotated profile.
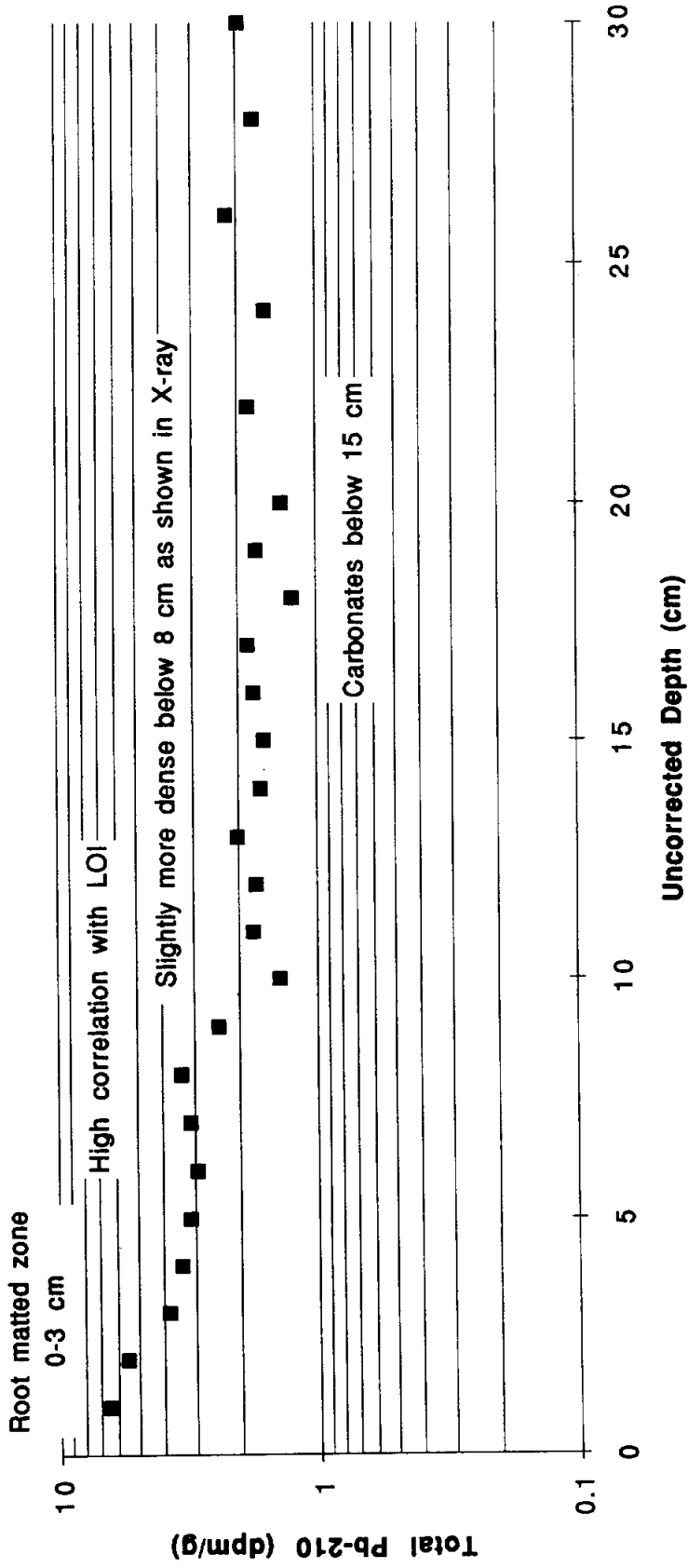
Figure 31. Core NR-4 annotated profile.

55
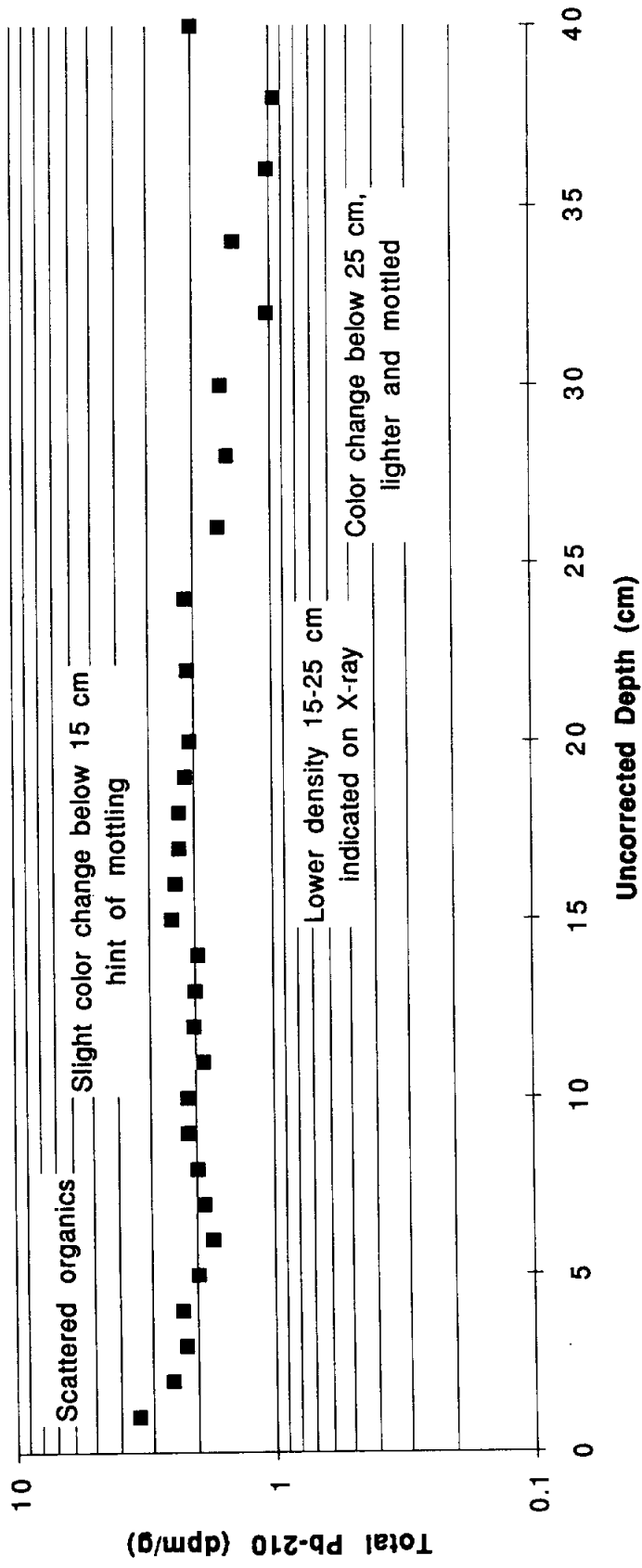
Figure 32. Core NR-5 annotated profile.
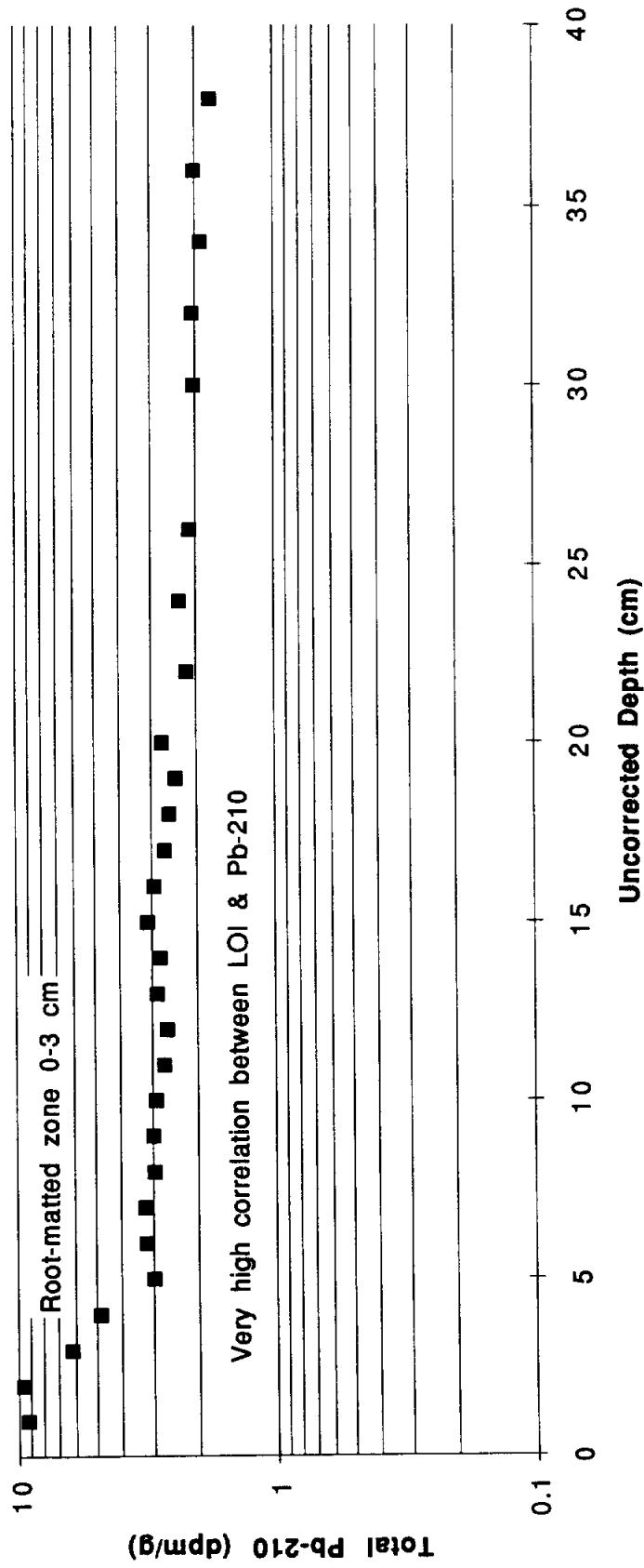
Figure 33. Core NR-6 annotated profile.

57

Figure 34. Core NR-7 annotated profile.

NR-8
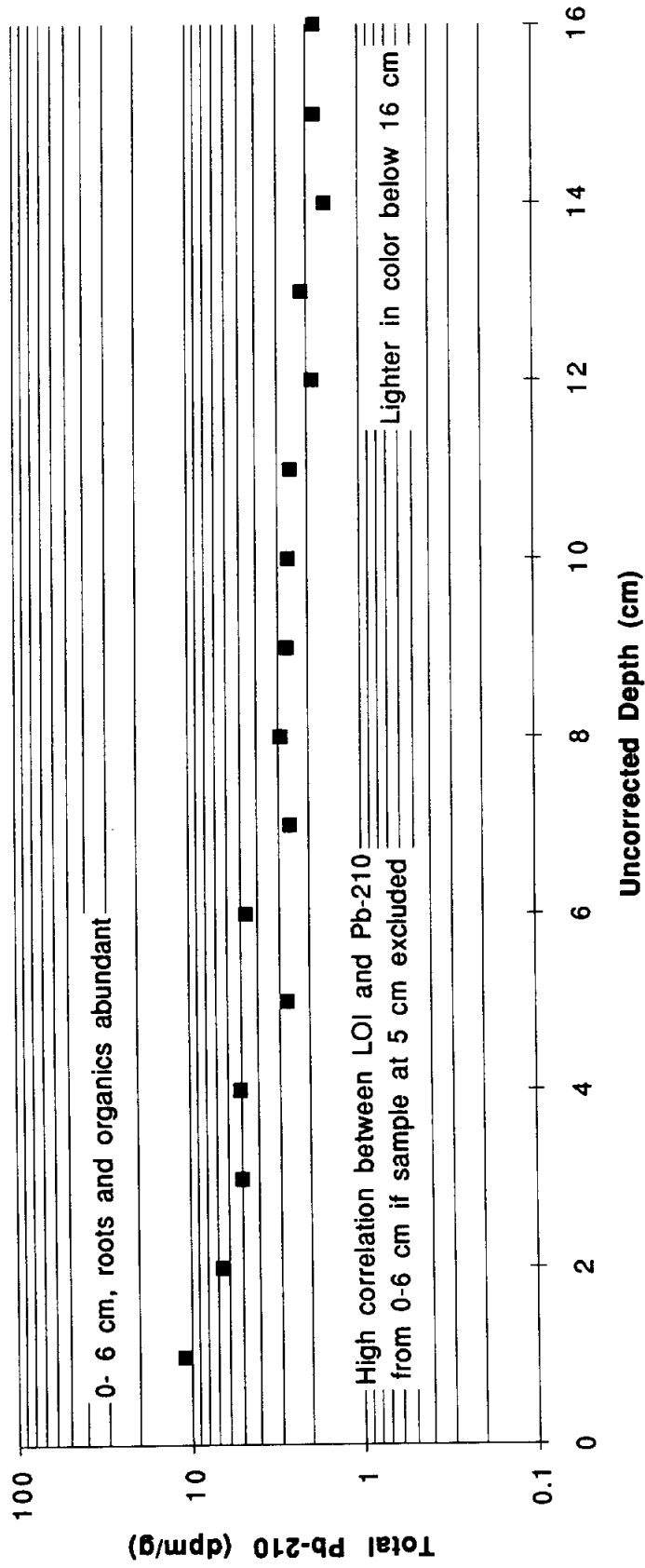
Figure 35. Core NR-8 annotated profile.
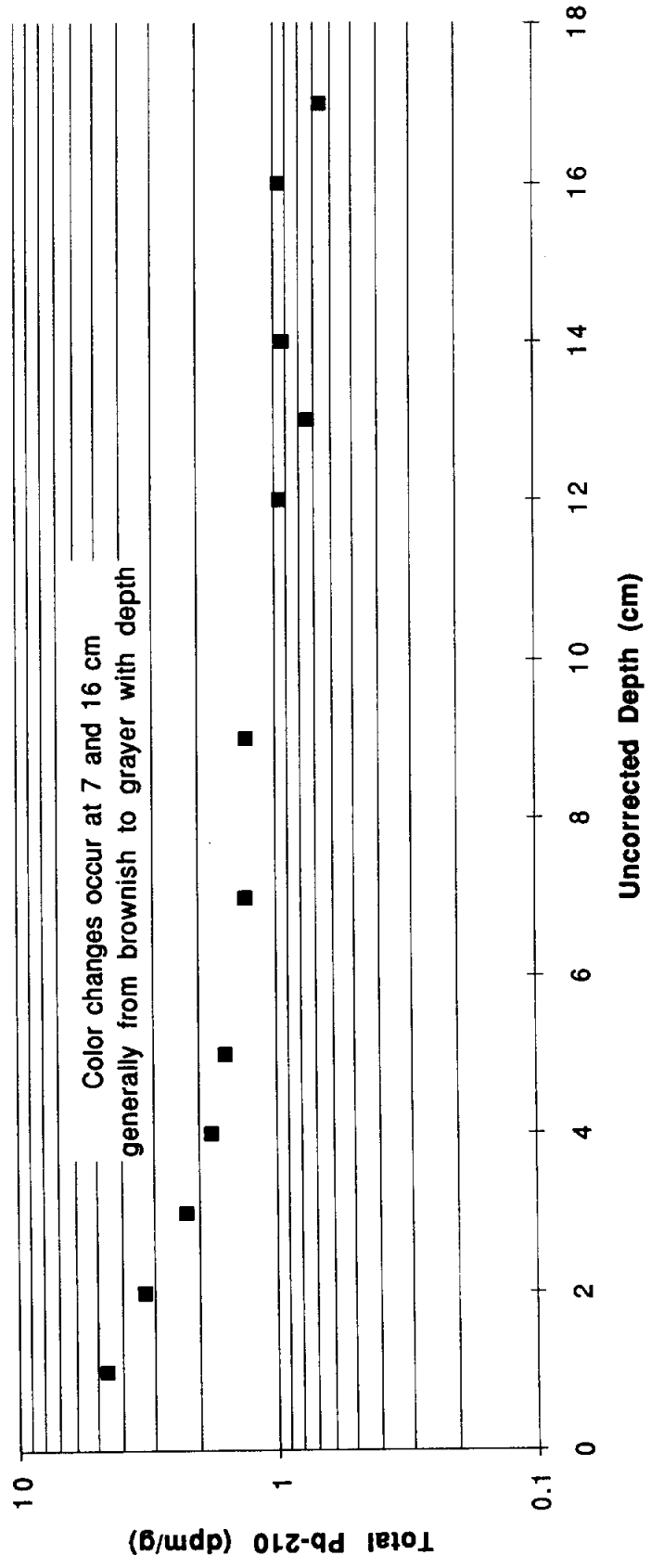
Figure 36. Core NR-9 annotated profile.
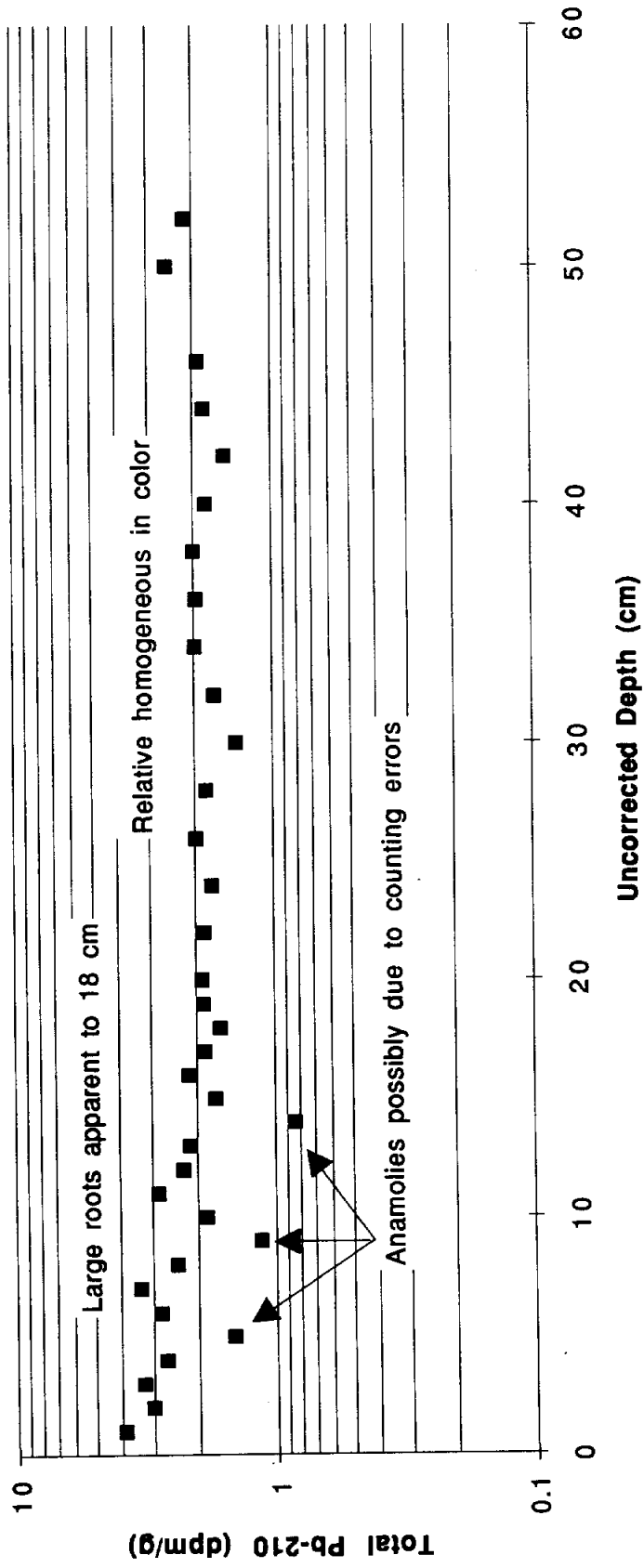
Figure 37. Core NR-10 annotated profile.
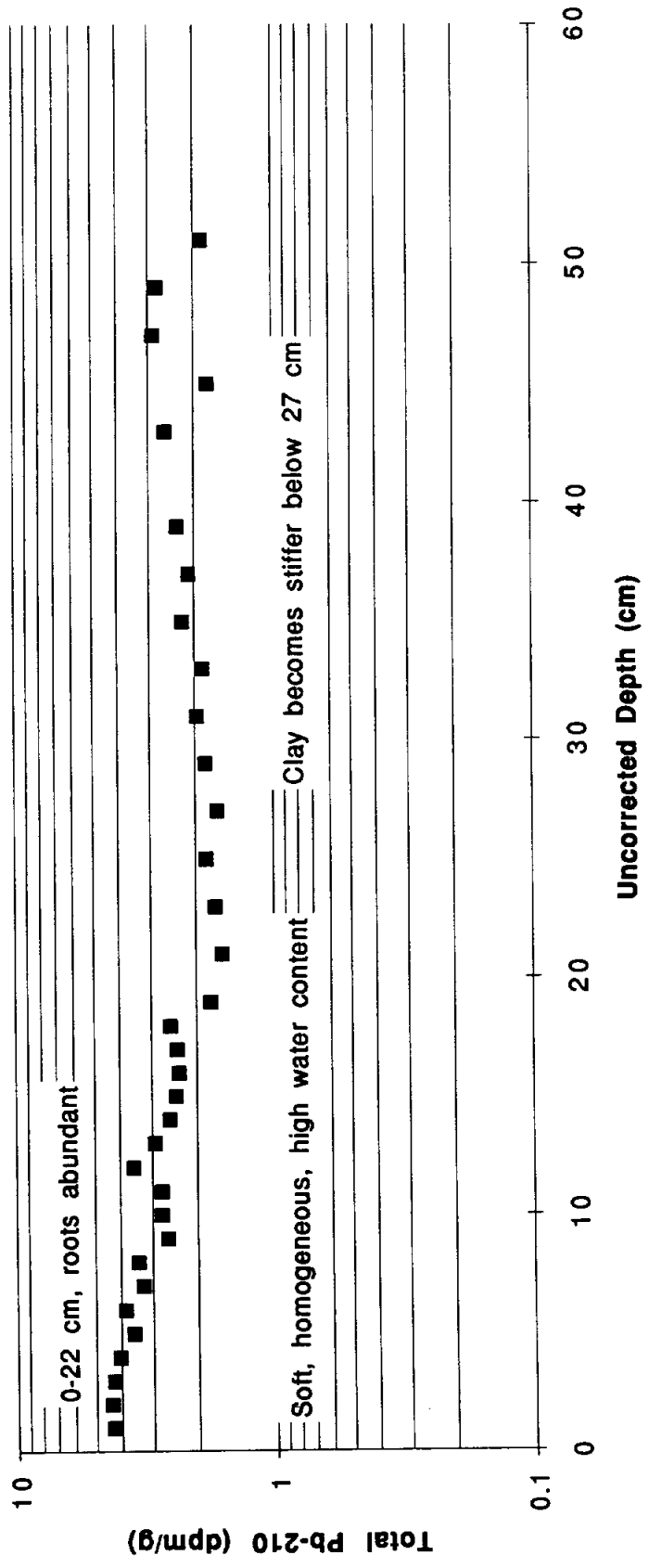
Figure 38. Core NR-11 annotated profile.

