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Final Report

UTILIZING GAMMA ISOTOPE TRACERS TO DETERMINE SEDIMENT SOURCE AT REEF SITES NEAR THE CHARLESTON OCEAN DREDGED MATERIAL DISPOSAL SITE (Phase II)

SCDNR Purchase Order No. 05 001230

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1.0 INTRODUCTION

In the early 1990's, the South Carolina Department of Natural Resources (SCDNR) initiated a monitoring program of the physical and biological conditions in and around the Charleston Ocean Dredged Material Disposal Site (ODMDS, Figure 1, Van Dolah *et al*, 1996). This monitoring program has documented increased sedimentation rates and elevated levels of silt/clay in surficial sediments in areas to the west and northwest of the ODMDS (Noakes, 2003; Gayes *et al*, 2003; Zimmerman *et al*, 2003). Possible sources of this material include the migration of dredged materials from the Charleston ODMDS, unauthorized disposal activity in the area, and trailings from barges as they enter or exit the ODMDS (Jutte *et al.*, 2001). Approximately 22 million cubic yards (mcy) of material was placed at the site as part of the 1999-2002 Charleston Harbor Deepening project. In addition, the ODMDS is continually utilized for dredged material disposal from channel maintenance activities, but considerably less material has been placed at the site since completion of the deepening project. Recent disposal activities included the placement of 1.6 mcy of entrance channel material (typically sediments high in sand and $CaCO_3$) from December 2003 through March 2004 at the ODMDS (USACE, pers. comm.). Ongoing dredging activities were occurring during fall 2004 immediately downstream of the Highway 17 Bridge spanning the Cooper River.

A companion monitoring program was initiated by the SCDNR in 2000 to study possible impacts to natural hard bottom reef communities in the vicinity of the Charleston ODMDS. Six hard bottom reef sites surrounding the Charleston ODMDS (Figure 1) were established, and have been assessed during spring and fall field seasons to document changes in sedimentation rates, condition of biological communities, and areal extent of hard bottom reef habitats.

Higher sedimentation rates have been documented at the inshore reef sites, which may be due to their proximity to the ODMDS (Jutte *et al*, 2003). However, another potential source of sedimentation at the inshore reef sites is density driven or tidal transport of estuarine sediments. An analysis of the isotopic signature of sediments collected by divers and sediment traps at reef sites, in addition to samples collected by a vessel-deployed sediment-grab sampler in Charleston Harbor and various tributaries was

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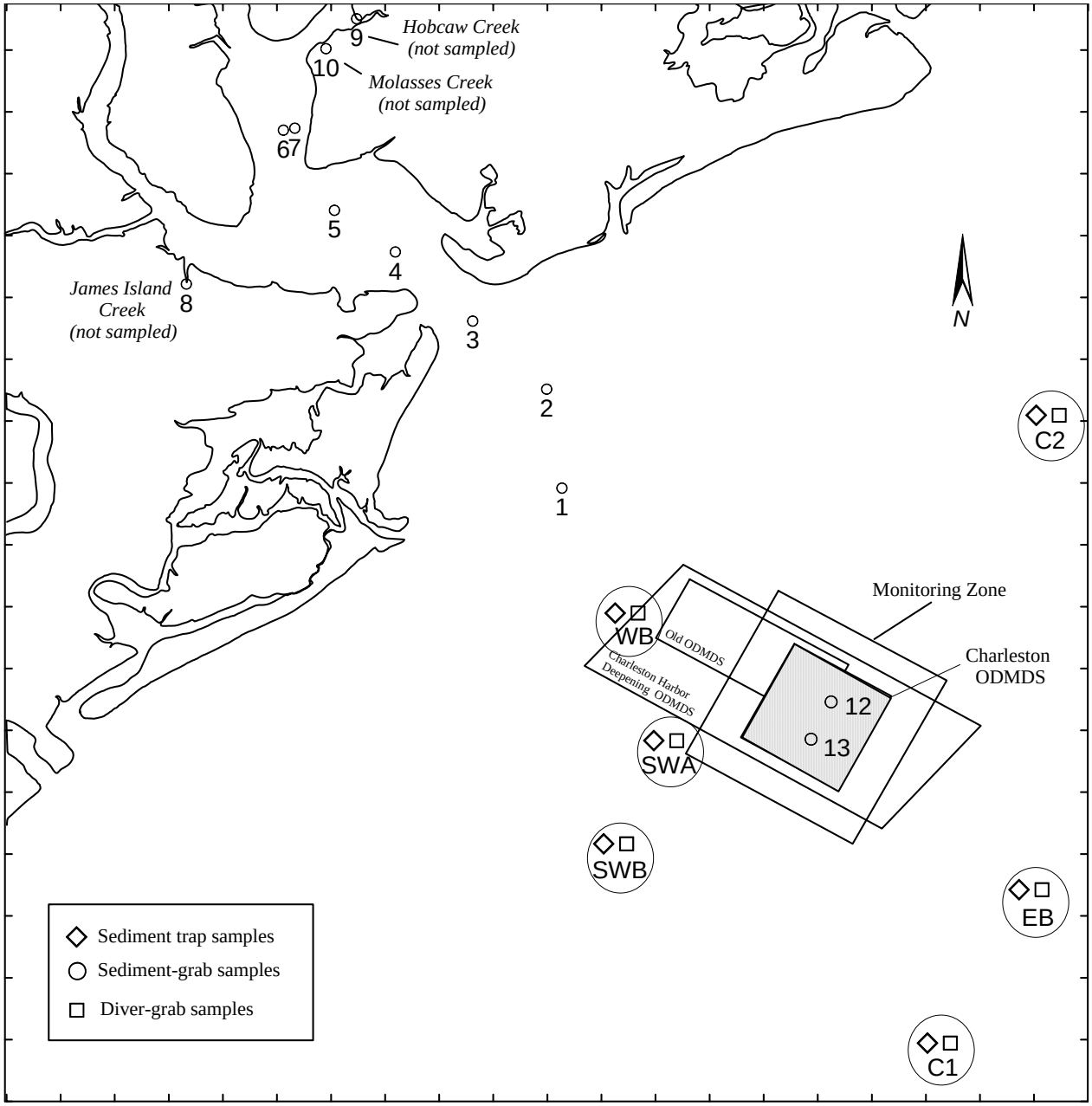

