APPENDIX D

Sediment Conditions

(Excerpted from CSE 2005)

APPENDIX D – EXCERPTED FROM

TECHNICAL REPORT

Preliminary Coastal Engineering Analyses for Large-Scale Beach Restoration at Nags Head

Prepared for:

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3.0 NATIVE BEACH SEDIMENT QUALITY

The second design element addressed in the present study is sediment quality. Nourishment success depends on finding a source of sand that is similar in character to the native beach. The next two sections of the report present sediment quality data for the existing beach and two potential borrow areas.

The degree to which a particular borrow sediment matches the native beach sediments strongly influences project longevity and environmental impacts. Three outcomes are possible (cf, Dean 1991, 2002):

- ***Borrow sediment is finer than native*** – The majority of fill will shift offshore and yield a more gently sloping profile. Dry beach will be narrowest.

- ***Borrow sediment is coarser than native*** – The majority of fill will tend to "perch" on the visible beach and yield a steeper profile through the surf zone. Dry beach will be widest.

- ***Borrow sediment matches the native sediment*** – The fill will tend to follow the natural contours of the profile and retain similar slopes and morphology.

It is generally accepted that environmental impacts of nourishment are most likely to be minimized if the borrow sediment "matches" the native (NRC 1995). However, the question of what constitutes "native" is still debatable. In some settings, such as many South Carolina beaches, sediments exist over a very narrow size range between the foredune and inshore zone [eg, mean = 0.18–0.22 millimeters (mm) with poor grading at Isle of Palms]. In these cases, it is relatively easy to distinguish between "coarser" and "finer" than native. Most North Carolina beaches, by contrast, exhibit more variable sediment size distributions. Fine sand may dominate in the dunes and offshore while coarse sand dominates the inner surf zone.

Methods for defining native sediment quality in North Carolina are being reviewed by the NC Coastal Resources Commission (NC CRC 2005). The draft sampling strategy recommended by NC CRC calls for collecting surface grab samples in the alongshore and cross-shore dimensions and then compositing the results to arrive at a characteristic sediment type for a particular beach. CSE attempted to follow the draft CRC strategy for the present study.

3.1 Sediment Sample Collection and Analysis

Consistent with NC CRC draft recommendations, CSE collected samples at 5,000-ft spacing across 14 representative profiles of Nags Head (Fig 13). Grab samples (~250 grams) were taken from the upper ~10 centimeters (cm) of substrate at the following morphologic features (abbreviations correspond to usage in laboratory data sheets):

- Dune – near crest of foredune, seaward of vegetation line
- Toe Dune – near base of dune at the primary change in slope
- Dry Berm – on top of the berm (dry beach) near the berm crest
- MHW – about midway along the sloping beach face in the swash zone
- LTT – near the low-tide mark, wave plunge point
- Trou – in the trough between the swash zone and outer bar
- Bar – along the crest of the outer bar
- Outer – seaward of the bar around the –15 ft depth contour

As the cross-section in Figure 14 shows, the samples collected represent the primary features of the littoral zone.

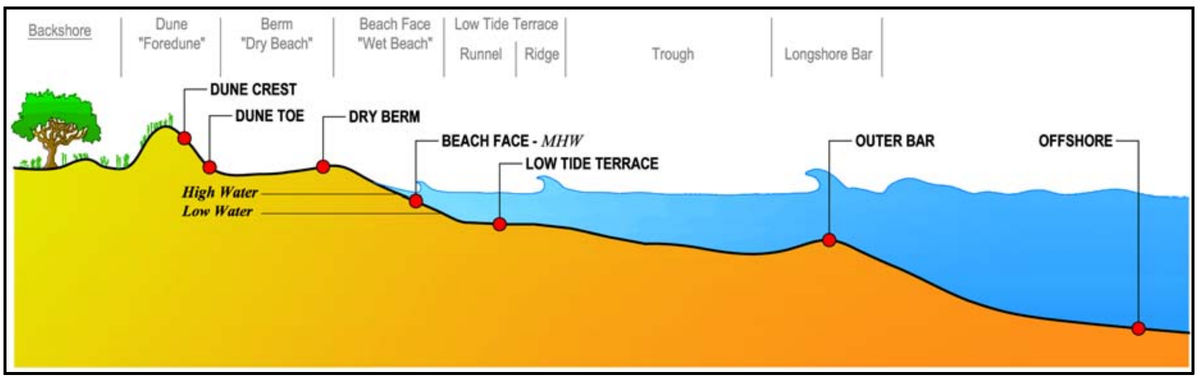


FIGURE 14. Littoral profile showing eight sediment sampling positions based on morphology used in the present study.