RELATIVE SEA-LEVEL RISE

Relative sea-level rise as used here is the relative vertical rise in water level with respect to a datum at the land surface, whether it is caused by a rise in mean-water level or subsidence of the land surface. Along the Texas coast both processes eustatic sea-level rise and subsidence, are part of the relative sea-level rise equation. Subsidence, especially associated with pumpage of ground water and oil and gas, is the overriding component. As defined in this report, relative sea-level rise does not include the offsetting effects of vertical accretion.

Eustatic Sea-Level Rise and Subsidence

Over the past century, sea level has been rising on a worldwide (eustatic) basis at a rate of about 1.2 mm/yr, with a rate in the Gulf of Mexico and Caribbean region of 2.4 mm/yr (Gornitz and others, 1982; Gornitz and Lebedeff, 1987). Adding compactional subsidence to these rates yields a relative sea-level rise that locally exceeds 10 mm/yr (Swanson and Thurlow, 1973; Penland and others, 1988).

Rates of "natural" compactional subsidence and eustatic sea-level rise, which together may range up to 12 mm/yr in the Galveston area (Swanson and Thurlow, 1973; Gornitz and Lebedeff, 1987; Penland and others, 1988), are locally dwarfed by human-induced subsidence, for example in the Houston area, where subsidence rates at some locations exceed 100 mm/yr (Gabrysch and Coplin, 1990). The major cause of human-induced subsidence is the withdrawal of underground fluids, principally ground water, oil, and gas (Pratt and Johnson, 1926; Winslow and Doyel, 1954; Gabrysch, 1969, 1984; Gabrysch and Bonnet, 1975; Kreitler, 1977; Verbeek and Clanton, 1981; Kreitler and others, 1988).

Relative Sea-Level Rise in the Study Area

Tide gauge records and benchmark releveling surveys from the National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS) provide data for determining rates of relative sea-level rise in the Nueces River valley near Odem. Paine (1993) compiled data on vertical movement using regional first-order levelings conducted by NGS in the 1950s, late 1970s, and early

63

1980s. Vertical movement at each benchmark in the network was determined with reference to an arbitrarily chosen benchmark, F46 at Sinton (Paine, 1993). The geodetic network was referenced to sea level through leveling lines to tide gauge stations at Galveston, Rockport, and Port Isabel (fig. 39). These data provide relative sea-rise rates at benchmarks along the main leveling line that crosses the Nueces River valley south of Odem (fig. 40).

Rates of relative sea-level rise in millimeters per year for the period 1951–1982 were determined for five benchmarks along the MOPAC railroad that crosses the Nueces River valley just east of U.S. Highway 77, between Odem and Calallen (fig. 41 and table 8). Rates of relative sea-level rise were estimated relative to the tide gauge at Port Isabel because dates of leveling surveys between Algoa and Harlingen and Harlingen and Port Isabel were in close agreement, and use of the Port Isabel gauge did not require extrapolation from a benchmark several kilometers away as was necessary for the Rockport gauge (Paine, 1993). Rates of relative sea-level rise are also relative to the reference benchmark F46. Movement of tide gauges relative to F46 are shown in table 9.

Table 8. Rate of vertical movement relative to BM F46 (Sinton) for selected benchmarks along a leveling line that crosses the Nueces River valley at the Missouri-Pacific Railroad between Odem and Calallen just east of U.S. Highway 77. Positive change is upward relative to BM F46. Data from National Geodetic Survey as compiled by Paine (1993).

NGS Benchmark	Rate of vertical movement of BM (mm/yr) 1951–1978
Z175	+7.10
V175	+0.80
K46	+1.63
P176	+0.71
R176	+16.73
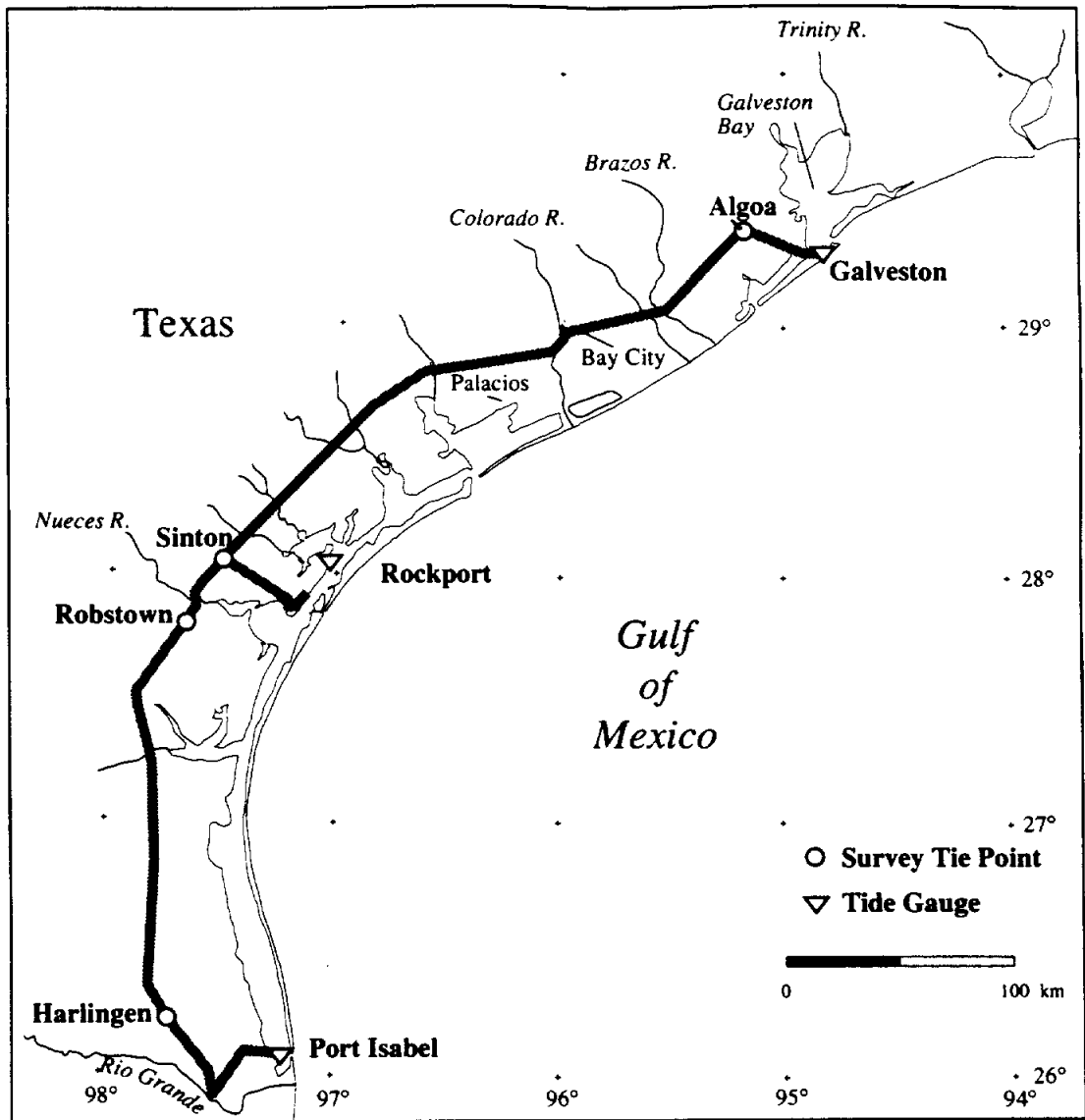
Figure 39. Location of National Geodetic Survey leveling lines and National Ocean Survey tide gauges. From Paine (1993).
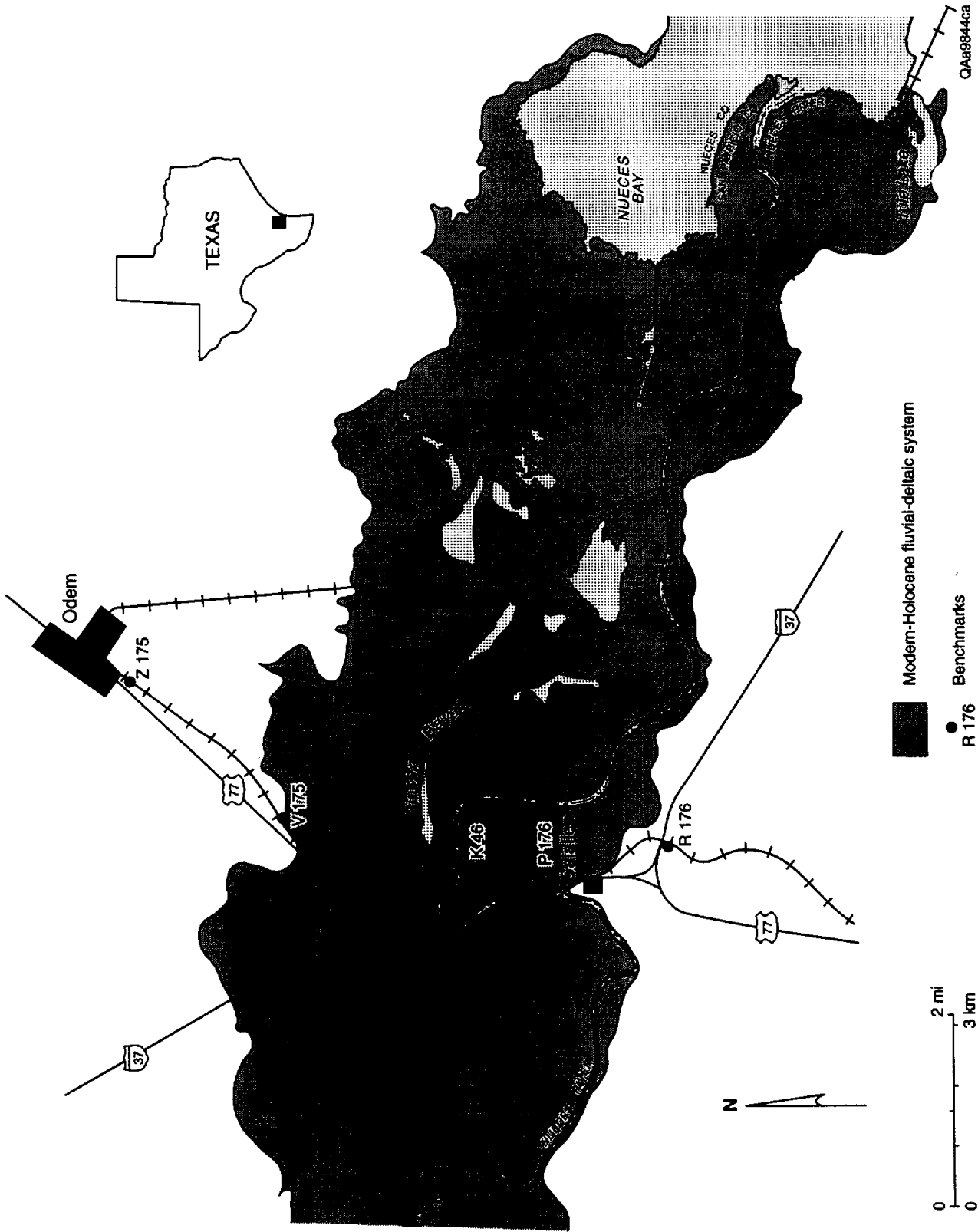
Figure 40. Location of benchmarks along the leveling line across the Nueces River south of Odem.
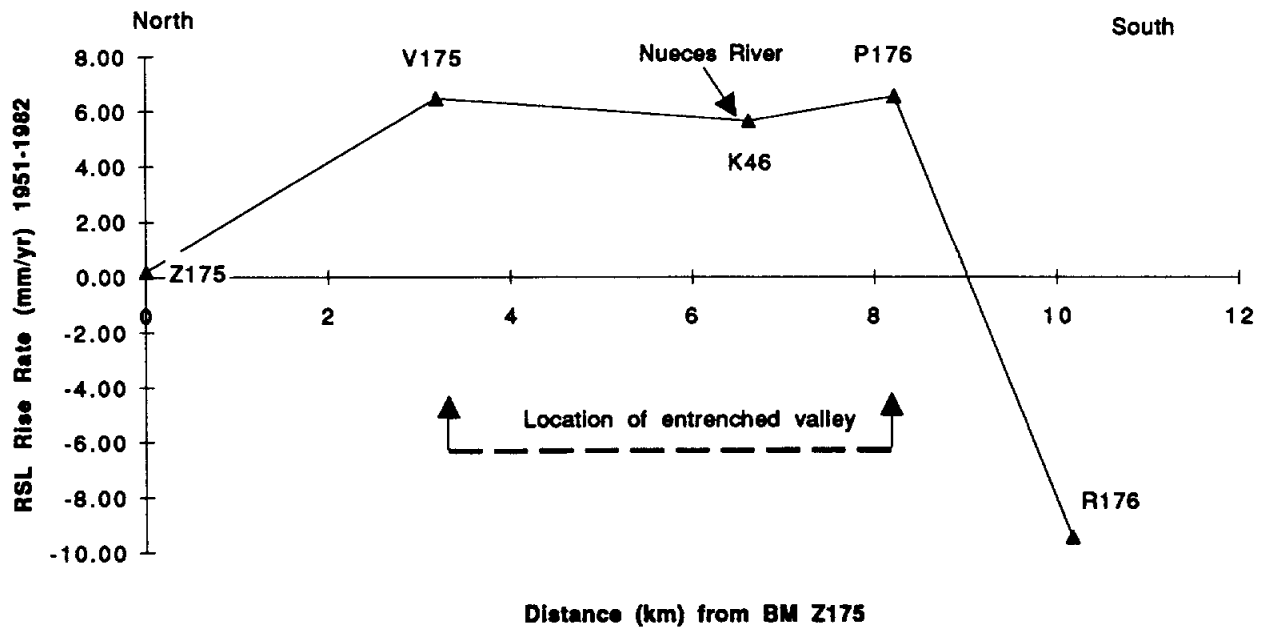
Figure 41. Rates of relative sea-level rise between 1951 and 1978 to 1982 along a line crossing the Nueces River valley south of Odem. Based on data from Paine (1993).