Figure 1. Charleston ODMDS, sediment sampling stations, and hard bottom reef monitoring stations (WB, SWA, SWB, EB, C1, and C2).

conducted as part of Year 4 and 5 monitoring efforts of the hard bottom reef communities in the vicinity of the Charleston ODMDS. The goal of this study was to determine the relative contribution of disposal materials from the Charleston ODMDS versus tidally transported or density driven sediment from Charleston Harbor.

Coastal marine sediments have many commonly found isotopes associated with them, as well as occurrences of rarer isotopes such as beryllium-7 (^{7}Be) and cesium-137 (^{137}Cs; IAEA, 2000). The isotopic signature of sediments has been successfully used by the Center for Applied Isotope Studies (CAIS) at The University of Georgia, to trace the placement and subsequent migration of dredged material placed at the Charleston ODMDS (Noakes, 2003). Evaluating isotopic signatures to identify the relative contribution of sediments deposited at natural reef sites is a novel use of this technique and could prove to be an important tool in future assessments.

Several isotopes were evaluated in the current study. The occurrence of ^{137}Cs is directly related to the atomic bomb testing era when this isotope was distributed throughout the world by atmospheric fallout. As a result of the cessation of atomic bomb testing, there is very little ^{137}Cs present in the atmosphere today. ^{7}Be has a cosmogenic origin and is uniquely associated with atmospheric fallout. What makes ^{7}Be a particularly good tracer is that it has a relatively short half-life of only 53 days. Therefore, ^{7}Be tends to disappear quickly from the marine sediment if there is not a constant source. The presence of ^{7}Be and ^{137}Cs isotopes in the marine environment would be expected at low levels, with higher levels typically found in estuarine sediments due to erosion of terrestrial sediments. When estuarine sediments are dredged and placed in offshore disposal areas, ^{137}Cs would be expected to persist, but due to its short half-life, very little ^{7}Be would be present for extended periods of time.

In addition to ^{7}Be and ^{137}Cs, uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K) were also analyzed as part of this study. These isotopes are considered pathfinder isotopes and are generally indicative of the nature of the seafloor (Jones *et al*, 1988). ^{238}U reflects the uranium content of phosphatic deposits often found in the coastal regions, ^{232}Th is associated with heavy mineral deposits, and ^{40}K is often found in fine-grained clay sediments.

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For this study, sediment samples were collected in the Charleston Harbor and along a transect leading towards the ODMDS. Additionally, two samples were collected within the ODMDS for a representative sample of dredged material deposited at the site. The primary purpose of the samples collected during this study was to measure the gamma activity of various isotopes (1) in estuarine sediments, (2) in areas where tidal deposition was expected, and (3) at the hard bottom reef sites in the vicinity of the ODMDS. The isotopic signature of sediments at the hard bottom reef sites in the vicinity of the ODMDS could then be used to identify the contribution of tidal and density driven transport to the sediment budget at these sites.

2.0 TECHNICAL APPROACH

A total of nine sediment-grab samples were collected in November 2004 from Charleston Harbor; the Cooper River; several near shore sites along a transect leading towards the disposal area; and the ODMDS (Figure 1). These samples were collected using a stainless steel sediment-grab sampler deployed from a surface vessel. Only the surficial sediment (~2 cm) was removed from the sampler to best represent recent deposition. Diver collected sediment-core samples were also collected in November 2004 from the surficial sediment at each of the six hard bottom reef monitoring stations (Figure 1). These sediment samples were dried according to standard operating procedures, and submitted for gamma analyses. Additionally, replicate sediment traps were deployed at the six hard bottom reef monitoring stations to collect a representative sediment sample from material settling on each monitoring site. Upon collection, SCDNR analyzed the trap sediments for composition and total dry weight and then shipped the samples to CAIS for gamma analysis.