Samples were collected by hand on the subaerial beach. Trough, bar, and outer samples were collected using a custom clam-shell grab sampler from CSE's *RV Irie*. Each sample was sealed in a labeled bag and transported to the laboratory for analysis. Samples were carefully washed of salts by decanting, then dried in an oven. Sample splits totaling ~100 grams were taken from the dried sample, and the remainder was retained for percent shell ($CaCO_3$) tests and archiving. Beach samples in high-energy settings such as Nags Head are generally free of mud (silts and clays). This was apparent upon inspection of samples as they were washed; therefore, no mud tests were run in this case. A total of 110 beach samples was analyzed spanning stations 430+00 to 1050+00 (ie, 14 transects of 8 samples per transect less 2 samples that were lost in handling).

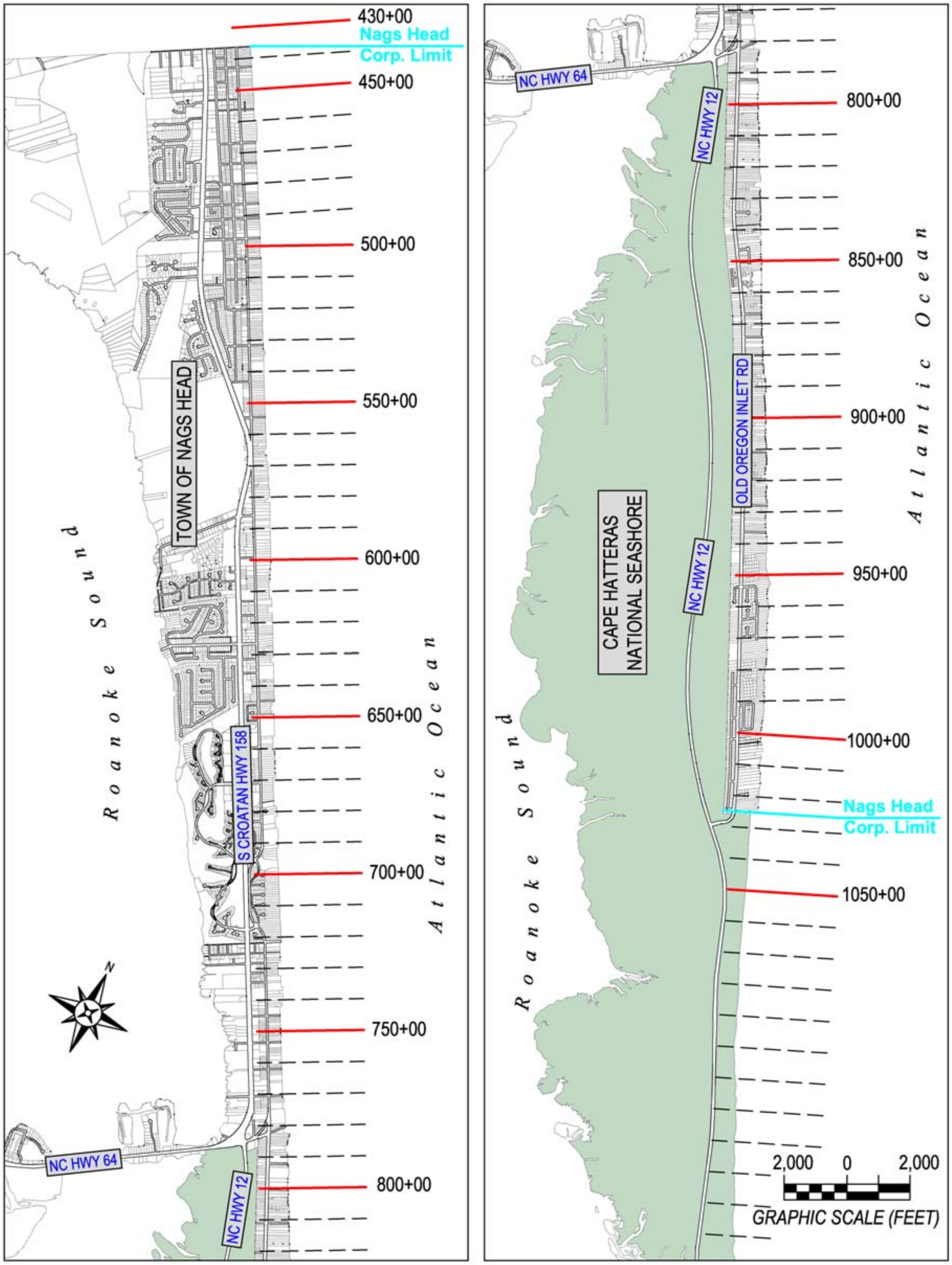


FIGURE 13. Beach sediment sample locations for the present study following NC CRC draft sampling protocols.

[Note: CSE's original scope of services for the present study called for 70 samples, but the total was increased in an attempt to match the draft sampling criteria recommended by NC CRC.]

Samples were analyzed for grain-size distribution via mechanical sieving at 0.25 phi intervals (sand size range). Selected samples having high percentages of gravel were analyzed using sieves in the fine gravel range. Otherwise, gravel (sediments >2 mm diameter) was reported as a simple weight percentage.