Table 9. Rates of vertical movement relative to NGS benchmark F46 and rates of relative sea-level rise at the Port Isabel, Rockport, and Galveston Pier 21 gauges. From Paine (1993).

Tide gauge	Vertical movement relative to F46 (mm/yr)	Relative sea-level rise rate 1951 to 1982 (mm/yr)	Relative sea-level rise rate relative to F46 (mm/yr)
Port Isabel	+2.7	4.6	7.3
Rockport	+2.2	5.4	7.6
Galveston Pier 21	-2.3	8.2	5.9

Table 10. Relative sea-level rise rates for selected benchmarks along a line that crosses the Nueces River valley between Odem and Calallen. Rates are relative to the Port Isabel tide gauge and benchmark F46 (Sinton) and were determined by adding the relative sea-level rise rate (equivalent to a negative vertical movement of the land surface) at the Port Isabel gauge (table 9) with the vertical movement of benchmarks shown in table 8. These data are from Paine (1993). See figure 40 for location of benchmarks and figure 41 for plot of rates of relative sea-level rise.

NGS benchmark	RSL rate (mm/yr) 1951-1982
Z175	0.2
V175	6.5
K46	5.7
P176	6.6
R176	-9.4

For the period of 1951 to 1982, rates at benchmarks on the north and south edges of the Nueces River valley were about 6.5 mm/yr (table 10 and fig. 41). Rates are considerably lower at benchmarks further north and south, and, in fact, BM R176 to the south moved upward relative to BM F46 and the Port Isabel tide gauge; the relative rate of sea-level rise at this benchmark is -9.4 mm/yr, indicating a rise in the land surface relative to sea level (table 10).

The rate of 5.7 mm/yr at benchmark K46 on the south bank of the Nueces River is similar to the RSL rate of 5.4 mm/yr for the Rockport tide gauge for the period 1951–1982. This rate (5.7 mm/yr) exceeds the Gulf of Mexico mean sea-level rise rate by a factor of about 2 to 5, based on the regional Gulf of Mexico rate of 2.4 mm/yr and the eustatic rate of 1.2 mm/yr, respectively (Gornitz and Lebedeff, 1987). The accelerated rates of sea-level rise are apparently related to subsidence, much of which may be the result of regional oil and gas production and depressurization (Paine, 1993). Subsidence and faulting associated with the Saxet oil and gas field west of Corpus Christi are well documented (Gustavson and Kreitler, 1976; Hillenbrand, 1985). NGS benchmark releveling data reported by Brown and others (1976) show subsidence of approximately 6.7 mm/yr from 1942 to 1951, encompassing an area of 389 km^2 north and northeast of Corpus Christi, an area that includes the Nueces River alluvial valley and delta south of U.S. Highway 77 (fig. 42).

Relative Sea-Level Rise at Coring Sites

Because rates of relative sea-level rise can be locally affected by subsidence associated with oil and gas production, it is difficult to determine with certainty the rates at locations away from the benchmark releveling line. Historically, wetland loss has been most extensive near the bayward reaches of the Nueces River delta (White and Calnan, 1990). Between the 1930s and 1979, approximately 130 ha of emergent vegetation was converted to open water and barren flats. Progradation of the Nueces River delta into Nueces Bay ended sometime between 1930 and 1959 (Morton and Paine, 1984). Subsidence and reductions in the volume of fluvial sediments delivered by the Nueces River as a result of upstream dams may account for the retreating shoreline and loss of interior emergent vegetation (White and Calnan, 1990). Still, without benchmark releveling data down the valley, it is not possible to determine if subsidence is occurring at a higher rate nearer to Nueces Bay. As mentioned, the closest tide gauge station with a sufficient period of record is at Rockport, where the relative sea-level rise rate for the period 1951–1982 is 5.4 mm/yr (Paine, 1993) and from the 1940s to 1980s, 4.5 mm/yr (fig. 15).
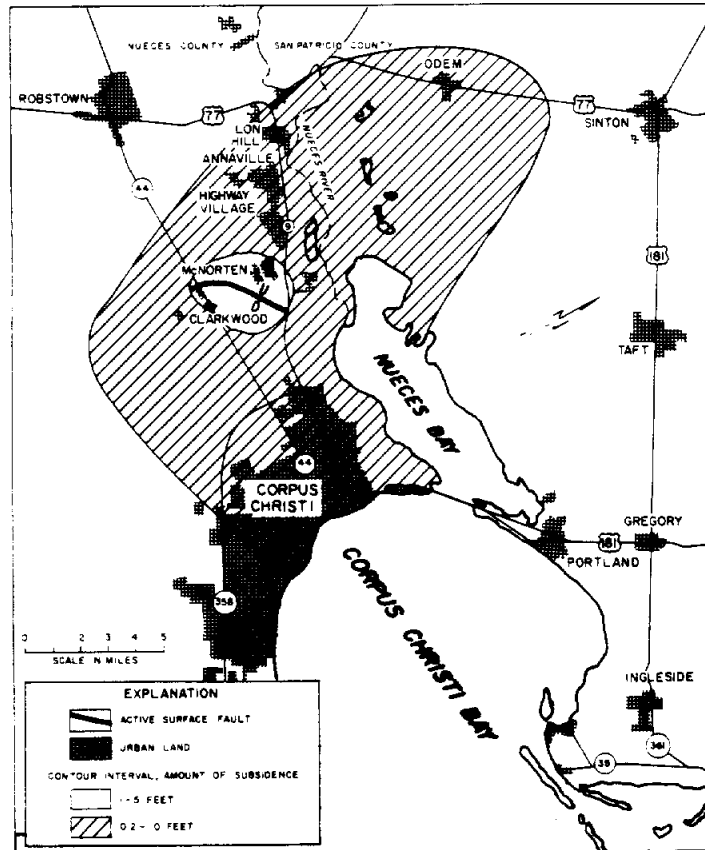
Figure 42. Land-surface subsidence in the Corpus Christi area (1942–1951). Level data from NOAA. After Brown and others (1976). Subsidence probably caused by oil and gas production.

70

NR-8

(Figure: Total Penetration (cm) versus Cumulative Shortening (cm))

NR-9

NR-9

Total Penetration (cm) vs Cumulative Shortening (cm)