The sediment samples (sediment-grab, diver-grab, and sediment-trap) were analyzed in the CAIS laboratory using a High Purity Germanium (HPGe) gamma radiation detector and pulse height-analyzer. Once dried, the sample was packed into a tared 0.5-L Marinelli beaker and weighed. Preliminary gamma analysis was completed on all the samples immediately after drying to obtain results for ^{7}Be, which has a relatively short half-life of only 53 days. The samples were then reanalyzed

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approximately two weeks later to obtain results for the ^{238}U, ^{232}Th, and ^{40}K which require a holding time for the ingrowth of the gamma-emitting U and Th daughter products. The sample was placed in an HPGe radiation detector for a counting time of 12,000 s. In addition to ^{7}Be and ^{137}Cs, the results for ^{238}U, ^{232}Th, and ^{40}K were recorded and converted to picocuries per kilogram (pCi/kg).

3.0 RESULTS

The results for the gamma analyses were plotted in bar graph format to aid comparison of the data. The U, Th, and K ratios for all the samples were very similar, which make it difficult to use these isotopes as definitive indicators for sediment transport. In addition to U, Th, and K isotopes, ^{7}Be and ^{137}Cs were also plotted on the graphs. To achieve a better concept of the distribution of both ^{7}Be and ^{137}Cs in the Charleston study area, the isotopes were plotted by stations in relation to relative activities (Figures 2 and 3). The data from these gamma analyses is presented in Appendix A.

No samples were collected in the small tributaries associated with the Cooper River during the fall sampling. However, the tributary samples collected in spring 2004 all demonstrated a strong presence of both ^{7}Be and ^{137}Cs (Noakes, 2004). These sediments were primarily from recently deposited terrestrial sediment eroded from the surrounding marshes.

Sediment samples were collected along a transect from the entrance channel inward to the Cooper River (Figure 1). All of the sediment-grab samples collected in the entrance channel, harbor, and Cooper River had nearly identical ^{40}K activity (Figure 4). However, the ^{238}U and ^{232}Th activities varied according to the amount of phosphatic and mineral sands present in the sample. Sample 1, located furthest out in the entrance channel, had the highest concentration of sand versus clay. The ^{238}U and ^{232}Th activity decreased into the harbor until Sample 4 where the ^{238}U activity increased considerably indicating a potential phosphatic deposit which is commonly found in the Charleston area. Samples 6 and 7 were located in the Cooper River near the most recent dredging activities and were very similar in gamma activity to the ODMDS samples (12 and 13).

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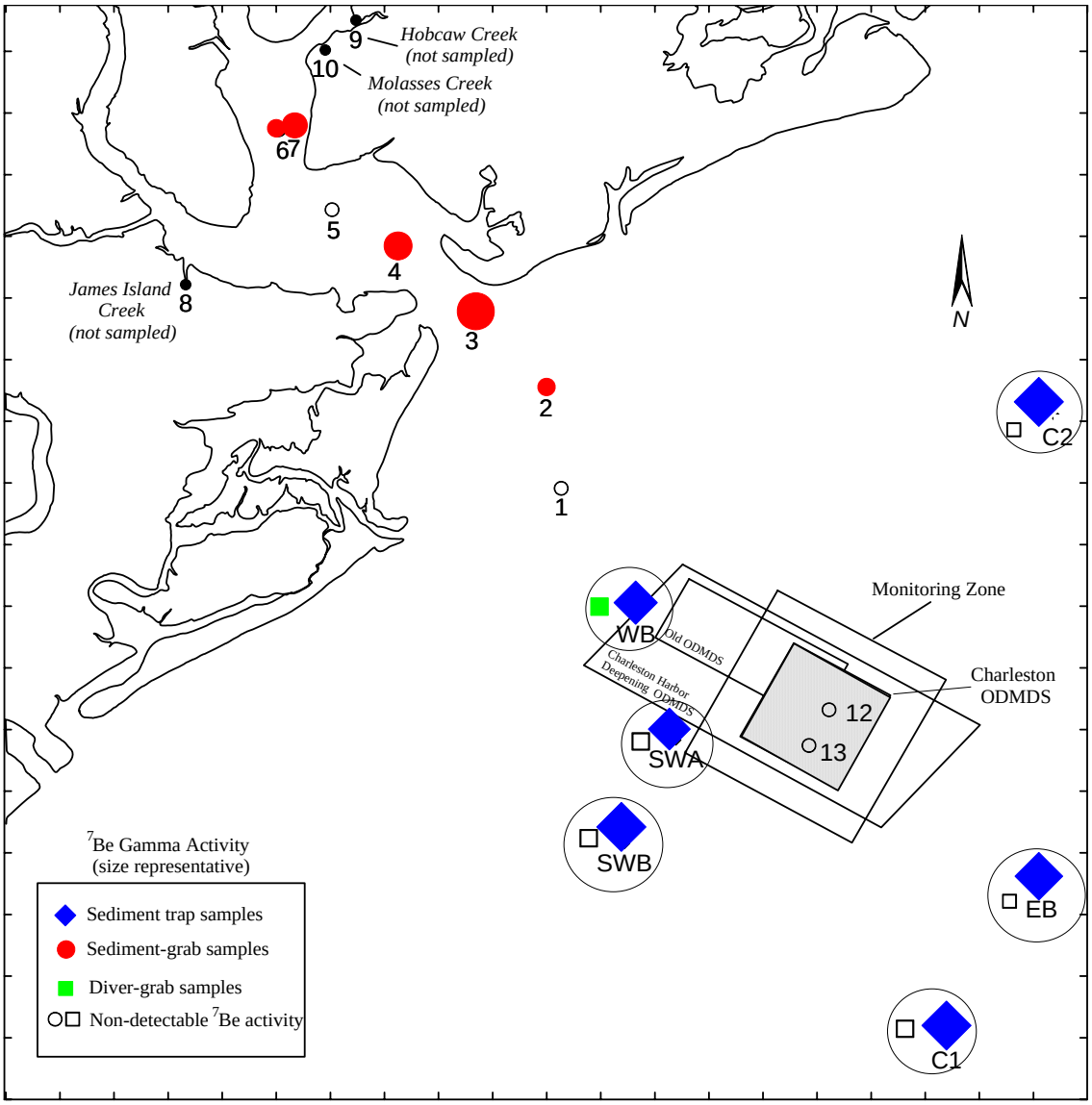