Sample splits were converted to percentages and graphed as frequency and cumulative frequency distributions. Standard statistical measures were computed including true-moment measures, graphic means, and standard deviations (ie, Inman 1952, Folk and Ward 1957). Results were reported in millimeters as well as standard phi units. Figure 15 shows a typical data sheet for one sample. The set of laboratory data sheets is given in Appendix B.

Statistical composites of groups of samples were determined mathematically by averaging results for each individual size class for a given group of samples, then calculating moment measures for the composite. Composites were developed for each morphological unit sampled (ie, all dune samples combined, all toe-of-dune samples combined, etc). Groups of morphological units such as dune and toe-of-dune were also composited mathematically. Results of composite size distributions are given after the individual sample results in Appendix B. In general, they are identified on the data sheets as station "NH Comp" followed by the morphological group. Multiple groups in some cases include a numerical value in the name corresponding to the applicable number of samples represented by the result (ie, Toe Dune–Trough 69 is a composite of 69 samples representing the Toe of Dune, Dry Berm, MHW, LTT and Trough).

Percent calcium carbonate ($CaCO_3$) is a representation of the amount of shell material in the sample. Separate splits totaling ~20 grams were taken from each raw sample and weighed, then immersed in diluted muriatic acid (HCl). After ~24 hours or once there was no evidence of bubbling, the remainder was rinsed, dried, and reweighed to the nearest 0.01 gram. The difference represented the proportion of shell in the sample. Summary tables of results, including shell percentages, follow in the next section.

Consistent with NC CRC (2005) draft recommendations, arithmetic (nonweighted) means of groups of samples were computed from tabulated results using simple statistics (ie, mean, standard deviation, and skewness). Mean is the commonly reported typical grain size; standard deviation is a measure of the degree of sorting; and skewness reflects the degree to which the sample contains higher proportions of coarse sediment or fine sediment. Most beaches tend to have well-sorted (low standard deviation) and slightly coarse (ie, negative), skewed sediments. Shell material often adds a coarse fracture, as do granules and pebbles which are common on Dare County beaches.

3.2 Results — Native Beach Sediments

Table 2 gives the sediment size results for Nags Head beach samples. Arithmetic averages for various groups of samples are given at the bottom of the table. Figures 16–17 show mean grain-size results by station for groups of samples, along with trend lines from north to south. Figure 16 (upper) shows the dune and toe-of-dune sample results. Figure 16 (lower) shows the dry beach, MHW, and low-tide-terrace results and also graphs arithmetic averages and the linear trend line for the three groups combined. Figure 17 shows the trough, outer bar, and offshore sample results (individually and grouped) along with the group trend line. Note the scale of each graph varies. Several trends are apparent:

- There is a high degree of variation in mean grain size from station to station and from position to position across the profile.

- The mean grain size of dune samples (dune, toe dune) averages between 0.3 mm and 0.36 mm but individual samples exhibit a range of ~0.2 mm to >0.7 mm.

- The mean grain size of dry beach and swash zone samples (dry berm, MHW, LTT) average around 1.0 mm, but individual samples span a range from 0.27 mm to >3.5 mm.

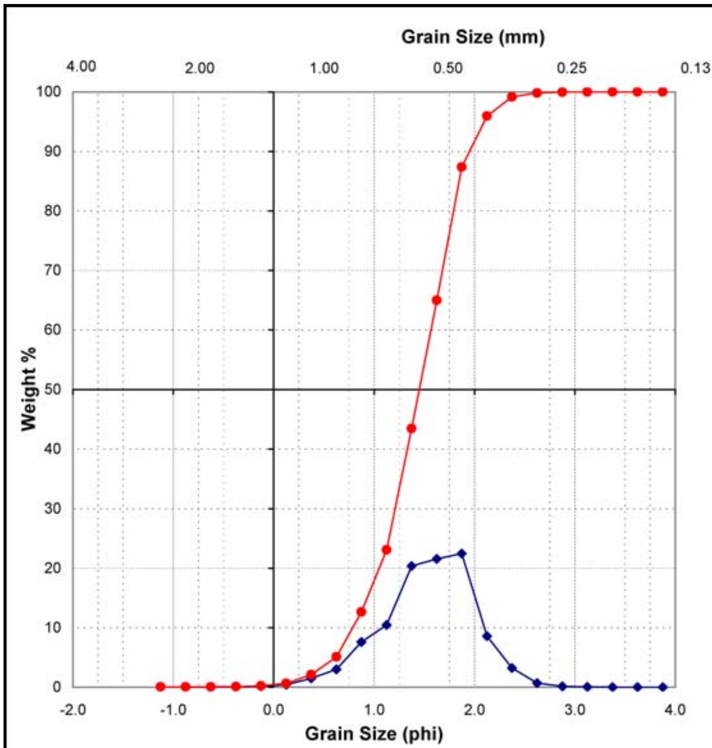
- Underwater samples (trough, bar, outer) show mean grain sizes that average 0.19 mm to ~0.23 mm, with the range for individual samples between ~0.17 mm and >0.3 mm.