NR-10

NR-10

NR-11

NR-11
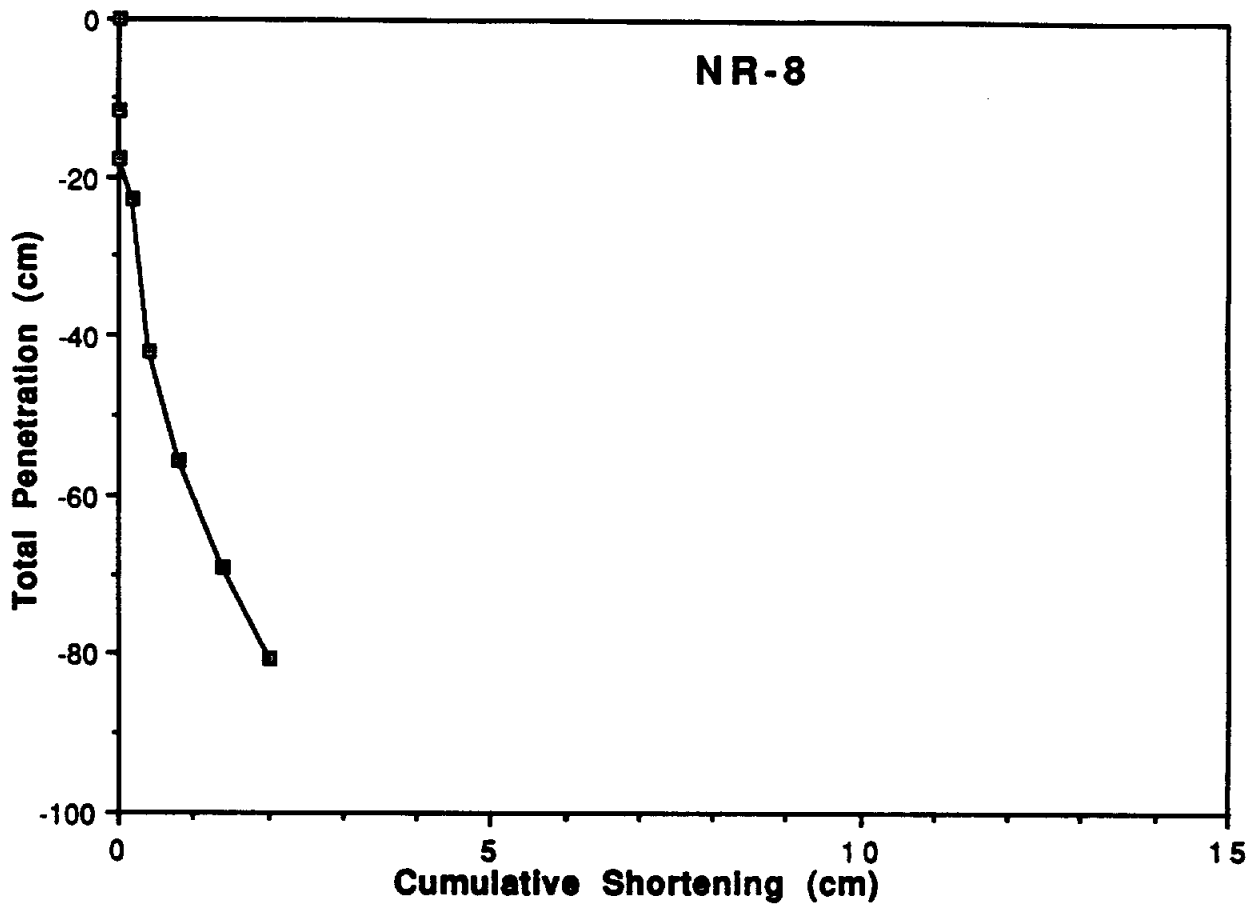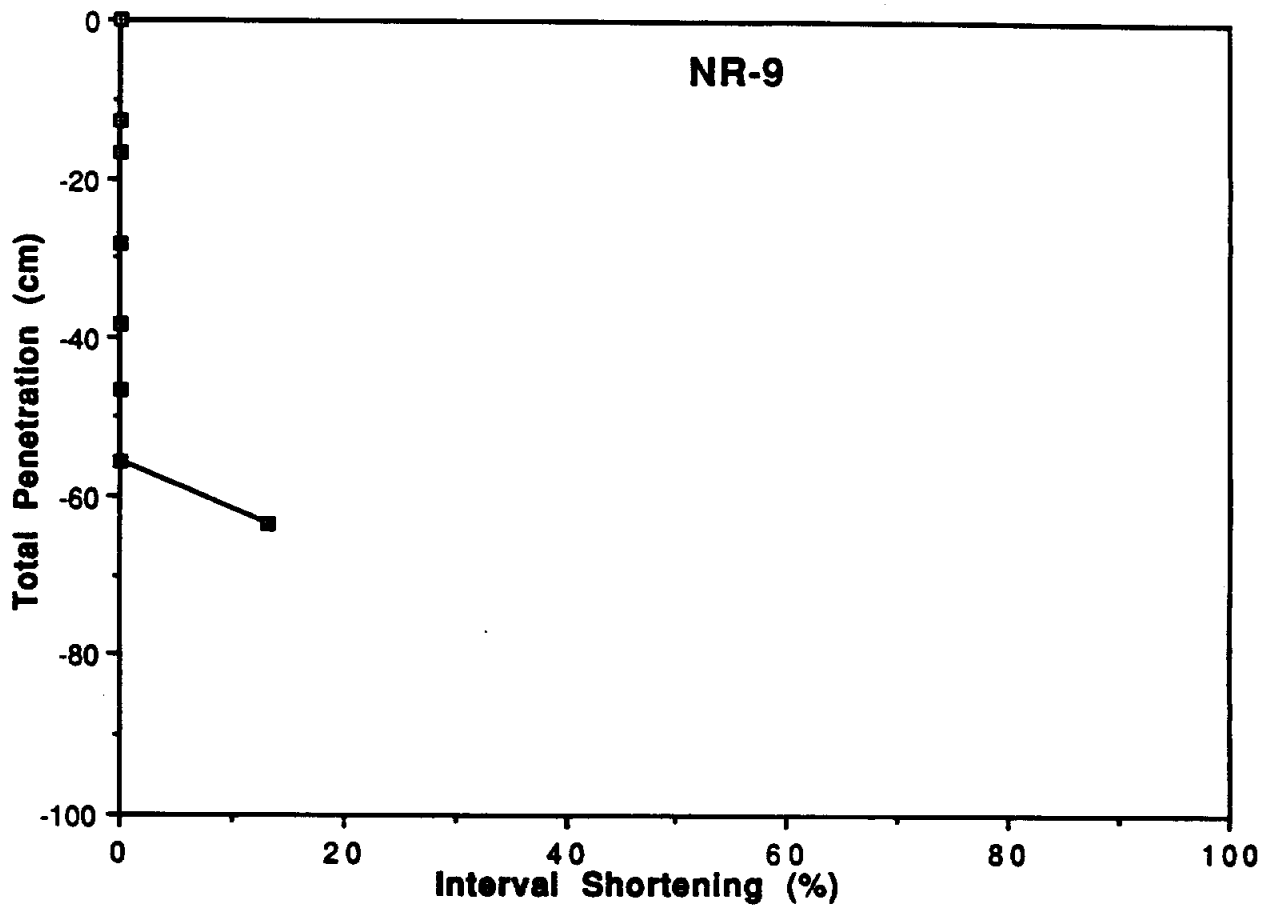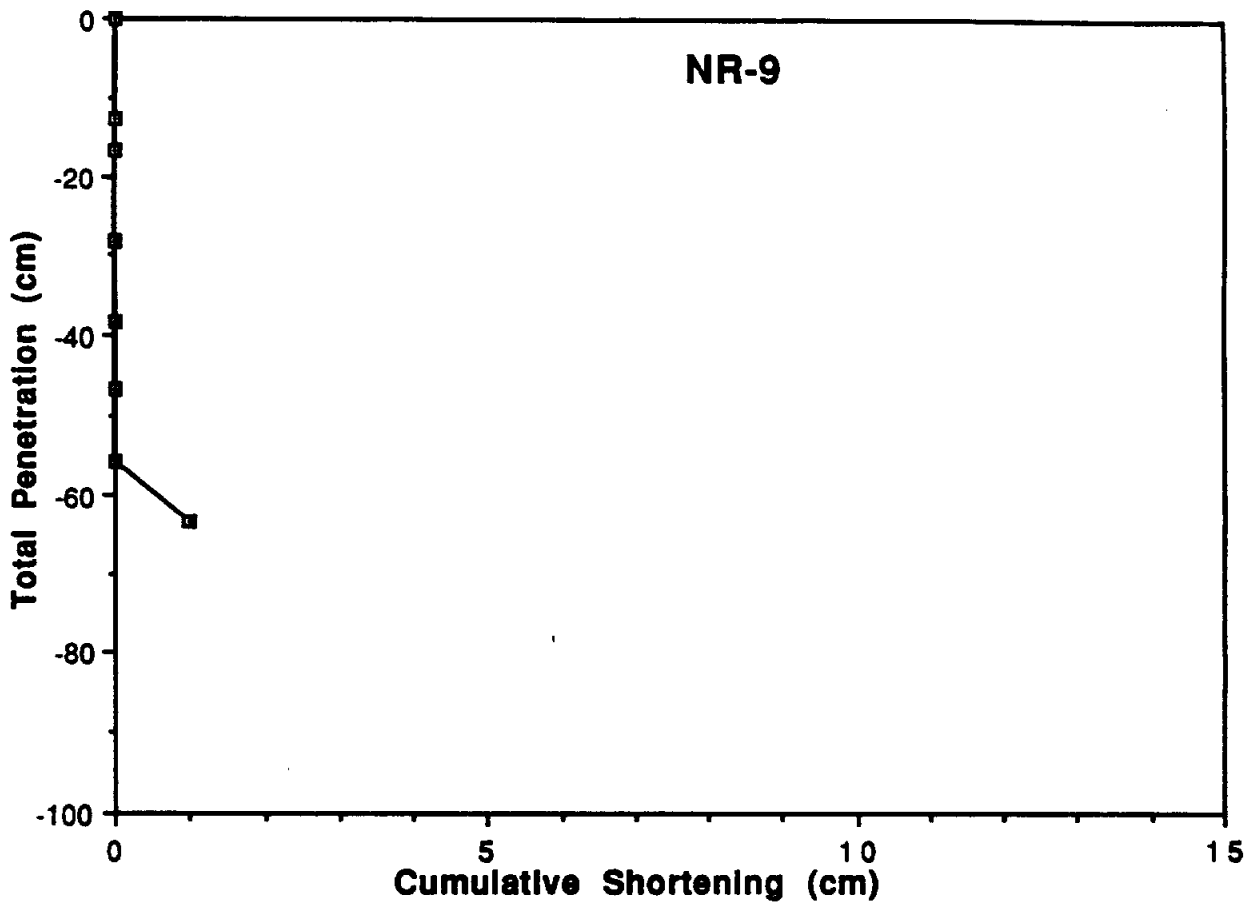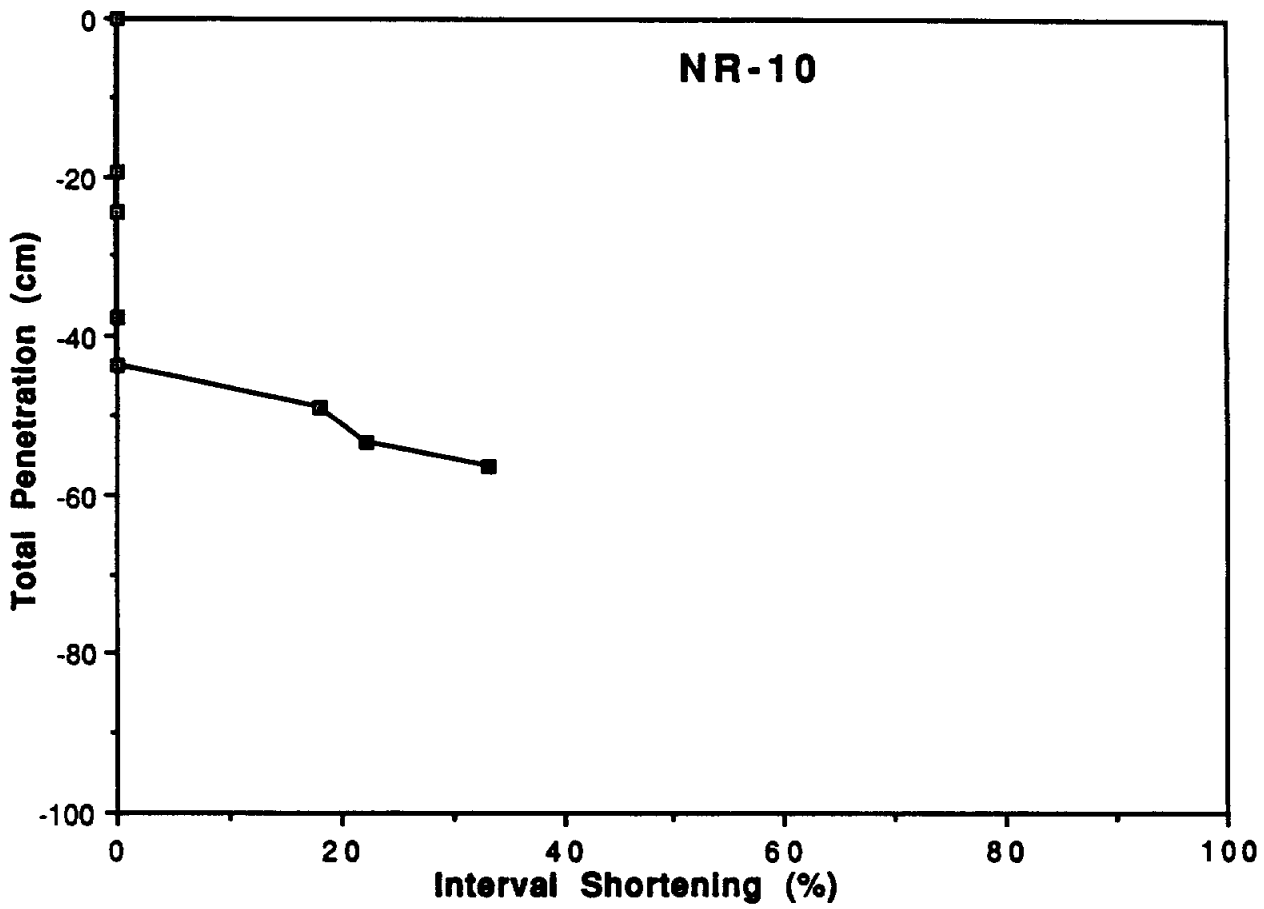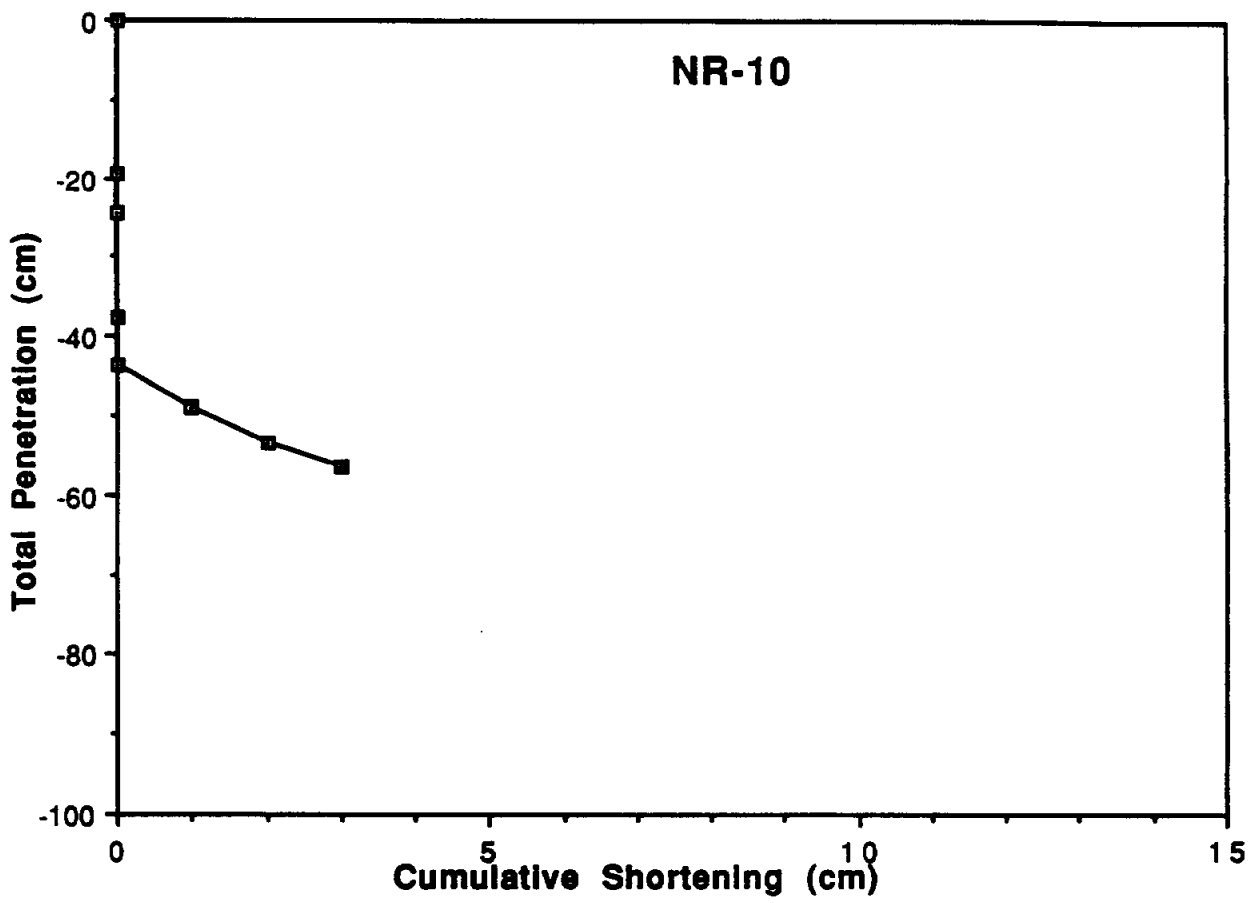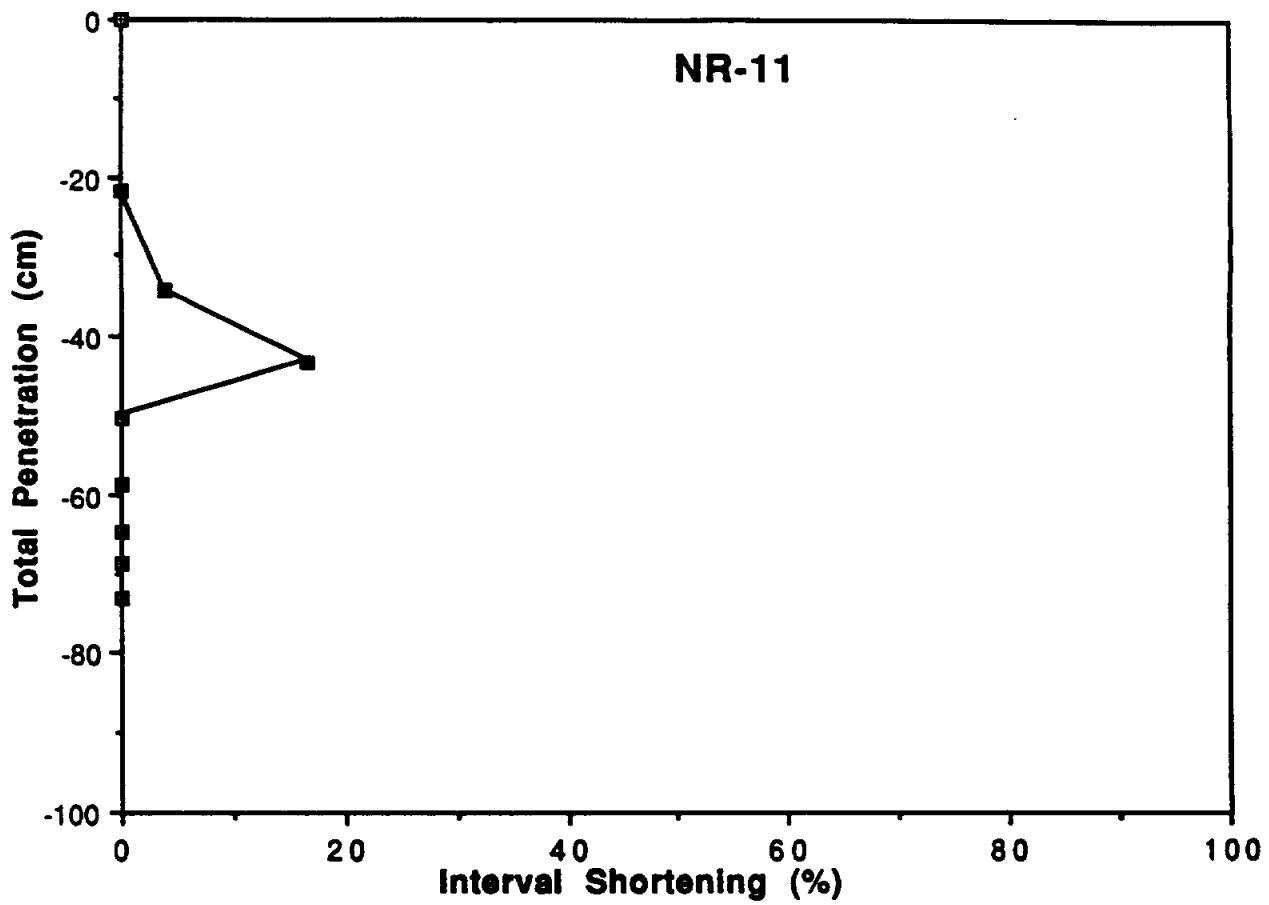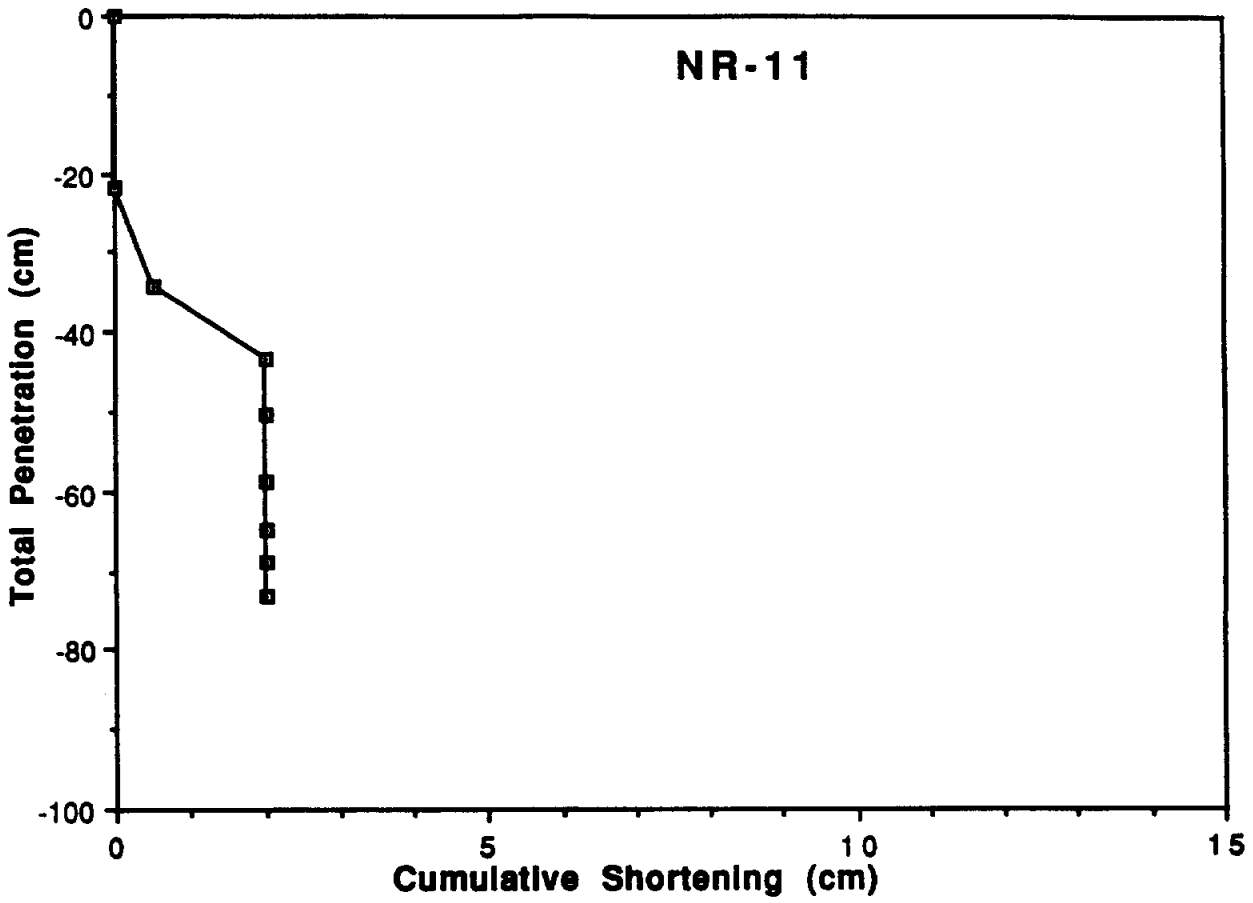
APPENDIX B

^{210}Pb, ^{226}Ra, Water Content, LOI, Bulk Density, Texture, and Depth Corrections from Shortening