Figure 2. ^{7}Be gamma activity (size representative).

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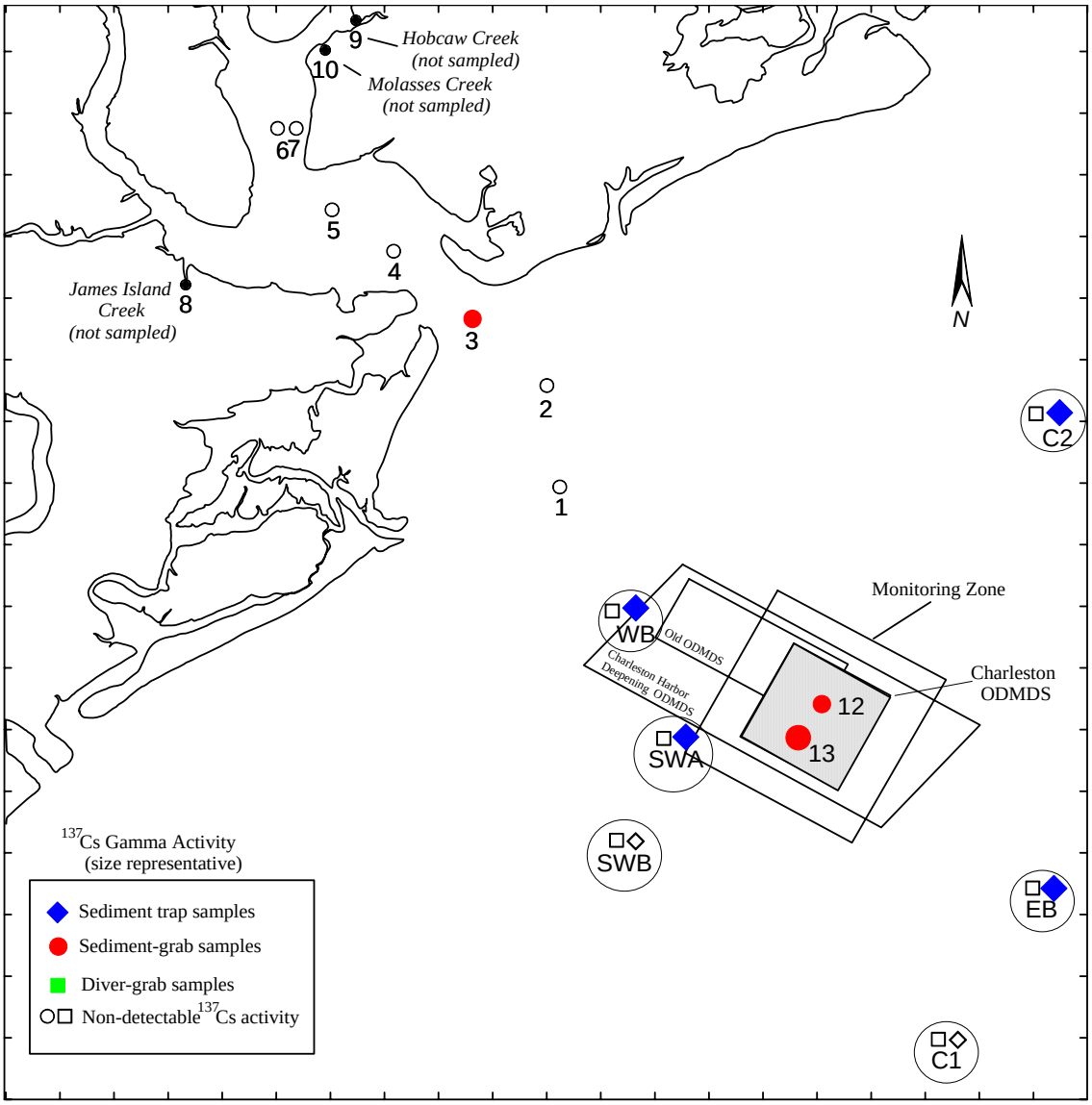

Figure 3. ^{137}Cs gamma activity (size representative).