The alongshore and cross-shore trends are more apparent when the samples are grouped (Fig 18). Figure 18 (upper) shows the alongshore trend for three groups of samples:

- Dry beach to LTT (ie, the breaker and swash zone)
- Underwater (ie, trough, outer bar, and offshore)
- All samples combined (ie, dune to offshore)

The results illustrate how coarse the swash zone samples are compared with the offshore samples. Offshore samples tend to be relatively uniform in mean grain size (around 0.2 mm). Swash zone samples, even when combined, still exhibit a wide range of grain sizes. Combining all samples (red line in Figure 18, upper) smooths the trend and suggests an (arithmetic) average range of mean grain sizes of the order ~0.45–0.65 mm. Mean sediment grain size tends to become finer toward the south, consistent with previous reports (cf, USACE 2000).

Figure 18 (lower) shows the cross-shore trend in mean grain size, giving the average of all samples from a particular position along the profile. The cross-shore trend shows a characteristic coarsening from the dune to the low-tide terrace (near wave plunge point), then a rapid fining of sediment seaward of the inner breaker zone.



Nags Head '05
Beach Samples
Date 15-May-05

STA # NH 90+000
Location Dry Berm

Mean 0.344 mm
Std. Deviation 0.730 mm
Skewness -0.217

Sediment Type
MEDIUM SAND
Well Sorted
Coarse-Skewed
Mesokurtic

Total weight (gram)	99.13
% finer than 4.00 phi	0.00
% coarser than -1.00 phi	0.04

Class Limits (phi)	Mid Point (phi)	Weight (gram)	Weight %	Cumm. Wt %
-1.000	-1.125	0.043	0.043	0.043
-0.750	-0.875	0.000	0.000	0.043
-0.500	-0.625	0.010	0.010	0.053
-0.250	-0.375	0.040	0.040	0.094
0.000	-0.125	0.130	0.131	0.225
0.250	0.125	0.390	0.393	0.618
0.500	0.375	1.460	1.473	2.091
0.750	0.625	2.950	2.976	5.067
1.000	0.875	7.500	7.566	12.633
1.250	1.125	10.340	10.430	23.063
1.500	1.375	20.190	20.367	43.430
1.750	1.625	21.350	21.537	64.966
2.000	1.875	22.230	22.424	87.391
2.250	2.125	8.490	8.564	95.955
2.500	2.375	3.170	3.198	99.153
2.750	2.625	0.660	0.666	99.818
3.000	2.875	0.130	0.131	99.950
3.250	3.125	0.040	0.040	99.990
3.500	3.375	0.010	0.010	100.000
3.750	3.625	0.000	0.000	100.000
4.000	3.875	0.000	0.000	100.000
>4.00		0.000	0.000	100.000

Percentiles				
1	*5*	*16*	*25*	*50*
0.315	0.744	1.081	1.274	1.576
75	*84*	*95*	*99*	
1.862	1.962	2.222	2.488	

Moment Measures	(phi)	(mm)
Mean	1.539	0.344
Standard Deviation	0.454	0.730
Skewness	-0.217	
Kurtosis	0.464	
Dispersion	0.263	
Standard Deviation	0.443	0.736
Deviation from Normal	-2.44%	

Graphic phi parameter	Inman (1952)	Folk & Ward (1957)
Mean	1.521	1.540
Standard Deviation	0.441	0.444
Skewness (1)	-0.124	-0.125
Skewness (2)	-0.211	
Kurtosis	0.676	1.030

FIGURE 15. Representative sediment-size distribution data sheet for station 900+00 (aka 90+000)–Dry Berm. Appendix B contains the set of data sheets followed by results of composite samples.

TABLE 2. Nags Head beach sediment characteristics (June–July 2005 survey).