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Ra-226 (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR1	1	1	1.0000	25.8	21.9	15.1	11.26	73.62	67.2	29.7	3.1	0.54	0.46	16.0603		15.1703	0.054
NR1	2	2	2.0000	32.8	25.5	22.3	9.74	68.00	35.6	47.7	16.7	0.69	0.54	10.6574		9.7674	0.035
NR1	3	3	3.0000	45.8	33.5	26.9	9.49	63.66	21.7	39.9	38.4	0.96	0.71	7.8611		6.9711	0.029
NR1	4	4	4.0000	66.4	48.9	26.4	7.86	65.79	17.2	39.1	43.7	1.40	1.03	3.5928		2.7028	0.020
NR1	5	5	5.0000	70.5	53	24.8	6.35	68.83	15.2	37.9	46.9	1.48	1.12	2.6808		1.7908	0.020
NR1	6	6	6.0000	66.5	50.4	24.2	6.16	69.63	14.5	41.8	43.6	1.40	1.06	1.9271		1.0371	0.013
NR1	7	7	7.0000	61.2	46.5	24.0	6.55	69.43	14.7	41.6	43.7	1.29	0.98	1.8586		0.9686	0.012
NR1	8	8	8.0000	70.3	52.8	24.9	6.59	68.52	13.4	39.3	47.2	1.48	1.11	1.5629		0.6729	0.010
NR1	9	9	9.0000	60.7	45.3	25.4	6.52	68.11	10.1	42.4	47.5	1.28	0.95	1.5851		0.6951	0.017
NR1	10	10	10.0000	72.0	53.2	26.1	5.91	67.98	8.8	36.6	54.6	1.52	1.12	1.2063		0.3163	0.015
NR1	11	11	11.0000	70.6	52.1	26.2	6.37	67.42	12.2	36.1	51.7	1.49	1.10	1.1901		0.3001	0.003
NR1	12	12	12.0000	61.9	45.4	26.7	6.56	66.78	12.9	38.6	48.6	1.30	0.96	1.1498		0.2598	0.009
NR1	13	13	13.0000	68.3	50.1	26.6	6.29	67.07	13.0	36.6	50.3	1.44	1.05	1.1083	0.85	0.2183	0.010
NR1	14	14	14.0000	67.9	49.7	26.8	5.92	67.28	11.4	38.1	50.5	1.43	1.05	1.0665		0.1765	0.010
NR1	15	15	15.0000	75.6	54.6	27.8	5.70	66.52	11.2	40.2	48.6	1.59	1.15	0.9453		0.0553	0.010
NR1	16	16	16.0000	63.3	45.9	27.5	5.30	67.21	12.5	43.7	43.7	1.33	0.97	0.8999		0.0099	0.004
NR1	17	17	17.0000	66.3	47.9	27.8	5.52	66.72	12.8	44.1	43.1	1.40	1.01	0.7955		-0.0945	0.004
NR1	18	18	18.0000	75.2	54.2	27.9	5.39	66.69	13.0	50.3	36.6	1.58	1.14	0.8546		-0.0354	0.006
NR1	19	19	19.0000	63.3	45.4	28.3	4.55	67.17	9.0	45.2	45.9	1.33	0.96	0.8929		0.0029	0.004
NR1	20	20	20.0000	73.8	52.5	28.9	5.54	65.59	10.4	37.0	52.6	1.55	1.10	1.1022	0.92	0.2122	0.004
NR1	21	22	22.0275	125.8	88.7	29.5	4.97	65.54	11.1	34.8	54.1	2.65	1.87	1.0145		0.1245	0.004
NR1	22	24	24.0642	147.7	104.3	29.4	5.17	65.45	14.4	38.9	46.6	3.11	2.20	1.1480		0.2580	0.007
NR1	23	26	26.1009	120.1	85.2	29.1	4.57	66.37	14.0	32.6	53.3	2.53	1.79	1.0396		0.1496	0.004
NR1	24	28	28.1376	141.8	100.4	29.2	4.55	66.26	12.0	42.8	45.2	2.98	2.11	1.0746		0.1846	0.002
NR1	25	30	30.1743	132.4	94.6	28.5	5.15	66.30	10.9	34.5	54.6	2.79	1.99	1.1502		0.2602	0.004
NR1	26	32	32.2000	121.1	87.5	27.7	4.79	67.46	10.7	37.3	52.0	2.55	1.84	1.0131		0.1231	0.002
NR1	27	34	34.2000	111.0	80.1	27.8	4.36	67.81	13.3	32.1	54.6	2.34	1.69	1.0996		0.2096	0.004
NR1	28	36	36.2000	134.5	97.7	27.4	3.98	68.66	16.4	31.4	52.2	2.83	2.06	1.0143		0.1243	0.004
NR1	29	38	38.2000	147.5	106.4	27.9	3.78	68.35	12.7	36.0	51.4	3.10	2.24	1.0773		0.1873	0.006
NR1	30	40	40.2000	170.8	122.4	28.3	3.78	67.88	11.7	34.7	53.6	3.59	2.58	1.1381		0.2481	0.003
NR1	31	42	42.2000	154.8	111.9	27.7	3.74	68.55	16.6	23.1	60.3	3.26	2.35	1.2238		0.3338	0.003
NR1	32	44	44.2182	132.0	95.4	27.7	3.38	68.89	12.7	41.2	46.1	2.78	2.01	1.1720		0.2820	0.006
NR1	33	46	46.3091	159.5	114.4	28.3	3.17	68.56	19.2	34.3	46.5	3.36	2.41	1.3485		0.4585	0.013
NR1	34	48	48.4000	160.8	114.8	28.6	2.77	68.62	17.3	42.5	40.3	3.38	2.42	1.4318		0.5418	0.009
NR1	35	50	50.4000	140.9	100.4	28.7	2.95	68.30	13.7	25.4	61.0	2.97	2.11	1.1731		0.2831	0.006
NR1	36	52	52.4833	108.2	77.9	28.0	4.35	67.65	11.3	37.9	50.8	2.28	1.64	1.0436		0.1536	0.004
															Avg = 0.89		

NR-2

Core No.	Sample No.	Uncorr. Depth (cm)	Corrected Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Ra-226 (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR 2	1	1	1.0000	80.1	45.1	43.7	11.13	45.17	19.3	37.9	42.8	1.69	0.95	4.5069		3.4669	0.063
NR 2	2	2	2.0000	57.9	30.2	47.8	11.93	40.23	26.1	46.2	27.7	1.22	0.64	3.9605		2.9205	0.049
NR 2	3	3	3.0000	54.0	25.2	53.3	11.61	35.05	41.2	34.7	24.1	1.14	0.53	4.0195	0.98	2.9795	0.028
NR 2	4	4	4.0000	66.5	33.3	49.9	11.49	38.59	28.1	37.5	34.5	1.40	0.70	2.9792		1.9392	0.043
NR 2	5	5	5.0000	60.0	32.7	45.5	10.58	43.92	19.2	33.5	47.4	1.26	0.69	3.5858		2.5458	0.040
NR 2	6	6	6.0000	72.5	41.7	42.5	10.74	46.78	12.4	31.6	56.0	1.53	0.88	2.7763		1.7363	0.040
NR 2	7	7	7.0000	83.5	46.5	44.3	10.66	45.03	10.9	40.1	49.0	1.76	0.98	2.9144		1.8744	0.020
NR 2	8	8	8.0000	70.7	41.4	41.4	11.05	47.51	9.5	39.7	50.8	1.49	0.87	2.6387		1.5987	0.036
NR 2	9	9	9.0000	96.4	52.8	45.2	11.20	43.57	13.5	32.3	54.3	2.03	1.11	2.5477		1.5077	0.017
NR 2	10	10	10.0000	53.2	31.2	41.4	11.78	46.87	12.1	33.7	54.2	1.12	0.66	2.1241		1.0841	0.022
NR 2	11	11	11.0000	74.9	43.6	41.8	11.03	47.18	13.9	36.5	49.6	1.58	0.92	2.8992		1.8592	0.077
NR 2	12	12	12.0000	91.1	54.8	39.8	12.01	48.15	14.6	31.5	53.9	1.92	1.15	2.6874		1.6474	0.025
NR 2	13	13	13.0000	71.4	44.0	38.4	12.03	49.59	8.5	22.7	68.8	1.50	0.93	2.3386	1.03	1.2986	0.024
NR 2	14	14	14.0000	62.2	39.0	37.3	11.73	50.97	8.5	30.9	60.7	1.31	0.82	1.9561		0.9161	0.005
NR 2	15	15	15.0000	79.8	48.6	39.1	11.58	49.32	7.9	28.8	63.3	1.68	1.02	2.2852		1.2452	0.021
NR 2	16	16	16.0000	72.6	43.9	39.5	11.51	48.96	7.0	29.5	63.5	1.53	0.92	2.2232		1.1832	0.012
NR 2	17	17	17.0000	72.4	43.7	39.6	11.68	48.68	5.0	31.3	63.7	1.52	0.92	2.4936		1.4536	0.017
NR 2	18	18	18.0000	68.4	42.0	38.6	11.75	49.65	7.4	24.1	68.5	1.44	0.88	1.9715		0.9315	0.034
NR 2	19	19	19.0000	69.5	43.1	38.0	11.46	50.55	6.0	25.4	68.7	1.46	0.91	1.6210		0.5810	0.062
NR 2	20	20	20.0000	77.0	47.8	37.9	10.52	51.56	9.2	25.0	65.8	1.62	1.01	2.0540		1.0140	0.007
NR 2	21	21	21.0000	67.7	43.6	35.6	10.93	53.47	7.1	21.2	71.7	0.71	0.46	1.9139		0.8739	0.009
NR 2	22	23	23.0143	98.7	62.9	36.3	9.98	53.75	7.5	27.4	65.0	1.04	0.66	1.8961	1.13	0.8561	0.006
NR 2	23	25	25.1095	118.4	74.5	37.1	10.22	52.71	10.6	35.7	53.7	1.25	0.78	1.6829		0.6429	0.005
NR 2	24	27	27.2001	133.8	85.3	36.2	9.29	54.46	11.0	36.0	53.0	1.41	0.90	1.6961		0.6561	0.004
NR 2	25	29	29.2000	138.3	88.3	36.2	9.16	54.68	9.9	40.1	50.0	1.46	0.93	1.7178		0.6778	0.006
NR 2	26	31	31.2000	126.5	80.9	36.0	8.70	55.26	16.4	34.1	49.5	1.33	0.85	1.7964		0.7564	0.005
NR 2	27	33	33.2000	129.0	83.7	35.1	8.51	56.37	10.3	31.6	58.2	1.36	0.88	1.4069		0.3669	0.011
NR 2	28	35	35.2000	146.6	95.9	34.6	8.00	57.42	9.3	32.7	58.0	1.54	1.01	1.2958		0.2558	0.006
NR 2	29	37	37.2000	143.0	92.6	35.2	7.66	57.09	9.9	30.5	59.6	1.50	0.97	1.5441		0.5041	0.010
NR 2	30	39	39.8600	157.5	102.8	34.7	6.89	58.38	9.4	27.5	63.1	1.66	1.08	1.4255		0.3855	0.003
NR 2	31	41	43.0125	132.4	85.9	35.1	6.78	58.10	9.2	28.7	62.1	1.39	0.90	1.5811		0.5411	0.004
NR 2	32	43	45.2278	141.1	92.5	34.4	6.89	58.67	8.2	23.2	68.6	1.48	0.97	1.4937		0.4537	0.012
NR 2	33	45	47.3389	155.3	101.7	34.5	5.04	60.45	8.5	29.6	61.9	1.63	1.07	1.6379		0.5979	0.014
NR 2	34	47	49.4243	132.0	87.2	33.9	3.04	63.02	10.9	27.2	62.0	1.39	0.92	1.0531		0.0131	0.011
NR 2	35	49	51.4784	151.2	100.6	33.5	4.67	61.86	13.1	13.5	73.5	1.59	1.06	1.2580		0.2180	0.024
NR 2	36	51	53.5324	146.3	95.2	34.9	na		10.0	26.3	63.7	1.54	1.00	na	na	na	na
NR 2	37	53	55.5865	142.5	93.8	34.2	na		11.6	23.2	65.3	1.50	0.99	na	na	na	na
NR 2	38	55	57.6000	151.9	102.2	32.7	na		16.1	27.1	56.8	1.60	1.08	na	na	na	na
NR 2	39	57	59.6000	155.6	109.1	29.9	na		25.9	33.3	40.8	1.64	1.15	na	na	na	na
NR 2	40	61	63.6000	153.4	106.9	30.3	na		26.4	34.5	39.1	1.61	1.12	na	na	na	na
NR 2	41	63	65.7370	164.9	119.1	27.8	na		34.5	31.7	33.9	1.74	1.25	na	na	na	na
NR 2	42	65	67.9875	168.3	123.0	26.9	na		46.8	23.1	30.1	1.77	1.29	na	na	na	na
NR 2	43	67		179.8	130.3	27.5	na		41.0	28.9	30.1	1.89	1.37	na	na	na	na

Avg = 1.04

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Ra-226 (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR3	1	1	1.0374	69.3	25.5	63.2	10.80	47.60	24.2	41.2	34.6	1.46	0.54	6.1770		4.8870	0.024
NR3	2	2	2.0748	68.9	32.7	52.5	8.49	55.95	31.9	39.4	28.7	1.45	0.69	5.9460	1.24	4.6560	0.022
NR3	3	3	3.1121	69.7	36.9	47.1	8.82	61.76	20.5	38.6	40.9	1.47	0.78	5.9981		4.7081	0.043
NR3	4	4	4.1495	68.2	37.5	45.0	8.20	63.19	11.9	34.2	54.0	1.44	0.79	5.2525	1.20	3.9625	0.022
NR3	5	5	5.1869	82.6	46.9	43.2	8.32	65.10	9.8	51.2	39.0	1.74	0.99	5.0692		3.7792	0.034
NR3	6	6	6.2243	92.6	64.3	30.6	6.40	75.84	6.3	37.3	56.3	1.95	1.35	3.7288		2.4388	0.030
NR3	7	7	7.2617	79.7	36	54.8	6.00	51.17	3.2	24.6	72.1	1.68	0.76	3.9459		2.6559	0.022
NR3	8	8	8.2991	85.7	51.3	40.1	6.51	66.37	4.9	27.6	67.5	1.80	1.08	3.8706	1.08	2.5806	0.016
NR3	9	9	9.3364	70.1	43.5	37.9	6.48	68.54	7.0	32.1	61.0	1.48	0.92	2.7594		1.4694	0.006
NR3	10	10	10.3738	87.0	55.2	36.6	6.37	69.81	7.4	57.5	35.1	1.83	1.16	2.3198		1.0298	0.008
NR3	11	11	11.4000	106.0	68	35.8	8.00	72.15	9.1	34.1	56.8	2.23	1.43	1.7950	1.41	0.5050	0.004
NR3	12	12	12.4000	83.3	53.5	35.8	7.49	71.72	8.3	40.7	51.0	1.75	1.13	1.8217		0.5317	0.004
NR3	13	13	13.4000	91.4	58.9	35.6	5.44	69.88	8.4	35.0	56.6	1.92	1.24	1.7774		0.4874	0.004
NR3	14	14	14.4000	87.0	55.4	36.3	5.32	69.00	8.4	34.4	57.3	1.83	1.17	1.5936	1.49	0.3036	0.002
NR3	15	15	15.4000	84.8	54.3	36.0	5.30	69.33	8.1	27.9	64.1	1.78	1.14	1.9913		0.7013	0.006
NR3	16	16	16.4000	82.2	53	35.5	6.09	70.57	8.3	31.7	60.0	1.73	1.12	1.9986		0.7086	0.008
NR3	17	17	17.4000	105.0	68.1	35.1	5.80	70.66	9.3	17.3	73.4	2.21	1.43	1.9901	1.42	0.7001	0.009
NR3	18	18	18.4000	107.7	70.1	34.9	5.10	70.19	8.6	22.3	69.1	2.27	1.48	na		na	na
NR3	19	19	19.4000	104.4	68	34.9	5.60	70.73	9.0	8.3	82.7	2.20	1.43	1.6988		0.4088	0.002
NR3	20	20	20.4000	87.1	56.2	35.5	5.60	70.12	7.8	28.5	63.8	1.83	1.18	1.6410	1.38	0.3510	0.002
NR3	21	22	22.4000	147.6	96	35.0	4.76	69.80	6.9	45.5	47.6	1.55	1.01	1.3954		0.1054	0.001
NR3	22	24	24.4000	141.3	92.6	34.5	5.57	71.10	8.8	15.0	76.2	1.49	0.97	1.5242		0.2342	0.004
NR3	23	26	26.4000	183.6	120.7	34.3	6.08	71.82	8.8	35.0	56.1	1.93	1.27	1.2710	1.21	-0.0190	-0.001
NR3	24	28	28.4000	170.3	112	34.2	6.10	71.86	8.8	57.7	33.5	1.79	1.18	1.4232		0.1332	0.003
NR3	25	30	30.4000	175.1	112.7	35.6	4.47	68.83	8.8	48.4	42.9	1.84	1.19	1.2960		0.0060	0.000
NR3	26	32	32.4000	153.3	100.3	34.6	5.43	70.86	9.4	37.0	53.6	1.61	1.06	1.4223	1.23	0.1323	0.001
NR3	27	34	34.4000	172.4	112.2	34.9	7.55	72.63	7.7	57.1	35.2	1.81	1.18	1.2858		-0.0042	0.000
NR3	28	36	36.4000	163.9	107.2	34.6	7.40	72.81	6.7	58.8	34.5	1.72	1.13	1.3475	1.31	0.0575	0.000
NR3	29	38	38.4000	154.5	101.7	34.2	7.46	73.28	8.7	74.3	17.0	1.63	1.07	1.2649		-0.0251	0.000
NR3	30	40	40.4000	168.0	111.4	33.7	6.76	73.07	9.9	68.7	21.4	1.77	1.17	1.2555		-0.0345	-0.001
NR3	31	42	42.4000	171.7	112.5	34.5	6.60	72.12	8.4	34.2	57.5	1.81	1.18	1.3062	1.26	0.0162	0.000
NR3	32	44	44.4000	142.2	93.2	34.5	6.14	71.68	10.4	64.8	24.8	1.50	0.98	1.3170		0.0270	0.000
NR3	33	46	46.4000	151.4	101.2	33.2	6.17	73.01	8.7	40.8	50.5	1.59	1.06	1.2788		-0.0112	0.000
NR3	34	48	48.4000	140.1	95.3	32.0	7.50	75.52	9.5	64.5	26.0	1.47	1.00	1.2736		-0.0164	0.000
NR3	35	50	50.4000	162.9	110.5	32.2	7.40	75.23	7.6	42.5	49.8	1.71	1.16	1.2452		-0.0448	-0.002
NR3	36	52	52.5737	191.4	131.3	31.4	5.90	74.50	12.9	67.2	19.8	2.01	1.38	1.5215		0.2315	0.007
															Avg = 1.29		