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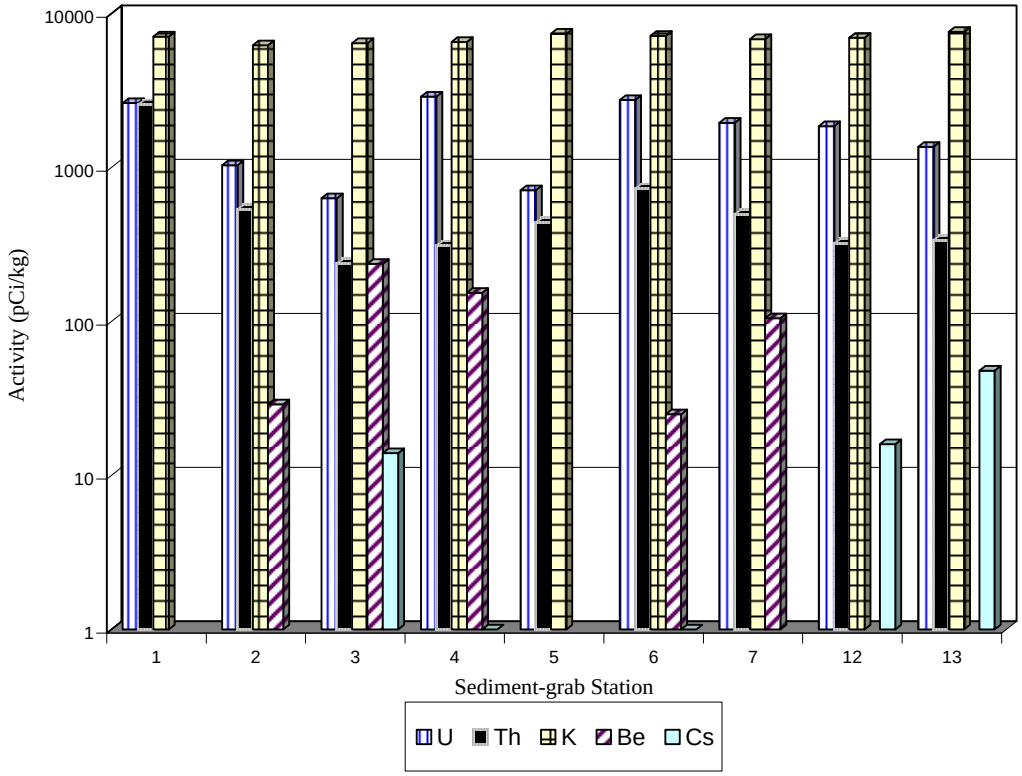

Figure 4. Sediment-grab stations in Charleston Harbor, Cooper River and ODMDS.

It should be noted that Samples 6 and 7 were located immediately east of the Cooper River channel and not exactly where the dredging was occurring.

The ^{7}Be activity in the sediment-grab samples identified an area of mostly fine-grained sediment near the mouth of the harbor. No ^{7}Be or ^{137}Cs were detected in Sample 1 (nearshore) indicating that terrestrial sediment either was not transported or at least was not deposited that far from the mouth of the harbor (Figures 2 and 3). Absence of ^{7}Be or ^{137}Cs does not rule out the possibility that fine-grained sediment containing either isotope could remain suspended in the water column and be deposited further offshore. Detectable levels of ^{7}Be were shown starting at Sample 2 with ^{7}Be gamma activity increasing considerably in Samples 3 and 4. Samples 3 and 4 were located at the harbor entrance and immediately inside the harbor, clearly indicating a major depositional zone. Similar to the spring 2004 sampling, no ^{7}Be was detected in Sample 5 which was located in the inner harbor area. Samples 6 and 7, located immediately east of the Cooper River channel, did have detectable levels of ^{7}Be. Sample 3, located in the mouth of the harbor, was the only channel/harbor sample that had ^{137}Cs present. The remainder of the samples, located in the entrance channel, inside the harbor, and Cooper River, did not indicate any ^{137}Cs. As expected, ^{238}U, ^{232}Th, and ^{40}K activities were similar across all sampling stations.

Two additional sediment-grab samples (12 and 13) were collected in recently deposited dredged material within the Charleston ODMDS. At the time of sample collection, dredging was actively taking place near the Highway 17 Bridge which spans the Cooper River. Samples 12 and 13 had similar gamma signatures to Samples 6 and 7 (Cooper River). Both of these samples had ^{137}Cs present, but not ^{7}Be. The absence of the ^{7}Be in the dredged material samples can be explained by the depth below surface that the sediments were being dredged. ^{7}Be would be expected in the surficial sediments, but not in the deeper dredged sediments. ^{137}Cs activity would be expected in sediments dating back to the 1950s when atomic bomb testing spread airborne particulate matter worldwide.