Locality	Sample	Typical	Grain Size Distributions			%Coarser	%	%	Sediment
Station	ID	Elev (ft-NGVD)	Mean (mm)	*Std Dev. (mm)*	*Skewness*	*Than 2 mm*	*Mud*	*Carbonate*	Description*
430+00	430Dune	~15	**0.287**	0.747	0.037	0.0	0	0.9	MS,ws ns
	430ToeDune	~10	**0.362**	0.728	0.144	0.0	0	1.4	MS,ws,ns
	430Dry	~8	**0.377**	0.707	0.060	0.0	0	2.0	MS, mws,ns
	430MHW	~3	**0.842**	0.617	0.325	2.4	0	2.7	CS,ms,f-s
	430LTT	~-3	**1.681**	0.574	0.030	44.5	0	5.0	VC,mws,f-s
	430Trou	~-8 to -10	**ND**				ND		
	430 Bar	~-6	**0.184**	0.591	-1.201	1.8	0	1.1	FS,mws,sc-s
	430Outer	~-15	**0.222**	0.680	-0.464	0.0	0	2.0	FS,mws,c-s
450+00	450Dune	~15	**0.421**	0.666	0.038	0.1	0	1.0	MS, mws ns
	450ToeDune	~10	**0.363**	0.676	-0.223	0.0	0	1.2	MS, mws,c-s
	450Dry	~8	**0.467**	0.638	0.036	0.1	0	1.4	MS,mws,ns
	450MHW	~3	**0.671**	0.566	0.241	2.0	0	3.9	CS,ms,f-s
	450LTT	~-3	**0.869**	0.617	0.481	26.1	0	4.3	VC,ps,ns
	450Trou	~-8 to -10	**0.207**	0.688	-0.742	0.0	0	1.0	FS,ws,c-s
	450 Bar	~-6	**0.181**	0.681	-0.658	0.0	0	1.5	FS,mws,c-s
	450Outer	~-15	**0.204**	0.647	-1.020	0.2	0	3.0	FS,mws,sc-s
500+00	500Dune	~15	**0.313**	0.675	-0.143	0.0	0	1.8	MS,mws,c-s
	500ToeDune	~10	**0.260**	0.509	-0.441	1.6	0	2.2	MS,ms,sc-s
	500Dry	~8	**0.411**	0.658	-0.023	0.0	0	1.1	MS,mws,ns
	500MHW	~3	**0.604**	0.619	0.038	8.7	0	1.6	CS,ms,c-s
	500LTT	~-3	**2.366**	0.619	0.329	68.7	0	3.5	G,mws,c-s
	500Trou	~-8 to -10	**0.214**	0.650	-0.738	0.4	0	1.4	FS,mws,sc-s
	500 Bar	~-6	**0.171**	0.694	-1.191	0.0	0	3.1	FS,ws,ns
	500Outer	~-15	**0.174**	0.722	-1.059	0.4	0	1.5	FS,ws,c-s
550+00	550Dune	~15	**0.255**	0.687	-0.388	0.0	0	0.5	MS,mws,c-s
	550ToeDune	~10	**0.467**	0.474	-0.103	31.7	0	2.8	CS,ps,sc-s
	550Dry	~8	**0.714**	0.558	0.207	2.8	0	2.2	CS,ms,f-s
	550MHW	~3	**0.928**	0.467	0.374	16.6	0	2.7	CS,ps,sf-s
	550LTT	~-3	**1.900**	0.626	0.293	57.8	0	5.2	VC,mws,f-s
	550Trou	~-8 to -10	**0.197**	0.703	-0.922	0.7	0	0.9	FS,ws,c-s
	550 Bar	~-6	**0.196**	0.658	-0.957	0.8	0	1.0	FS,ws,c-s
	550Outer	~-15	**0.191**	0.660	-1.251	0.6	0	1.1	FS,ws,sc-s
600+00	600Dune	~15	**0.443**	0.631	0.041	0.5	0	1.8	MS,mws,ns
	600ToeDune	~10	**0.572**	0.531	0.203	42.2	0	4.0	CS,ps,sc-s
	600Dry	~8	**0.384**	0.655	-0.177	0.1	0	1.1	MS,mws,c-s
	600MHW	~3	**1.162**	0.521	0.482	25.5	0	3.7	VC,ms,sf-s
	600LTT	~-3	**1.746**	0.465	0.235	58.3	0	3.0	VC,ps,f-s
	600Trou	~-8 to -10	**0.180**	0.689	-0.735	0.3	0	2.7	FS,ws,c-s
	600 Bar	~-6	**0.194**	0.656	-0.703	0.0	0	1.4	FS,mws,c-s
	600Outer	~-15	**0.187**	0.693	-1.015	0.1	0	1.3	FS,ws,c-s
650+00	650Dune	~15	**0.305**	0.647	-0.324	0.8	0	0.9	MS,mws,ns
	650ToeDune	~10	**0.305**	0.653	-0.530	2.1	0	0.9	MS,mws,c-s
	650Dry	~8	**0.382**	0.683	-0.072	0.1	0	1.1	MS,mws,ns
	650MHW	~3	**1.438**	0.511	0.475	45.2	0	5.1	VC,ms,sf-s
	650LTT	~-3	**3.766**	0.498	0.441	97.6	0	8.2	P,ws,f-s
	650Trou	~-8 to -10	**0.192**	0.709	-0.768	0.6	0	1.6	FS,ws,c-s
	650 Bar	~-6	**0.201**	0.650	-0.736	0.2	0	0.9	FS,mws,sc-s
	650Outer	~-15	**0.258**	0.616	-0.453	0.4	0	3.2	MS,mws,sc-s
700+00	700Dune	~15	**0.360**	0.698	-0.139	0.0	0	0.8	MS,mws,ns
	700ToeDune	~10	**0.571**	0.647	-0.038	1.5	0	1.3	CS,mws,ns
	700Dry	~8	**0.424**	0.610	-0.038	3.3	0	1.3	MS,ms.ns
	700MHW	~3	**1.476**	0.630	0.332	34.6	0	2.3	VC,mws,ns
	700LTT	~-3	**1.490**	0.535	0.313	35.9	0	14.1	VC,ms,ns
	700Trou	~-8 to -10	**0.228**	0.480	-0.823	3.7	0	2.6	FS,ms,sc-s
	700 Bar	~-6	**0.169**	0.737	-0.976	0.0	0	1.1	FS,ws,c-s
	700Outer	~-15	**0.177**	0.780	-1.301	0.1	0	1.2	FS,vws,ns
750+00	750Dune	~15	**0.299**	0.667	0.033	0.0	0	0.9	MS,mws,ns
	750ToeDune	~10	**0.259**	0.491	-0.453	3.8	0	1.4	MS,ps,sc-s
	750Dry	~8	**0.750**	0.572	0.271	9.3	0	1.8	CS,ms,ns
	750MHW	~3	**0.619**	0.471	0.205	18.2	0	2.4	CS,ps,f-s