NR-4

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Ra-226 (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR4	1	1	1.0000	45.2	20.1	55.5	16.74	27.73	37.3	37.3	25.4	0.95	0.42	6.4919		5.4019	0.025
NR4	2	2	2.0000	69.0	33.6	51.3	14.44	34.25	25.9	45.4	28.7	1.45	0.71	5.5217		4.4317	0.027
NR4	3	3	3.0000	69.0	37.3	45.9	15.69	38.37	16.3	46.1	37.6	1.45	0.78	3.8301	0.79	2.7401	0.017
NR4	4	4	4.0000	46.0	26.5	42.4	13.81	43.80	6.3	49.8	43.9	0.97	0.56	3.4065		2.3165	0.014
NR4	5	5	5.0000	68.9	41.5	39.8	10.76	49.47	15.7	43.7	40.6	1.45	0.87	3.1395		2.0495	0.014
NR4	6	6	6.0000	78.5	47.9	39.0	11.48	49.54	11.8	49.4	38.8	1.65	1.01	2.9447		1.8547	0.020
NR4	7	7	7.0000	75.0	46.6	37.9	11.67	50.47	13.1	44.9	41.9	1.58	0.98	3.1239		2.0339	0.010
NR4	8	8	8.0000	63.8	40.5	36.5	10.70	52.78	12.3	46.2	41.5	1.34	0.85	3.3906		2.3006	0.012
NR4	9	9	9.0000	79.1	50.7	35.9	10.30	53.79	13.6	46.5	39.9	1.66	1.07	2.4281		1.3381	0.009
NR4	10	10	10.0000	69.1	46.2	33.1	8.96	57.90	9.8	44.7	45.5	1.45	0.97	1.4049		0.3149	0.001
NR4	11	11	11.0000	54.5	36.8	32.5	9.90	57.62	11.4	46.5	42.1	1.15	0.77	1.7758		0.6858	0.002
NR4	12	12	12.0000	74.9	50.4	32.7	8.31	58.98	8.8	39.8	51.3	1.58	1.06	1.7313		0.6413	0.003
NR4	13	13	13.0000	74.5	51.1	31.4	9.43	59.16	6.9	38.6	54.4	1.57	1.08	2.0374	1.2	0.9474	0.007
NR4	14	14	14.0000	61.9	42.4	31.5	8.85	59.65	5.1	41.4	53.5	1.30	0.89	1.6511		0.5611	0.003
NR4	15	15	15.0000	67.1	46.1	31.3	9.58	59.12	7.6	36.8	55.6	1.41	0.97	1.6075		0.5175	0.003
NR4	16	16	16.0000	67.2	46.2	31.3	9.38	59.37	9.2	32.2	58.6	1.41	0.97	1.7494		0.6594	0.002
NR4	17	17	17.0000	73.9	51.4	30.4	10.75	58.80	11.7	43.4	44.9	1.56	1.08	1.8428		0.7528	0.008
NR4	18	18	18.0000	63.0	43.7	30.6	7.68	61.68	15.1	43.2	41.7	1.33	0.92	1.2438		0.1538	0.000
NR4	19	19	19.0000	74.9	52.2	30.3	9.35	60.34	12.5	45.7	41.8	1.58	1.10	1.7112		0.6212	0.002
NR4	20	20	20.0000	74.6	52.1	30.2	7.67	62.17	13.7	46.3	40.0	1.57	1.10	1.3661		0.2761	0.000
NR4	21	22	22.0400	132.6	91.8	30.8	10.25	58.98	13.2	47.2	39.6	1.40	0.97	1.8281		0.7381	0.003
NR4	22	24	24.1200	111.2	76.8	30.9	9.02	60.05	11.9	46.2	41.9	1.17	0.81	1.5722		0.4822	0.001
NR4	23	26	26.2000	124.9	87.1	30.3	10.02	59.72	7.8	43.8	48.4	1.31	0.92	2.2069	1.3	1.1169	0.005
NR4	24	28	28.2000	88.7	59.9	32.5	9.40	58.13	8.9	45.6	45.6	0.93	0.63	1.7375		0.6475	0.008
NR4	25	30	30.2000	131.8	87.5	33.6	10.65	55.74	9.0	42.3	48.7	1.39	0.92	1.9707		0.8807	0.005
NR4	26	32	32.2000	85.3	57.0	33.2	na		10.4	32.3	57.3	0.90	0.60	na		na	na
NR4	27	34	34.2000	157.2	104.0	33.8	na		9.3	39.6	51.1	1.65	1.09	na		na	na
NR4	28	36	36.2000	138.1	92.9	32.7	na		11.1	36.4	52.5	1.45	0.98	na		na	na
NR4	29	38	38.2000	144.8	97.4	32.7	na		8.2	36.7	55.1	1.52	1.02	na		na	na
NR4	30	40	40.2000	162.5	108.2	33.4	na		5.4	34.7	59.8	1.71	1.14	na		na	na
NR4	31	42	42.2000	138.7	94.4	31.9	na		7.1	26.6	66.3	1.46	0.99	na		na	na
NR4	32	44	44.2000	155.7	107.5	31.0	na		9.6	28.7	61.7	1.64	1.13	na		na	na
NR4	33	46	46.2000	123.9	83.4	32.7	na		7.4	30.5	62.1	1.30	0.88	na		na	na
NR4	34	48	48.2000	159.2	105.6	33.7	na		10.8	31.0	58.2	1.68	1.11	na		na	na

Avg = 1.09

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Ra-226 (dpm/g)	USGS Excess Pb-210 (dpm/g) 1.11 SPb	+/-
NR5	1	1	1.0308	63.3	50.2	20.7	11.13	68.17	13.7	57.0	29.3	1.33	1.06	3.4112		2.2612	0.015
NR5	2	2	2.0615	65.8	50.4	23.4	11.93	64.67	12.1	57.2	30.7	1.38	1.06	2.5192		1.3692	0.008
NR5	3	3	3.0923	71.6	54.5	23.9	11.61	64.50	11.9	51.2	36.9	1.51	1.15	2.2214		1.0714	0.004
NR5	4	4	4.1231	67.4	50.5	25.1	11.49	63.44	12.3	49.3	38.4	1.42	1.06	2.3041		1.1541	0.006
NR5	5	5	5.1538	61.7	46.5	24.6	10.58	64.79	11.9	45.8	42.3	1.30	0.98	1.9889		0.8389	0.010
NR5	6	6	6.1846	68.8	51.3	25.4	10.74	63.83	12.4	54.7	32.9	1.45	1.08	1.7430		0.5930	0.006
NR5	7	7	7.2154	75.6	55.7	26.3	11.66	62.02	8.8	37.3	53.8	1.59	1.17	1.8824		0.7324	0.011
NR5	8	8	8.2462	62.9	45.9	27.0	11.05	61.93	9.4	33.9	56.7	1.32	0.97	1.9927	1.18	0.8427	0.004
NR5	9	9	9.2769	71.1	51.1	28.1	11.20	60.67	7.3	33.6	59.1	1.50	1.08	2.1655		1.0155	0.005
NR5	10	10	10.3077	71.8	51.4	28.4	11.78	59.81	7.0	39.8	53.1	1.51	1.08	2.1681		1.0181	0.007
NR5	11	11	11.3385	68.5	49.6	27.6	12.03	60.38	7.1	36.1	56.8	1.44	1.04	1.8840		0.7340	0.004
NR5	12	12	12.3692	77.2	55.5	28.1	12.01	59.88	8.6	37.9	53.5	1.62	1.17	2.0321		0.8821	0.005
NR5	13	13	13.4000	75.6	54.2	28.3	12.03	59.66	7.5	42.9	49.6	1.59	1.14	2.0170	1.08	0.8670	0.006
NR5	14	14	14.4000	63.5	45.4	28.5	11.73	59.77	9.3	48.9	41.9	1.34	0.96	1.9575		0.8075	0.007
NR5	15	15	15.4000	72.3	51.8	28.4	11.68	59.96	9.9	50.5	39.6	1.52	1.09	2.4645		1.3145	0.008
NR5	16	16	16.4000	70.5	50	29.1	11.51	59.41	9.7	40.5	49.8	1.48	1.05	2.3881		1.2381	0.004
NR5	17	17	17.4000	63.6	45	29.2	11.68	59.07	10.3	49.4	40.2	1.34	0.95	2.3004		1.1504	0.006
NR5	18	18	18.4000	74.9	52.6	29.8	11.75	58.47	7.4	44.9	47.7	1.58	1.11	2.3042		1.1542	0.004
NR5	19	19	19.4000	77	54.3	29.5	11.46	59.06	7.6	49.6	42.8	1.62	1.14	2.1795		1.0295	0.004
NR5	20	20	20.4000	81.4	57.7	29.1	10.52	60.37	7.0	57.4	35.6	1.71	1.21	2.0863		0.9363	0.004
NR5	21	22	22.4000	140.9	98.9	29.8	10.93	59.26	7.2	47.1	45.7	1.48	1.04	2.1251		0.9751	0.005
NR5	22	24	24.4000	163.2	113.2	30.6	9.98	59.38	7.8	53.0	39.1	1.72	1.19	2.1740		1.0240	0.007
NR5	23	26	26.4000	160	113.3	29.2	10.22	60.60	10.5	56.2	33.3	1.68	1.19	1.6066		0.4566	0.002
NR5	24	28	28.4000	165.1	118.8	28.0	9.29	62.67	15.2	42.2	42.6	1.74	1.25	1.4833	1.2	0.3333	0.002
NR5	25	30	30.4000	180.3	131.4	27.1	9.16	63.72	15.9	44.5	39.6	1.90	1.38	1.5641		0.4141	0.002
NR5	26	32	32.4000	184.4	136.9	25.8	8.70	65.55	22.9	30.9	46.2	1.94	1.44	1.0297		-0.1203	0.000
NR5	27	34	34.4000	176.9	132.6	25.0	8.51	66.44	29.3	38.4	32.3	1.86	1.40	1.3888		0.2388	0.002
NR5	28	36	36.5125	198.6	151.9	23.5	8.00	68.49	34.0	25.6	40.4	2.09	1.60	1.0276		-0.1224	0.000
NR5	29	38	39.1000	219.3	169.3	22.8	8.00	69.20	36.8	38.5	24.7	2.31	1.78	0.9619		-0.1881	0.000
NR5	30	40	41.6000	198.6	152.6	23.2	7.66	69.18	34.1	28.7	37.3	2.09	1.61	2.0101		0.8601	0.005
															Avg. = 1.15		

NR-6

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Radium (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR 6	1	1	1.0000	47.9	15.8	67.0	21.70	11.28	52.6	23.0	24.4	1.05	0.34	9.2320		8.3620	0.024
NR 6	2	2	2.0000	52.1	20.7	60.3	19.01	20.72	47.5	23.2	29.4	1.14	0.45	9.6026		8.7326	0.021
NR 6	3	3	3.0000	90.6	43.2	52.3	16.90	30.78	6.0	30.9	63.1	1.98	0.94	6.2242	0.69	5.3542	0.013
NR 6	4	4	4.0000	66.7	37.2	44.2	14.46	41.32	13.3	41.7	45.0	1.46	0.81	4.8421		3.9721	0.016
NR 6	5	5	5.0000	88.8	50.4	43.2	14.06	42.70	10.5	35.7	53.7	1.94	1.10	3.0042		2.1342	0.005
NR 6	6	6	6.0000	74.2	43.9	40.8	12.08	47.09	3.4	43.6	53.0	1.62	0.96	3.2046		2.3346	0.006
NR 6	7	7	7.0000	104.4	59.8	42.7	12.28	45.00	7.3	43.1	49.7	2.28	1.31	3.2338	0.99	2.3638	0.014
NR 6	8	8	8.0000	70.9	41.4	41.6	12.50	45.89	3.4	40.7	56.0	1.55	0.90	2.9632		2.0932	0.008
NR 6	9	9	9.0000	88.7	52.6	40.7	12.28	47.02	2.1	39.5	58.4	1.94	1.15	2.9966		2.1266	0.007
NR 6	10	10	10.0000	80.1	48.5	39.5	11.88	48.67	1.1	40.1	58.8	1.75	1.06	2.9173		2.0473	0.008
NR 6	11	11	11.0000	60.5	37.2	38.5	12.33	49.16	2.4	34.4	63.2	1.32	0.81	2.7048		1.8348	0.006
NR 6	12	12	12.0000	79.3	48	39.5	12.03	48.50	0.8	32.4	66.8	1.73	1.05	2.6353		1.7653	0.006
NR 6	13	13	13.0000	68.2	42	38.4	12.33	49.26	1.1	29.8	69.1	1.49	0.92	2.8762		2.0062	0.013
NR 6	14	14	14.0000	73.9	45.2	38.8	11.66	49.50	0.7	32.8	66.4	1.61	0.99	2.7940		1.9240	0.008
NR 6	15	15	15.0000	69.9	43.5	37.8	12.20	50.03	1.5	36.5	62.0	1.53	0.95	3.1220		2.2520	0.015
NR 6	16	16	16.0000	71.2	44.9	36.9	10.96	52.11	0.7	38.3	61.0	1.55	0.98	2.9589		2.0889	0.006
NR 6	17	17	17.0000	69.1	43.4	37.2	11.66	51.15	1.8	27.6	70.6	1.51	0.95	2.6822		1.8122	0.006
NR 6	18	18	18.0000	72.2	45.8	36.6	11.39	52.04	1.1	44.2	54.7	1.58	1.00	2.5748		1.7048	0.006
NR 6	19	19	19.0000	65.2	41.1	37.0	11.22	51.82	1.5	49.8	48.7	1.42	0.90	2.4254		1.5554	0.007
NR 6	20	20	20.0000	72.3	45.7	36.8	10.50	52.71	2.6	32.3	65.0	1.58	1.00	2.7427		1.8727	0.008
NR 6	21	22	22.0000	106.8	67	37.3	11.22	51.51	0.7	44.8	54.5	1.17	0.73	2.1978		1.3278	0.006
NR 6	22	24	24.0000	124.8	79.8	36.1	11.05	52.90	2.4	55.1	42.5	1.36	0.87	2.3372		1.4672	0.006
NR 6	23	26	26.1067	146.6	93.6	36.2	10.69	53.15	2.1	55.7	42.2	1.60	1.02	2.1289		1.2589	0.004
NR 6	24	28	28.2000	147.4	93.7	36.4	10.89	52.68	2.6	45.0	52.4	1.61	1.02	na			na
NR 6	25	30	30.6000	144.5	93.9	35.0	9.88	55.10	1.1	41.8	57.1	1.58	1.03	2.0500		1.1800	0.007
NR 6	26	32	34.6000	175.4	113.9	35.1	10.08	54.86	2.1	41.8	56.1	1.91	1.24	2.0648	0.94	1.1948	0.008
NR 6	27	34	37.9600	187.5	122.6	34.6	9.66	55.72	1.3	48.2	50.5	2.05	1.34	1.9170		1.0470	0.008
NR 6	28	36	41.1600	171.2	114.7	33.0	9.84	57.16	1.9	52.1	46.0	1.87	1.25	2.0358		1.1658	0.007
NR 6	29	38	45.5429	178.5	118.9	33.4	8.86	57.75	1.6	51.9	46.5	1.95	1.30	1.7547		0.8847	0.005
															Avg=0.87		