The gamma activity levels for the sediment-trap samples were all very similar (Figure 5). All of the sediment-trap samples also had considerable ^{7}Be activity present. Elevated ^{7}Be in the traps would be expected primarily due to the preferential sampling of

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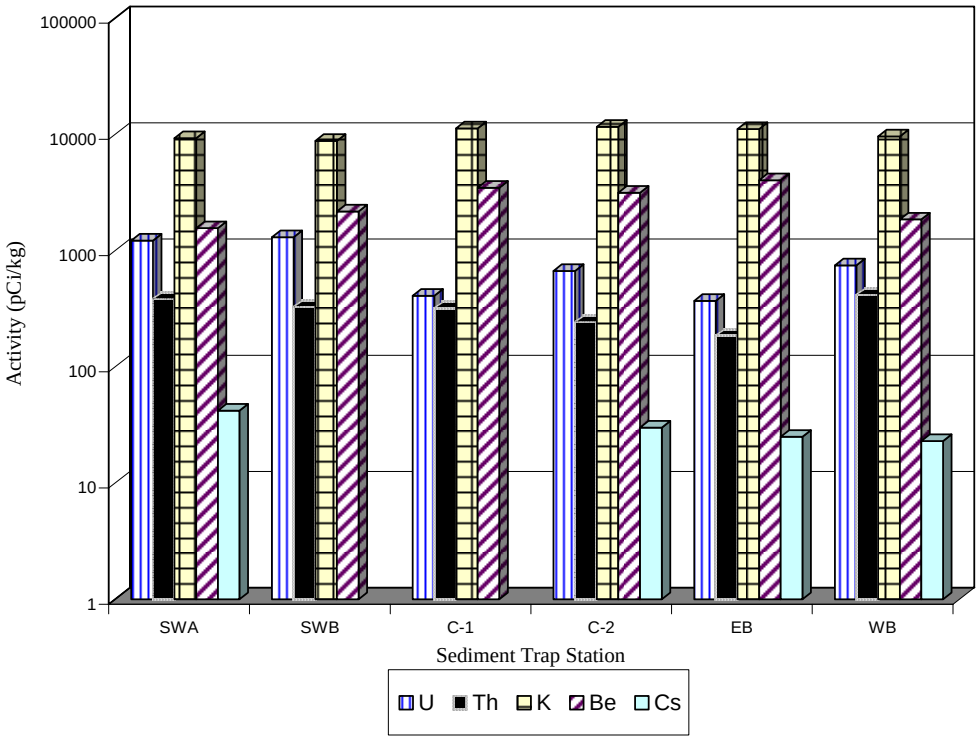

Figure 5. Sediment-trap stations at the Charleston ODMDS.

fine-grained sediment by the traps. ^{7}Be is associated with the fine-grained clay particles and organic matter in the water column. As this particulate matter settles to the seafloor, the sediment traps collect the particles and prevents them from leaving the trap. The fine-grained particulate matter that reaches the seafloor is continuously resuspended into the water column, some of which is collected by the sediment traps. This process works the seafloor over and over again effectively keeping the fine-grained sediment from accumulating on the seafloor. However, when an unusually high volume of fine-grained sediment is introduced into the water column as would be the case from dredged material disposal or rain events, sufficient fine-grained sediment can reach the seafloor and remain until the winnowing process eventually transports the sediment away.

Four of the six sediment-trap samples had detectable ^{137}Cs: WB, SWA, C2, and EB (Figure 5). However, none of the diver-grab samples (Figure 6) had any detectable ^{137}Cs present indicating resuspension and winnowing as discussed in relation to the ^{7}Be. The two sediment grab samples collected in the recently deposited dredged material did have ^{137}Cs present (Samples 12 and 13). Since the dredged material was deposited in greater volume to the ODMDS seafloor than the particulate matter collected in the reef sediment traps, it was expected to find ^{137}Cs in the fine-grained bottom sediment. It was also anticipated that ^{137}Cs would be detected in sediment-trap samples for both WB (potentially affected by the sediment plume from the harbor) and SWA (located near the ODMDS). However, it was not expected that ^{137}Cs would be detected in either C2 (considered a control site) or EB (furthest offshore). Since ^{137}Cs is no longer present in atmospheric fallout, any ^{137}Cs detected offshore would have originated from eroded terrestrial sediment and transported either by tidal action, density driven transport or dredged material deposition. Levels of U, Th and K were similar across all diver-grab samples collected at the hard bottom reef sites (Figure 6), and were similar to levels observed in sediment grab samples.

WB, which was one of the six diver-grab samples, did have detectable ^{7}Be present (Figure 6). This station was the closest reef monitoring station to the coast and within reach of the sediment plume from the harbor (Figure 7). Since several of the other reef monitoring stations were closer to the ODMDS and did not have any ^{7}Be present, the ^{7}Be at WB may have been transported from the harbor through natural processes. In addition,