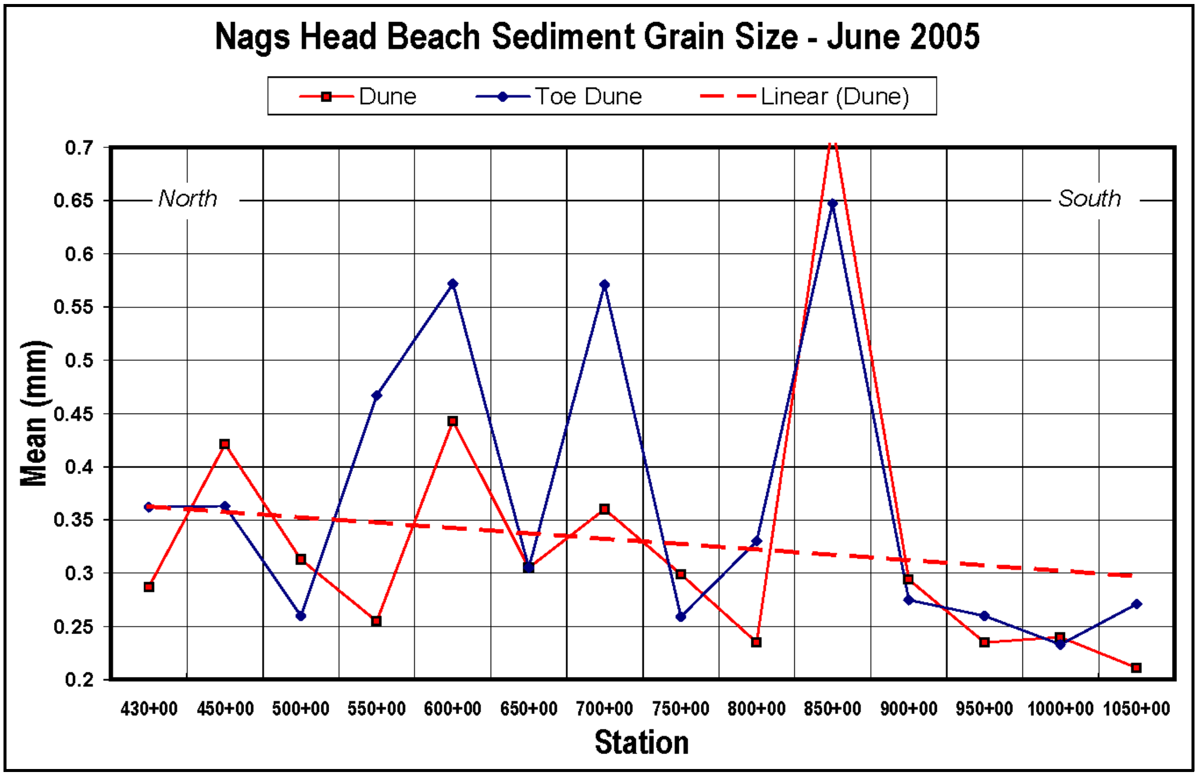
TABLE 2. (continued) Nags Head beach sediment characteristics (June–July 2005 survey).