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Radium (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR7	1	1	1.0000	67.2	40.8	39.3	10.93	49.78	27.2	43.7	29.1	1.71	1.04	4.7458		3.7658	0.018
NR7	2	2	2.0000	60.5	39.6	34.5	11.00	54.45	18.5	47.7	33.8	1.54	1.01	5.3559		4.3759	0.023
NR7	3	3	3.0000	62.3	41.6	33.2	10.69	56.08	16.6	44.0	39.4	1.59	1.06	3.4786	1.01	2.4986	0.012
NR7	4	4	4.0000	72.8	50.3	30.9	10.47	58.62	10.3	49.6	40.1	1.85	1.28	2.6182		1.6382	0.012
NR7	5	5	5.0000	80.5	54.4	32.4	10.34	57.24	14.4	44.8	40.7	2.05	1.39	3.0155		2.0355	0.009
NR7	6	6	6.0000	87.0	59.6	31.5	10.50	58.01	17.1	50.6	32.3	2.22	1.52	2.8674		1.8874	0.018
NR7	7	7	7.0000	60.1	40.8	32.1	10.50	57.39	16.5	40.4	43.1	1.53	1.04	1.9938		1.0138	0.011
NR7	8	8	8.0000	70.9	48.0	32.3	10.87	56.83	7.9	39.9	52.2	1.81	1.22	2.0058		1.0258	0.007
NR7	9	9	9.0000	80.2	54.1	32.5	10.36	57.10	8.9	44.0	47.1	2.04	1.38	1.6316		0.6516	0.005
NR7	10	10	10.0000	82.2	55.8	32.1	10.34	57.55	10.1	42.9	47.0	2.09	1.42	1.5354		0.5554	0.005
NR7	11	11	11.0000	69.6	47.1	32.3	10.45	57.22	7.4	36.0	56.6	1.77	1.20	1.6548	1.01	0.6748	0.004
NR7	12	12	12.0000	76.7	51.8	32.5	10.81	56.73	6.8	46.4	46.8	1.95	1.32	1.5085		0.5285	0.004
NR7	13	13	13.0000	75.8	50.8	33.0	10.34	56.68	8.4	37.8	53.8	1.93	1.29	1.5507		0.5707	0.006
NR7	14	14	14.0000	82.0	55.4	32.4	10.22	57.34	10.1	44.4	45.5	2.09	1.41	1.5640		0.5840	0.004
NR7	15	15	15.0000	96.6	64.9	32.8	10.71	56.47	10.3	36.8	52.9	2.46	1.65	1.5262		0.5462	0.003
NR7	16	16	16.0000	82.2	55.8	32.1	10.34	57.55	10.3	43.2	46.5	2.09	1.42	1.5375		0.5575	0.002
NR7	17	17	17.0000	90.2	60.8	32.6	10.26	57.15	9.6	33.8	56.6	2.30	1.55	1.5556		0.5756	0.004
NR7	18	18	18.0000	79.6	54.2	31.9	9.36	58.73	10.9	39.3	49.8	2.03	1.38	1.4502		0.4702	0.003
NR7	19	19	19.0000	94.9	64.6	31.9	10.06	58.01	8.8	35.2	56.0	2.42	1.65	1.1981		0.2181	0.002
NR7	20	20	20.0000	84.8	58.9	30.5	9.66	59.79	10.8	35.3	53.8	2.16	1.50	1.6375		0.6575	0.004
NR7	21	22	22.0000	167.7	115.9	30.9	9.41	59.70	9.7	28.5	61.8	2.14	1.48	1.4748	0.91	0.4948	0.003
NR7	22	24	24.0000	108.6	76.2	29.8	8.25	61.91	11.5	28.2	60.3	1.38	0.97	1.6243		0.6443	0.002
NR7	23	26	26.0000	152.7	105.6	30.8	9.29	59.87	11.3	32.3	56.4	1.94	1.34	1.4549		0.4749	0.003
NR7	24	28	28.0000	176.3	121.5	31.1	8.51	60.40	12.9	33.3	53.7	2.24	1.55	1.4341		0.4541	0.002
NR7	25	30	30.0000	162.1	111.6	31.2	8.33	60.51	10.5	44.4	45.1	2.06	1.42	1.4126		0.4326	0.002
NR7	26	32	32.0000	159.4	111.9	29.8	8.38	61.82	16.2	50.7	33.1	2.03	1.42	1.3923		0.4123	0.003
NR7	27	34	34.0000	151.5	115.2	24.0	8.53	67.51	12.2	43.2	44.6	1.93	1.47	1.4244		0.4444	0.003
NR7	28	36	36.0000	140.3	97.7	30.4	8.32	61.32	13.5	35.7	50.8	1.79	1.24	1.0771		0.0971	0.000
NR7	29	38	38.0000	182.8	127.4	30.3	7.91	61.79	13.9	47.6	38.5	2.33	1.62	1.4745		0.4945	0.016
NR7	30	40	40.0000	130.7	92.6	29.2	8.07	62.78	11.9	46.0	42.1	1.66	1.18	1.3228		0.3428	0.002
NR7	31	42	42.0000	162.5	114.3	29.7	8.12	62.22	13.2	41.4	45.4	2.07	1.46	1.1440		0.1640	0.001
NR7	32	44	44.0000	166.4	116.0	30.3	7.48	62.23	12.5	45.9	41.6	2.12	1.48	1.0625		0.0825	0.002
NR7	33	46	46.0762	180.5	126.6	29.9	7.11	63.02	14.4	43.1	42.5	2.30	1.61	1.0506		0.0706	0.000
NR7	34	48	48.1714	179.7	127.4	29.1	7.75	63.14	16.6	41.7	41.7	2.29	1.62	1.3057		0.3257	0.009
															Avg = 0.98		

NR-8

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Radium (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR8	1	1	1.0000	53.8	30.4	43.5	21.61	34.89	10.3	29.0	60.7	1.13	0.64	11.0118		10.1018	0.067
NR8	2	2	2.0000	62.9	39.5	37.2	17.04	45.75	11.0	34.5	54.5	1.32	0.83	6.6259		5.7159	0.034
NR8	3	3	3.0000	67.2	43.0	36.0	9.98	54.00	9.1	26.4	64.6	1.41	0.90	5.0639	0.98	4.1539	0.017
NR8	4	4	4.0000	78.6	51.6	34.4	11.20	54.45	12.4	29.1	58.5	1.65	1.09	5.1215		4.2115	0.029
NR8	5	5	5.0000	71.7	46.4	35.3	21.71	43.00	10.2	20.4	69.4	1.51	0.98	2.7153		1.8053	0.012
NR8	6	6	6.0000	83.3	54.5	34.6	9.18	56.25	15.5	24.7	59.8	1.75	1.15	4.6890		3.7790	0.032
NR8	7	7	7.0000	66.7	44.4	33.4	7.83	58.73	22.7	35.4	41.9	1.40	0.93	2.5838		1.6738	0.028
NR8	8	8	8.0000	72.7	48.3	33.6	7.74	58.70	20.3	33.0	46.7	1.53	1.02	2.9125		2.0025	0.011
NR8	9	9	9.0000	106.0	70.8	33.2	6.88	59.92	18.9	39.8	41.3	2.23	1.49	2.6762		1.7662	0.010
NR8	10	10	10.0000	81.8	55.9	31.7	8.87	59.46	22.4	37.6	39.9	1.72	1.18	2.6136		1.7036	0.025
NR8	11	11	11.0000	99.7	67.5	32.3	7.88	59.82	23.5	30.2	46.3	2.10	1.42	2.5290	0.94	1.6190	0.010
NR8	12	12	12.0000	74.2	50.0	32.6	8.53	58.85	19.4	29.0	51.6	1.56	1.05	1.8801		0.9701	0.012
NR8	13	13	13.0000	75.9	50.5	33.5	11.40	55.14	16.0	28.9	55.1	1.60	1.06	2.1565		1.2465	0.022
NR8	14	14	14.0000	104.2	70.5	32.3	8.00	59.66	15.5	25.2	59.4	2.19	1.48	1.5858		0.6758	0.004
NR8	15	15	15.0000	82.5	56.8	31.2	9.08	59.77	20.1	21.6	58.4	1.74	1.20	1.8149	0.82	0.9049	0.005
NR8	16	16	16.0000	87.0	60.0	31.0	7.27	61.70	14.9	23.5	61.6	1.83	1.26	1.8138		0.9038	0.010
NR8	17	17	17.0000	76.3	52.6	31.1	na		16.7	32.7	50.6	1.61	1.11	na		na	na
NR8	18	18	18.0083	109.0	75.1	31.1	na		15.4	38.3	46.2	2.29	1.58	na		na	na
NR8	19	19	19.0500	69.5	48.4	30.4	na		19.2	23.8	56.9	1.46	1.02	na		na	na
NR8	20	20	20.0917	77.8	54.9	29.4	na		18.4	23.8	57.9	1.64	1.16	na		na	na
NR8	21	22	22.1750	141.6	99.1	30.0	na		24.8	28.8	46.4	1.49	1.04	na		na	na
NR8	22	24	24.2147	132.9	91.8	30.9	na		21.2	21.2	57.6	1.40	0.97	na		na	na
NR8	23	26	26.2358	160.0	111.2	30.5	na		24.6	25.3	50.2	1.68	1.17	na		na	na
NR8	24	28	28.2568	169.5	119.2	29.7	na		24.1	28.9	47.0	1.78	1.25	na		na	na
NR8	25	30	30.2779	166.1	118.7	28.5	na		21.8	34.5	43.7	1.75	1.25	na		na	na
NR8	26	32	32.2989	183.0	128.9	29.6	na		23.6	31.6	44.9	1.93	1.36	na		na	na
NR8	27	34	34.3200	138.0	95.0	31.2	na		16.1	36.3	47.6	1.45	1.00	na		na	na
NR8	28	36	36.3411	169.0	113.8	32.7	na		17.0	37.7	45.3	1.78	1.20	na		na	na
NR8	29	38	38.3621	166.7	112.3	32.6	na		18.2	25.2	56.6	1.75	1.18	na		na	na
NR8	30	40	40.3832	185.2	121.2	34.6	na		18.9	30.7	50.4	1.95	1.28	na		na	na
NR8	31	42	42.4119	128.2	83.4	34.9	na		13.8	29.2	56.9	1.35	0.88	na		na	na
NR8	32	44	44.4716	137.7	91.4	33.6	na		20.3	28.6	51.0	1.45	0.96	na		na	na
NR8	33	46	46.5313	179.7	117.9	34.4	na		16.7	21.4	61.9	1.89	1.24	na		na	na
NR8	34	48	48.5910	178.8	118.4	33.8	na		21.8	22.9	55.3	1.88	1.25	na		na	na
NR8	35	50	50.6507	151.8	101.6	33.1	na		20.0	26.2	53.8	1.60	1.07	na		na	na
NR8	36	52	52.7104	177.0	120.0	32.2	na		22.7	23.9	53.4	1.86	1.26	na		na	na
NR8	37	54	54.7701	199.7	129.4	35.2	na		34.7	17.9	47.4	2.10	1.36	na		na	na
NR8	38	56	56.8469	186.1	122.4	34.2	na		35.1	22.9	42.1	1.96	1.29	na		na	na
NR8	39	58	58.9406	162.5	104.4	35.8	na		21.7	16.5	61.8	1.71	1.10	na		na	na
NR8	40	60	61.0344	212.4	132.5	37.6	na		19.0	21.3	59.7	2.24	1.39	na		na	na
NR8	41	62	63.1281	146.2	93.4	36.1	na		29.9	29.1	41.0	1.54	0.98	na		na	na
NR8	42	64	65.2219	164.9	105.5	36.0	na		42.0	16.3	41.6	1.74	1.11	na		na	na
NR8	43	66	67.3156	156.0	97.2	37.7	na		17.0	26.6	56.4	1.64	1.02	na		na	na
NR8	44	68	69.2000	170.5	102.8	39.7	na		12.5	26.7	60.8	1.79	1.08	na		na	na
NR8	45	70	71.5222	164.3	97.7	40.5	na		10.6	21.5	67.9	1.73	1.03	na		na	na
NR8	46	72	73.6333	133.5	79.9	40.1	na		12.3	25.7	62.1	1.40	0.84	na		na	na
NR8	47	73	74.6889	119.6	72.8	39.1	na		15.5	23.9	60.6	1.26	0.77	na	Avg = 0.91	na	na

NR-9

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Radium (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR9	1	1	1.0000	65.0	49.6	23.7	11.64	64.67	24.2	48.4	27.4	1.32	1.01	4.6208		3.6308	0.093
NR9	2	2	2.0000	59.7	47.0	21.3	22.43	56.30	28.6	39.4	32.0	1.21	0.95	3.2768		2.2868	0.017
NR9	3	3	3.0000	53.2	42.7	19.7	8.45	71.81	24.6	44.4	31.0	1.08	0.87	2.2588	1.1	1.2688	0.012
NR9	4	4	4.0000	78.5	61.4	21.8	8.24	69.98	15.2	41.2	43.7	1.59	1.25	1.8010		0.8110	0.020
NR9	5	5	5.0000	79.9	60.9	23.8	8.89	67.33	15.5	35.9	48.6	1.62	1.24	1.5851		0.5951	0.004
NR9	6	6	6.0000	83.7	63.6	24.0	21.14	54.84	18.1	41.3	40.6	1.70	1.29	na		na	na
NR9	7	7	7.0000	92.1	73.3	20.4	20.86	58.73	30.6	43.0	26.5	1.87	1.49	1.3142		0.3242	0.004
NR9	8	8	8.0000	81.1	65.2	19.6	20.93	59.47	33.7	30.6	35.8	1.65	1.32	na		na	na
NR9	9	9	9.0000	59.8	48.2	19.4	6.24	74.36	33.7	37.2	29.1	1.21	0.98	1.3045		0.3145	0.003
NR9	10	10	10.0000	56.0	44.6	20.4	7.86	71.79	25.7	34.6	39.8	1.14	0.91	na		na	na
NR9	11	11	11.0000	90.0	71.7	20.3	7.38	72.29	37.1	35.3	27.6	1.83	1.46	na		na	na
NR9	12	12	12.0000	57.6	46.3	19.6	8.41	71.97	31.4	36.8	31.8	1.17	0.94	0.9576		-0.0324	-0.001
NR9	13	13	13.0000	109.4	88.0	19.6	2.33	78.11	39.9	24.7	35.4	2.22	1.79	0.7424	0.82	-0.2476	-0.003
NR9	14	14	14.0000	70.1	56.7	19.1	6.33	74.55	39.0	25.5	35.6	1.42	1.15	0.9296		-0.0604	-0.001
NR9	15	15	15.0000	81.5	65.2	20.0	7.60	72.40	40.1	28.2	31.8	1.65	1.32	na		na	na
NR9	16	16	16.0000	75.8	58.8	22.4	7.36	70.22	40.5	32.7	26.8	1.54	1.19	0.9593		-0.0307	-0.001
NR9	17	17	17.0000	80.3	64.0	20.3	16.44	63.26	43.7	28.4	28.0	1.63	1.30	0.6657		-0.3243	-0.003
NR9	18	18	18.0000	91.9	72.8	20.8	11.88	67.34	43.1	34.5	22.4	1.87	1.48	na	1.06	na	na
NR9	19	19	19.0000	100.2	78.5	21.7	na		35.4	39.3	25.4	2.03	1.59	na		na	na
NR9	20	20	20.0000	61.3	48.4	21.0	na		36.3	32.4	31.3	1.24	0.98	na		na	na
NR9	21	22	22.0000	220.5	174.1	21.0	na		41.4	27.5	31.1	2.24	1.77	na		na	na
NR9	22	24	24.0000	163.9	130.1	20.6	na		48.2	31.2	20.6	1.66	1.32	na		na	na
NR9	23	26	26.0000	204.2	160.7	21.3	na		43.9	26.8	29.4	2.07	1.63	na		na	na
NR9	24	28	28.0000	184.7	143.4	22.4	na		46.4	24.0	29.6	1.87	1.46	na		na	na
NR9	25	30	30.0000	182.8	141.8	22.4	na		42.1	36.7	21.2	1.86	1.44	na		na	na
NR9	26	32	32.0000	192.0	149.0	22.4	na		35.4	38.8	25.8	1.95	1.51	na		na	na
NR9	27	34	34.0000	173.9	135.2	22.3	na		46.0	29.6	24.4	1.77	1.37	na		na	na
NR9	28	36	36.0000	178.9	138.7	22.5	na		40.9	29.2	29.9	1.82	1.41	na		na	na
NR9	29	38	38.0000	190.3	146.5	23.0	na		29.2	37.9	32.8	1.93	1.49	na		na	na
NR9	30	40	40.0000	178.6	138.0	22.7	na		37.7	32.6	29.7	1.81	1.40	na		na	na
NR9	31	42	42.0000	183.0	141.7	22.6	na		42.7	33.7	23.5	1.86	1.44	na		na	na
NR9	32	44	44.0000	180.0	140.3	22.1	na		41.4	26.5	32.1	1.83	1.42	na		na	na
NR9	33	46	46.0000	210.7	161.6	23.3	na		41.4	29.7	28.9	2.14	1.64	na		na	na
NR9	34	48	48.0000	174.8	134.8	22.9	na		43.0	28.5	28.5	1.77	1.37	na		na	na
NR9	35	50	50.0000	188.5	137.9	26.8	na		41.2	34.2	24.6	1.91	1.40	na		na	na
NR9	36	52	52.0000	168.2	128.2	23.8	na		40.1	28.8	31.2	1.71	1.30	na		na	na
NR9	37	54	54.0000	219.1	166.5	24.0	na		43.1	24.2	32.7	2.22	1.69	na		na	na
NR9	38	56	56.0308	172.0	130.7	24.0	na		40.7	28.1	31.2	1.75	1.33	na		na	na
NR9	39	58	58.3385	201.2	154.3	23.3	na		53.1	24.0	22.9	2.04	1.57	na		na	na
NR9	40	60	60.6462	175.5	134.4	23.4	na		47.0	21.7	31.2	1.78	1.36	na		na	na
NR9	41	61	61.8000	159.7	119.0	25.5	na		36.8	25.7	37.5	1.62	1.21	na	Avg = 0.99	na	na