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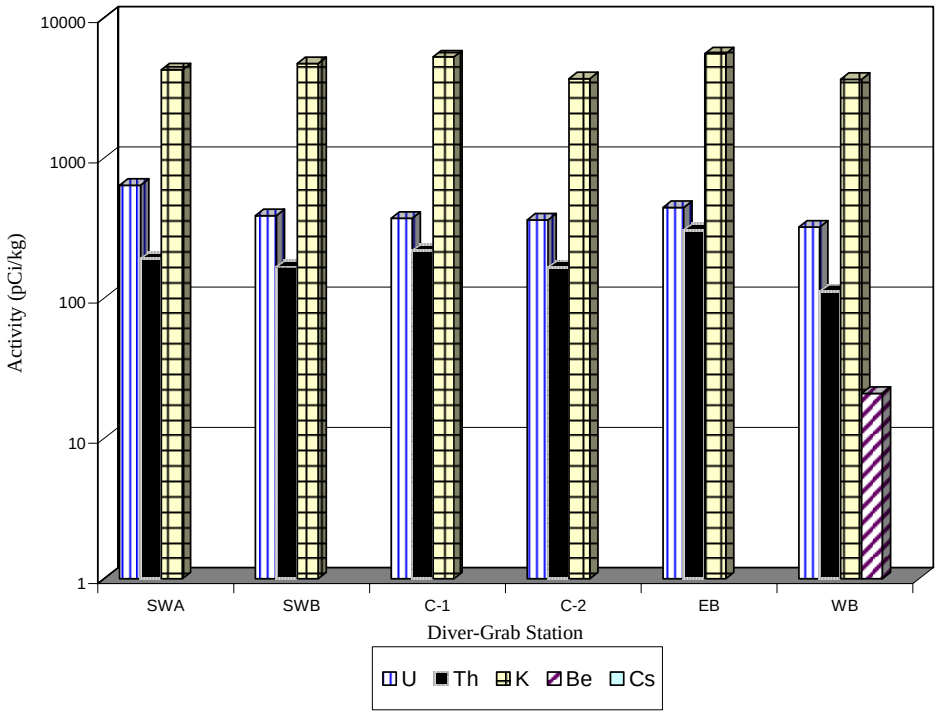

Figure 6. Diver-grab sediment samples at the Charleston ODMDS.

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Figure 7. Satellite view of Charleston including the ODMDS and sampling stations.
*Image courtesy of Earth Sciences and Image Analysis Laboratory (NASA, 2003).

no ^{7}Be was detected in the recent dredged material deposited at the ODMDS. Since ^{137}Cs was detected in recently deposited dredged material at the ODMDS, it would be expected to find ^{137}Cs at some of the monitoring stations. However, none of the diver-grab samples had any ^{137}Cs present. Therefore, if fine-grained sediment was dispersed as a result of dredge material disposal at the ODMDS, it would have been at levels small enough to have been winnowed by natural forces.

4.0 DISCUSSION

The original intention for the fall 2004 isotope tracer sampling was to repeat the spring 2004 results (Noakes, 2004). In the spring, there was a very clear indication of recent terrestrial sediment deposition (as indicated by ^{7}Be) at the offshore reef monitoring stations. However, the fall results were somewhat different from that of the spring. In contrast to the spring results when ^{7}Be was detected at four of the reef monitoring stations (diver-grab samples) only one fall collected diver-grab sample had ^{7}Be present. In addition, only one sediment trap collected in the spring had detectable ^{137}Cs while four sediment traps (fall collected) had detectable ^{137}Cs present.

There were similarities between the spring and fall results in that WB, the reef monitoring station closest to the entrance channel, had both ^{7}Be and ^{137}Cs present. WB had detectable ^{7}Be in the diver-grab sample and ^{7}Be and ^{137}Cs in the sediment-trap sample. Satellite photos have shown in the past that WB has been within range of the harbor sediment plume during rainfall events (Figure 7). The presence of both ^{7}Be and ^{137}Cs at WB for the spring and fall samples along with the satellite photo gave a good indication that the harbor sediment plume had extended to this reef monitoring site.

The remainder of the reef monitoring sites had similar ^{7}Be in the sediment-trap samples from spring versus fall. Other than WB, no reef monitoring sites had any detectable ^{7}Be present in the diver-grab samples. With similar ^{7}Be in the sediment-trap samples from spring versus fall and no additional accumulation on the seafloor, this would indicate that atmospheric ^{7}Be deposition rates were relatively constant and that additional sources such as dredged material disposal or density driven plumes were not adding significantly to the system to increase sediment deposition. The occurrence of

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^{137}Cs at C2, EB, and SWA (fall sediment trap samples) indicate an increase of ^{137}Cs into the system. The additional ^{137}Cs that appeared at the reef monitoring site maybe from the dredged material deposited at the ODMDS. As discussed previously, the dredged material recently deposited at the ODMDS had detectable ^{137}Cs, but not ^{7}Be.

An additional factor that could create a difference in the spring versus fall sampling results was shown in the annual rainfall (NADP, 2004; Figure 8). The precipitation plot clearly showed that considerably more rainfall was recorded in the fall as compared to the spring. The increased precipitation in the Charleston area was due to the unusually active hurricane season experienced during 2004 which produced several rain events during the fall. As a result of the increased precipitation, a greater volume of suspended sediment could be transported offshore by the river plume. However, the diver-grab samples did not reflect any ^{7}Be (other than at WB) which would indicate recent sediment deposition on the seafloor.