Locality	Sample	Typical	Grain Size Distributions			%Coarser	%	%	Sediment
Station	ID	Elev (ft-NGVD)	Mean (mm)	*Std Dev. (mm)*	*Skewness*	*Than 2 mm*	*Mud*	*Carbonate*	Description*
750+00	750LTT	~-3	**3.117**	0.572	0.429	81.7	0	9	G,mws,sf-s
	750Trou	~-8 to -10	**0.193**	0.704	-0.629	0.3	0	1	FS,ws,c-s
	750 Bar	~-6	**0.172**	0.756	-1.537	0.6	0	1.1	FS,vws,c-s
	750Outer	~-15	**0.193**	0.616	-1.068	1.0	0	3.2	FS,mws,sc-s
800+00	800Dune	~15	**0.235**	0.738	-0.272	0.0	0	0.4	FS,ws,c-s
	800ToeDune	~10	**0.330**	0.673	0.032	0.0	0	0.8	MS,mws,ns
	800Dry	~8	**0.259**	0.755	-0.231	0.0	0	0.8	MS,ws,ns
	800MHW	~3	**0.639**	0.577	0.109	24.4	0	6.6	CS,ps,sc-s
	800LTT	~-3	**0.586**	0.572	0.128	10.9	0	3	CS,ps,c-s
	800Trou	~-8 to -10	**0.278**	0.647	-0.544	1.2	0	0.9	MS,mws,c-s
	800 Bar	~-6	**0.248**	0.547	-0.628	3.7	0	1.2	FS,ms,sc-s
	800Outer	~-15	**0.223**	0.651	-0.704	0.3	0	1.4	FS,mws,sc-s
850+00	850 Dune	~15	**0.721**	0.536	0.562	60.6	0	5.8	G,vps,ns
	850 Toe Dune	~10	**0.647**	0.511	0.472	59.1	0	1.7	P,eps,sc-s
	850 Dry	~8	**0.626**	0.540	0.325	51.2	0	11.7	P,eps,sc-s
	850 MHW	~3	**0.626**	0.498	0.250	36.1	0	1.9	VC,ps,ns
	850 LTT	~-3	**2.347**	0.539	0.388	63.5	0	2.3	G,ms,ns
	850 Trou	~-8 to -10	**0.204**	0.707	-0.897	0.2	0	0.9	FS,ws,c-s
	850 Bar	~-6	**0.244**	0.625	-0.720	1.1	0	1.1	FS,mws,sc-s
	850 Outer	~-15	**0.188**	0.697	-1.120	0.2	0	1.1	FS,ws,c-s
900+00	900 Dune	~15	**0.294**	0.690	-0.369	0.3	0	0.7	MS,ws,ns
	900 Toe Dune	~10	**0.275**	0.624	-0.347	0.1	0	1.3	MS,mws,c-s
	900 Dry	~8	**0.344**	0.730	-0.217	0.0	0	0.4	MS,ws,c-s
	900 MHW	~3	**0.730**	0.564	0.222	13.1	0	3.4	CS,ps,ns
	900 LTT	~-3	**0.990**	0.712	0.331	20.2	0	2.4	VC,ms,c-s
	900 Trou	~-8 to -10	**0.241**	0.729	-0.542	0.1	0	0.6	FS,ws,c-s
	900 Bar	~-6	**0.217**	0.667	-0.684	0.3	0	1.4	FS,mws,c-s
	900 Outer	~-15	**0.193**	0.589	-1.059	2.8	0	3.6	FS,mws,sc-s
950+00	950 Dune	~15	**0.235**	0.532	-0.462	1.4	0	2.2	FS,ms,c-s
	950 Toe Dune	~10	**0.260**	0.761	-0.005	0.0	0	0.7	MS,ws,ns
	950 Dry	~8	**ND**				ND		
	950 MHW	~3	**1.290**	0.414	0.285	46.7	0	4	VC,ps,sf-s
	950 LTT	~-3	**0.252**	0.609	-0.749	1.8	0	1.3	FS,mws,sc-s
	950 Trou	~-8 to -10	**0.239**	0.654	-0.650	0.7	0	0.8	FS,mws,c-s
	950 Bar	~-6	**0.224**	0.700	-0.595	0.2	0	1	FS,ws,c-s
	950 Outer	~-15	**0.221**	0.643	-0.966	1.0	0	4.4	FS,mws,sc-s
1000+00	1000 Dune	~15	**0.240**	0.683	-0.338	0.5	0	8.1	FS,mws,ns
	1000 Toe Dune	~10	**0.233**	0.672	-0.104	0.5	0	6.8	FS,mws,ns
	1000 Dry	~8	**0.290**	0.742	-0.134	0.0	0	7.7	MS,ws,ns
	1000 MHW	~3	**0.759**	0.559	0.367	27.8	0	13	VC,ps,ns
	1000 LTT	~-3	**0.713**	0.549	0.303	21.4	0	6.9	CS,ps.ns
	1000 Trou	~-8 to -10	**0.444**	0.486	-0.109	13.4	0	15.1	CS,ps,sc-s
	1000 Bar	~-6	**0.230**	0.661	-0.709	0.3	0	2.2	FS,mws,c-s
	1000 Outer	~-15	**0.179**	0.749	-1.265	0.8	0	2.3	FS,vws,ns
1050+00	1050 Dune	~15	**0.211**	0.718	-0.134	0.0	0	0.9	FS,ws,ns
	1050 ToeDune	~10	**0.271**	0.686	0.070	0.1	0	2.1	MS,mws,f-s
	1050 Dry	~8	**0.332**	0.653	-0.214	0.0	0	0.2	MS,mws,c-s
	1050 MHW	~3	**0.688**	0.522	0.386	39.4	0	3	VC,nps,ns
	1050 LTT	~-3	**1.259**	0.439	0.516	44.4	0	7.4	VC,ps,sf-s
	1050 Trou	~-8 to -10	**0.194**	0.737	-1.042	0.4	0	3.5	FS,ws,c-s
	1050 Bar	~-6	**0.192**	0.731	-1.014	0.2	0	1	FS,ws,c-s
	1050 Outer	~-15	**0.181**	0.713	-1.402	0.2	0	4.4	FS,vws,c-s
Arithmetic Averages									
(Unweighted)									
n= 14 Samples	Dune	~15	**0.330**	0.665	-0.133	4.6	0	1.9	MS,mws,c-s
n= 14 Samples	Toe Dune	~10	**0.370**	0.617	-0.095	10.2	0	2.0	MS,mws,ns
n= 13 Samples	Dry Beach	~8	**0.443**	0.654	-0.016	5.1	0	2.5	MS,mws,sym
n= 14 Samples	MHW - UBF	~3	**0.891**	0.538	0.293	24.3	0	4.0	VC,ms,f-s
n= 14 Samples	Low Tide Terrace	~-3	**1.649**	0.566	0.248	45.2	0	5.4	G,ps,f-s
n= 13 Samples	Trough	~-8 to -10	**0.232**	0.660	-0.703	1.7	0	2.5	FS,mws,c-s
n= 14 Samples	Outer Bar	~-6	**0.202**	0.668	-0.879	0.7	0	1.4	FS,mws,c-s
n= 14 Samples	Offshore	~-15	**0.199**	0.675	-1.011	0.6	0	2.4	FS,mws,sc-s
n= 69 Samples	ToeDune to Trou	~15 to ~-3	**0.736**	0.608	0.059	17.9	0	3.2	CS,ps,ns
n= 110 Samples	Dune to Offshore	~15 to ~-15	**0.539**	0.631	-0.287	11.5	0	2.8	MS,ms,c-s