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Radium (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR 10	1	1	1.0000	41.1	34.9	15.1	11.78	73.14	3.6	57.3	39.1	0.97	0.82	3.8828		2.3128	0.006
NR 10	2	2	2.0000	47.8	39.3	17.8	11.68	70.53	4.2	61.5	34.3	1.13	0.93	3.0244	1.30	1.4544	0.004
NR 10	3	3	3.0000	42.7	34.8	18.5	11.71	69.79	5.0	60.2	34.8	1.01	0.82	3.2737		1.7037	0.004
NR 10	4	4	4.0000	46.9	37.4	20.3	11.22	68.52	3.9	58.9	37.2	1.10	0.88	2.6864	1.60	1.1164	0.002
NR 10	5	5	5.0000	53.8	42.0	21.9	11.53	66.54	2.3	49.0	48.7	1.27	0.99	1.4646		-0.1054	0.000
NR 10	6	6	6.0000	52.4	40.7	22.3	11.33	66.34	1.9	53.5	44.6	1.23	0.96	2.8113	1.60	1.2413	0.004
NR 10	7	7	7.0000	59.0	45.9	22.2	11.26	66.53	3.3	52.7	44.0	1.39	1.08	3.3776		1.8076	0.007
NR 10	8	8	8.0000	74.4	56.5	24.1	11.09	64.85	2.2	52.0	45.7	1.75	1.33	2.4304	1.60	0.8604	0.002
NR 10	9	9	9.0000	49.6	37.4	24.6	11.73	63.67	2.5	57.4	40.1	1.17	0.88	1.1461		-0.4239	-0.001
NR 10	10	10	10.0000	72.1	53.8	25.4	10.76	63.86	2.7	49.0	48.2	1.70	1.27	1.8585	1.42	0.2885	0.001
NR 10	11	11	11.0000	81.0	60.0	25.9	10.76	63.32	2.1	47.8	50.2	1.91	1.41	2.8517		1.2817	0.005
NR 10	12	12	12.0000	73.3	53.8	26.6	11.95	61.44	1.4	45.4	53.2	1.73	1.27	2.2882		0.7182	0.001
NR 10	13	13	13.0000	73.4	53.4	27.2	10.85	61.90	1.5	73.7	24.8	1.73	1.26	2.1500	1.72	0.5800	0.002
NR 10	14	14	14.0000	89.5	64.3	28.2	11.11	60.73	1.0	85.0	14.0	2.11	1.51	0.8423		-0.7277	-0.005
NR 10	15	15	15.0000	85.2	61.3	28.1	11.44	60.51	1.8	74.7	23.5	2.01	1.44	1.7054		0.1354	0.001
NR 10	16	16	16.0000	67.5	48.8	27.7	10.78	61.52	0.8	73.4	25.8	1.59	1.15	2.1604	1.51	0.5904	0.007
NR 10	17	17	17.0000	79.6	56.8	28.6	11.55	59.80	1.6	63.2	35.3	1.87	1.34	1.8702		0.3002	0.002
NR 10	18	18	18.0000	74.3	53.3	28.3	10.76	60.98	1.1	73.2	25.7	1.75	1.25	1.6269		0.0569	0.000
NR 10	19	19	19.0000	71.8	51.8	27.9	11.02	61.12	1.5	57.7	40.8	1.69	1.22	1.8910	1.67	0.3210	0.002
NR 10	20	20	20.0000	73.6	53.0	28.0	10.47	61.54	1.2	52.0	46.8	1.73	1.25	1.9072		0.3372	0.002
NR 10	21	22	22.0000	141.6	100.3	29.2	11.42	59.42	1.2	52.7	46.1	1.67	1.18	1.8701		0.3001	0.001
NR 10	22	24	24.0000	155.2	110.0	29.1	10.65	60.23	1.9	74.5	23.6	1.83	1.29	1.7327	1.71	0.1627	0.001
NR 10	23	26	26.0000	108.2	77.3	28.6	11.46	59.98	1.8	46.6	51.6	1.27	0.91	1.9965		0.4265	0.003
NR 10	24	28	28.0000	129.4	91.5	29.3	10.45	60.26	2.0	53.8	44.2	1.52	1.08	1.8174		0.2474	0.001
NR 10	25	30	30.0000	141.5	99.9	29.4	10.52	60.08	1.8	48.5	49.6	1.67	1.18	1.3888		-0.1812	-0.003
NR 10	26	32	32.0000	122.8	86.6	29.5	10.54	59.98	1.9	58.6	39.5	1.45	1.02	1.6823		0.1123	0.001
NR 10	27	34	34.0000	148.2	103.8	30.0	11.24	58.80	2.7	56.5	40.8	1.74	1.22	1.9930		0.4230	0.004
NR 10	28	36	36.0000	141.4	98.8	30.1	10.74	59.14	1.6	50.6	47.8	1.66	1.16	1.9681		0.3981	0.003
NR 10	29	38	38.0000	142.9	99.6	30.3	10.93	58.76	2.7	79.5	17.9	1.68	1.17	2.0166		0.4466	0.003
NR 10	30	40	40.0000	153.7	106.9	30.4	10.30	59.25	5.1	60.2	34.8	1.81	1.26	1.8050		0.2350	0.002
NR 10	31	42	42.0000	163.9	112.6	31.3	11.42	57.28	2.9	57.8	39.4	1.93	1.33	1.5224		-0.0476	0.000
NR 10	32	44	44.1111	183.8	126.1	31.4	10.76	57.85	2.9	68.0	29.0	2.16	1.48	1.8262		0.2562	0.005
NR 10	33	46	46.5556	158.8	109.6	31.0	11.16	57.86	1.5	59.3	39.2	1.87	1.29	1.9179		0.3479	0.002
NR 10	34	48	49.0000	153.8	106.2	30.9	10.91	58.14	3.9	73.2	22.8	1.81	1.25	na		na	na
NR 10	35	50	51.5714	158.9	110.2	30.6	12.03	57.32	3.5	63.8	32.7	1.87	1.30	2.5290		0.9590	0.007
NR 10	36	52	54.2500	147.9	102.1	31.0	10.50	58.54	4.8	57.8	37.5	1.74	1.20	2.1618		0.5918	0.003
															Avg = 1.57		

Core No.	Sample No.	Uncorr. Depth (cm)	Corr. Depth (cm)	Wt. Wet Sample (g)	Wt. Dry Sample (g)	Water (%)	LOI (%)	Mineral (%)	Coarse Fraction (%)	Silt Fraction (%)	Clay Fraction (%)	Wet Bulk Dens (g/cc)	Dry Bulk Dens (g/cc)	Total Pb-210 (dpm/g)	Radium (dpm/g)	USGS Excess Pb-210 (dpm/g)	+/-
NR 11	1	1	1.0000	81.8	30.8	62.3	10.80	26.85	13.8	37.1	49.1	2.08	0.78	4.3043		3.3643	0.044
NR 11	2	2	2.0000	67.5	25.5	62.2	8.49	29.29	9.6	31.4	59.0	1.72	0.65	4.3657		3.4257	0.055
NR 11	3	3	3.0000	65.7	25.3	61.5	8.82	29.69	10.3	40.6	49.1	1.67	0.64	4.2482		3.3082	0.054
NR 11	4	4	4.0000	61.9	23.8	61.6	8.20	30.25	9.4	34.9	55.7	1.58	0.61	4.0670		3.1270	0.023
NR 11	5	5	5.0000	50.2	20.1	60.0	8.32	31.72	2.8	28.7	68.5	1.28	0.51	3.5721	0.87	2.6321	0.022
NR 11	6	6	6.0000	71.1	28.1	60.5	6.40	33.12	6.7	34.8	58.5	1.81	0.72	3.8408		2.9008	0.028
NR 11	7	7	7.0000	62.6	25.9	58.6	6.00	35.37	3.9	43.3	52.8	1.59	0.66	3.2790		2.3390	0.051
NR 11	8	8	8.0000	65.8	28.5	56.7	6.51	36.80	5.7	39.8	54.4	1.68	0.73	3.4285		2.4885	0.013
NR 11	9	9	9.0000	58.7	25.4	56.7	6.48	36.79	4.8	46.3	48.9	1.49	0.65	2.6304		1.6904	0.035
NR 11	10	10	10.0000	70.5	30.1	57.3	6.37	36.33	6.7	37.8	55.6	1.80	0.77	2.7722		1.8322	0.021
NR 11	11	11	11.0000	62.8	27.5	56.2	8.00	35.79	4.1	50.4	45.5	1.60	0.70	2.7647		1.8247	0.022
NR 11	12	12	12.0000	60.4	26.7	55.8	7.49	36.71	4.2	40.6	55.2	1.54	0.68	3.5565	1.01	2.6165	0.017
NR 11	13	13	13.0000	65.1	28.8	55.8	25.44	18.80	7.0	47.3	45.7	1.66	0.73	2.9294		1.9894	0.045
NR 11	14	14	14.0000	67.9	29.7	56.3	5.32	38.42	6.3	40.4	53.3	1.73	0.76	2.5652		1.6252	0.018
NR 11	15	15	15.0000	72.4	34.7	52.1	5.30	42.63	17.1	50.8	32.2	1.84	0.88	2.4228		1.4828	0.017
NR 11	16	16	16.0000	64.4	31.8	50.6	6.09	43.28	19.8	45.5	34.7	1.64	0.81	2.3575		1.4175	0.013
NR 11	17	17	17.0000	69.1	32.4	53.1	5.80	41.09	15.3	42.6	42.2	1.76	0.83	2.3970		1.4570	0.043
NR 11	18	18	18.0000	65.5	32.3	50.7	5.10	44.21	19.5	44.2	36.3	1.67	0.82	2.5361		1.5961	0.025
NR 11	19	19	19.0000	59.2	29.8	49.7	5.60	44.74	26.7	37.1	36.3	1.51	0.76	1.7740		0.8340	0.006
NR 11	20	21	21.0000	95.5	46.1	51.7	5.60	42.67	30.7	32.3	37.1	1.22	0.59	1.5906		0.6506	0.005
NR 11	21	23	23.0542	98.3	56.2	42.8	4.76	52.41	21.4	34.6	44.0	1.25	0.72	1.6890		0.7490	0.004
NR 11	22	25	25.1375	114.8	56.6	50.7	5.57	43.74	14.9	29.3	55.8	1.46	0.72	1.8331		0.8931	0.007
NR 11	23	27	27.2208	100	57	43.0	6.08	50.92	8.4	30.7	60.9	1.27	0.73	1.6566		0.7166	0.004
NR 11	24	29	29.3042	95	55.5	41.6	6.10	52.33	5.9	20.1	74.0	1.21	0.71	1.8290		0.8890	0.003
NR 11	25	31	31.3875	111.3	65.8	40.9	4.47	54.65	6.0	29.7	64.3	1.42	0.84	1.9667		1.0267	0.004
NR 11	26	33	33.4708	92.6	55.7	39.8	5.43	54.72	7.9	27.0	65.1	1.18	0.71	1.8770		0.9370	0.004
NR 11	27	35	35.7600	106.7	63.3	40.7	7.55	51.77	7.9	17.6	74.5	1.36	0.81	2.2434		1.3034	0.006
NR 11	28	37	38.1600	131.9	80.8	38.7	7.40	53.86	2.6	33.5	63.9	1.68	1.03	2.1123		1.1723	0.004
NR 11	29	39	40.5600	123.9	76.2	38.5	7.46	54.04	3.2	36.6	60.2	1.58	0.97	2.3385		1.3985	0.004
NR 11	30	41	42.9600	120.1	72.4	39.7	6.76	53.52	2.3	31.3	66.4	1.53	0.92	na	na	na	na
NR 11	31	43	45.0000	102.4	60.8	40.6	6.60	52.78	1.4	22.8	75.8	1.30	0.77	2.5941		1.6541	0.025
NR 11	32	45	47.0000	115	67.8	41.0	6.14	52.82	1.8	22.5	75.6	1.46	0.86	1.7795		0.8395	0.005
NR 11	33	47	49.0000	117.7	70.6	40.0	6.17	53.82	2.6	19.1	78.3	1.50	0.90	2.8901		1.9501	0.010
NR 11	34	49	51.0000	121.9	74.2	39.1	7.50	53.37	0.4	15.3	84.3	1.55	0.94	2.8026		1.8626	0.013
NR 11	35	51	53.0000	119.5	74.6	37.6	7.40	55.03	0.4	34.3	65.4	1.52	0.95	1.8782		0.9382	0.004
NR 11	36	53	55.0000	115.9	70.4	39.3	5.90	54.84	1.1	30.5	68.4	1.48	0.90	na	na	na	na
NR 11	37	55	57.0000	123.8	77.2	37.6	na		1.9	30.9	67.2	1.58	0.98	na	na	na	na
NR 11	38	57	59.0000	124.9	78.9	36.8	na		1.5	35.9	62.5	1.59	1.00	na	na	na	na
NR 11	39	59	61.0000	116.3	67	42.4	na		2.4	30.6	67.1	1.48	0.85	na	na	na	na
NR 11	40	61	63.0000	125.8	80.7	35.9	na		0.4	28.1	71.5	1.60	1.03	na	na	na	na
NR 11	41	63	65.0000	135.3	83	38.7	na		0.8	37.7	61.5	1.72	1.06	na	na	na	na
NR 11	42	65	67.0000	133.7	83.2	37.8	na		0.4	41.1	58.5	1.70	1.06	na	na	na	na
NR 11	43	67	69.0000	147.4	89.8	39.1	na		1.5	16.6	81.9	1.88	1.14	na	na	na	na
NR 11	44	69	71.0000	144.4	90.6	37.3	na		0.4	37.1	62.5	1.84	1.15	na	na	na	na
NR 11	45	71	73.0000	85.6	52.7	38.4	na		1.6	23.0	75.5	1.09	0.67	na	na	na	na
															Avg = 0.94		

APPENDIX C

Laboratory Procedures for Determining ^{210}Pb Activities

The U.S. Geological Survey's Analytical Laboratory at Denver analyzed ^{210}Pb activity in the cores. Analyses were completed under the direction of Dr. Charles W. Holmes. Other USGS personnel involved in the analyses were James D. Cathcart and Margaret Marot. The cores were sampled at either 1 cm or 2 cm intervals from the center of each core from top to bottom. Analyzed samples were prepared using the following 14 steps modified from Flynn (1968) and Martin and Rice (1981).

1. Wet samples are placed into clean, preweighed procelain evaporating dishes, weighed, dried at 40°C, and reweighed to determine water loss.

2. Dried samples are ground to a fine powder (75-100 U.S. Standard mesh) in a grinding mill to obtain an homogeneous sample for analysis.

3. Sample splits of approximately 5 g are made and weighed, placed into precleaned, preweighed crucibles and heated in a muffle furnace at 450°C for 6 hrs until a stable weight is obtained. The samples are allowed to cool to room temperature and reweighed.

4. Each sample is transferred to a 100-ml Teflon beaker using 5-10 m. of reagent grade 16N nitric acid (HNO$_3$). A known amount of calibrated ^{209}Po spike is added and the sample swirled to mix the spike. The beaker is covered with a watchglass and allowed to stand overnight.

5. The solution is evaporated under heat lamps at 109°C. The dried sample is washed from the sides of the beaker using 8N hydrochloric acid (HCL) and swirled again to insure proper mixing. The solution is evaporated to dryness and allowed to cool.

6. One-milliliter aliquots of 30 percent hydrogen peroxide (H$_2$O$_2$) are added to the sample until it is completely wet, and the resulting solution is again evaporated to dryness. The sample is placed under heat lamps only after the peroxide reaction has subsided. The cooling and peroxide steps are repeated twice more.

7. The sample is then washed twice with 8N HCL and evaporated to dryness between each washing. This step is to remove all traces of the nitric acid which interferes with the autoplating onto the silver planchet.

8. Five milliliters of 8N HCL are added to the dried sample, which is then transferred to a 100-ml glass beaker using additional amounts of HCL and deionized water.

119

APPENDIX D

BEG Data on Moisture and Bulk Density

APPENDIX D

Location I.D.	Most Complete Sample Extraction	Sample Length (cm)	Volume (cc)	Moisture (wt%)	Dry Bulk Density (g/cc)
NRD1 /top - 5 cm		5.5	5.91	32.6	0.61
NRD1 /top - 23		5.6	6.02	31.7	0.80
NRD1 /top - 50		5.9	6.34	31.3	0.90
NRD2 /top - 5		5.0	5.38	51.7	0.71
NRD2 /top - 35		5.3	5.70	37.5	0.89
NRD2 /top - 62		5.7	6.13	29.2	1.23
NRD3 /top - 5		5.0	5.38	43.5	0.52
NRD3 /top - 33		4.8	5.16	34.7	0.85
NRD3 /top - 54		4.9	5.27	32.5	0.92
NRD4 /top - 5		5.1	5.48	43.9	0.68
NRD4 /top - 25		5.0	5.38	33.2	0.81
NRD4 /top - 45		4.8	5.16	35.1	0.72
NRD5 /top - 5	X	5.0	5.38	26.1	0.71
NRD5 /top - 24	X	5.0	5.38	31.2	0.75
NRD5 /top - 39	X	5.1	5.48	23.8	1.00
NRD6 /top - 11		5.0	5.38	43.4	0.51
NRD6 /top - 22		5.3	5.70	38.4	0.79
NRD6 /top - 36		5.4	5.81	35.9	0.80
NRD7 /top - 11		5.1	5.48	34.3	0.64
NRD7 /top - 25		5.5	5.91	32.0	0.84
NRD7 /top - 44		5.4	5.81	32.8	0.75
NRD8 /top - 12	X	4.9	5.27	32.0	0.85
NRD8 /top - 42	X	5.0	5.38	37.6	0.72
NRD8 /top - 72	X	5.0	5.38	41.0	0.84
NRD9 /top - 5	X	5.0	5.38	26.3	0.58
NRD9 /top - 32	X	4.5	4.84	25.5	1.40
NRD9 /top - 59	X	4.9	5.27	25.4	1.39
NRD10 /top - 10	X	5.1	5.48	29.8	0.61
NRD10 /top - 27		4.7	5.05	31.0	0.68
NRD10 /top - 48		4.9	5.27	33.4	0.92
NRD11 /top - 28	X	5.3	5.70	43.9	0.55
NRD11 /top - 62	X	5.0	5.38	36.6	0.64
NRD11 /top - 67	X	5.1	5.48	41.9	0.73