5.0 CONCLUSION

Analyses of the tributary and harbor sediments in the Charleston area have clearly shown that ^{7}Be and ^{137}Cs are associated with terrestrial sediment (Noakes, 2004). The presence of ^{7}Be and ^{137}Cs in the offshore diver-grab and sediment-trap samples indicate that this sediment was also of terrestrial origin. The novel approach of utilizing ^{7}Be and ^{137}Cs as tracers in this study to identify the relative contribution of density driven sediment from the harbor versus disposal material migration suggests that some terrestrial sediment has been transported to a subset of the hard bottom reef monitoring stations through natural and anthropogenic processes.

As a result of this study, it would appear that the offshore reef monitoring sites have been affected by both density driven plumes as well as dredged material disposal. WB, as indicated by the spring and fall results and satellite photography, has been affected by the sediment plume from the Charleston Harbor. Indications are that the remaining reef monitoring sites may have been affected by the dredged material disposal. The presence of ^{137}Cs in the recently deposited dredged material at the ODMDS as well as several of the reef monitoring sediment trap samples would support the dredged

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material dispersion. However, with the absence of ^{137}Cs and ^{7}Be on the seafloor, it was clear that at the reef monitoring sites, most of the sediment settling from the water column was either resuspended or winnowed away and did not readily accumulate at the sites.

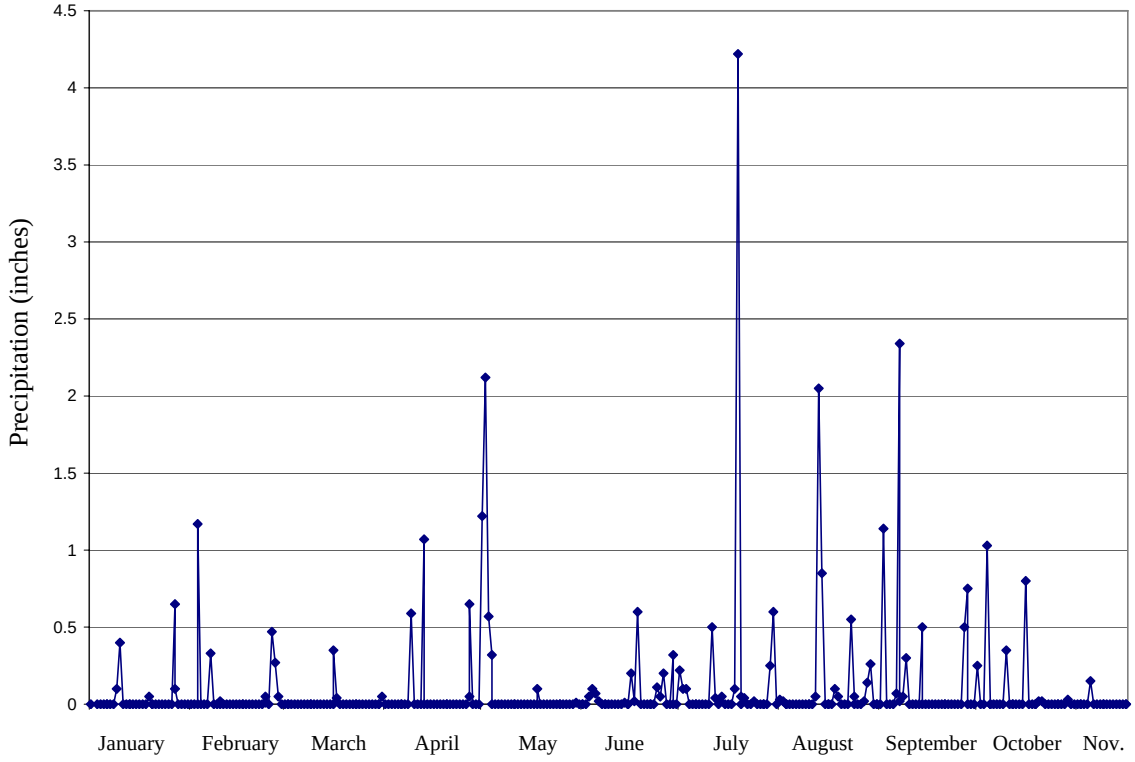

Figure 8. Charleston, South Carolina area annual rainfall for 2004 (NADP, 2004).

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Appendix A. HPGe Gamma Analyses on collected sediment.

Sediment-grab Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
1	2623	2564	7084		
2	1035	536	6216	29	
3	632	238	6430	237	14
4	2884	311	6538	154	
5	712	440	7398		
6	2747	731	7171	25	
7	1949	497	6815	105	
12	1861	322	6971		16
13	1361	337	7610		48

Sediment-trap Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
SWA	1221	384	9285	1561	42
SWB	1305	328	8799	2166	
C1	409	319	11280	3476	
C2	668	243	11600	3153	30
EB	369	185	11110	4034	25
WB	746	417	9596	1854	23

Diver-collected Samples

Station	Isotope (pCi/kg)				
	^{238}U	^{232}Th	^{40}K	^{7}Be	^{137}Cs
SWA	640	1916	4259		
SWB	388	167	4714		
C1	372	218	5254		
C2	362	166	3677		
EB	444	306	5541		
WB	322	112	3646	21	

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