TABLE 2. (continued) Nags Head beach sediment characteristics (June–July 2005 survey).

				Mean (mm)					Dry Beach to LTT	Trough to Offshore	Dune to Offshore
Station	Dune	Toe Dune	Dry Beach	MHW - UBF	LT Terrace	Trough	Outer Bar	Offshore	Arith Avg	Arith Avg	Arith Avg
430+00	0.287	0.362	0.377	0.842	1.681		0.184	0.222	0.967	0.203	0.565
450+00	0.421	0.363	0.467	0.671	0.869	0.207	0.181	0.204	0.669	0.197	0.423
500+00	0.313	0.260	0.411	0.604	2.366	0.214	0.171	0.174	1.127	0.186	0.564
550+00	0.255	0.467	0.714	0.928	1.900	0.197	0.196	0.191	1.181	0.195	0.606
600+00	0.443	0.572	0.384	1.162	1.746	0.180	0.194	0.187	1.097	0.187	0.609
650+00	0.305	0.305	0.382	1.438	3.766	0.192	0.201	0.258	1.862	0.217	0.856
700+00	0.360	0.571	0.424	1.476	1.490	0.228	0.169	0.177	1.130	0.191	0.612
750+00	0.299	0.259	0.750	0.619	3.117	0.193	0.172	0.193	1.495	0.186	0.700
800+00	0.235	0.330	0.259	0.639	0.586	0.278	0.248	0.223	0.495	0.250	0.350
850+00	0.721	0.647	0.626	0.626	2.347	0.204	0.244	0.188	1.200	0.212	0.700
900+00	0.294	0.275	0.344	0.730	0.990	0.241	0.217	0.193	0.688	0.217	0.411
950+00	0.235	0.260		1.290	0.252	0.239	0.224	0.221	0.771	0.228	0.389
1000+00	0.240	0.233	0.290	0.759	0.713	0.444	0.230	0.179	0.587	0.284	0.386
1050+00	0.211	0.271	0.332	0.688	1.259	0.194	0.192	0.181	0.760	0.189	0.416
Arith Mean	0.330	0.370	0.443	0.891	1.649	0.232	0.202	0.199	0.994	0.211	0.539
Wentworth Sizes - Upper Limit											
Fine Sand Limit	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*	*0.25*			
Medium Sand Limit	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*			
Coarse Sand Limit	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*			
Very Coarse Sand Limit	*2*	*2*	*2*	*2*	*2*	*2*	*2*	*2*			
Granule Limit	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*			
Pebble Limit	*64*	*64*	*64*	*64*	*64*	*64*	*64*	*64*			

**P-Pebble; G-Granule; VCS-Very Coarse Sand; CS-Coarse Sand; MS-Medium Sand; FS-fine sand; ms-moderately sorted; mws-moderately well sorted; ws-well sorted;*
ps-poorly sorted; c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution; ns - nearly symmetrical.
% Mud not tested. Visual inspection of samples indicated only trace mud content except as noted on core logs.



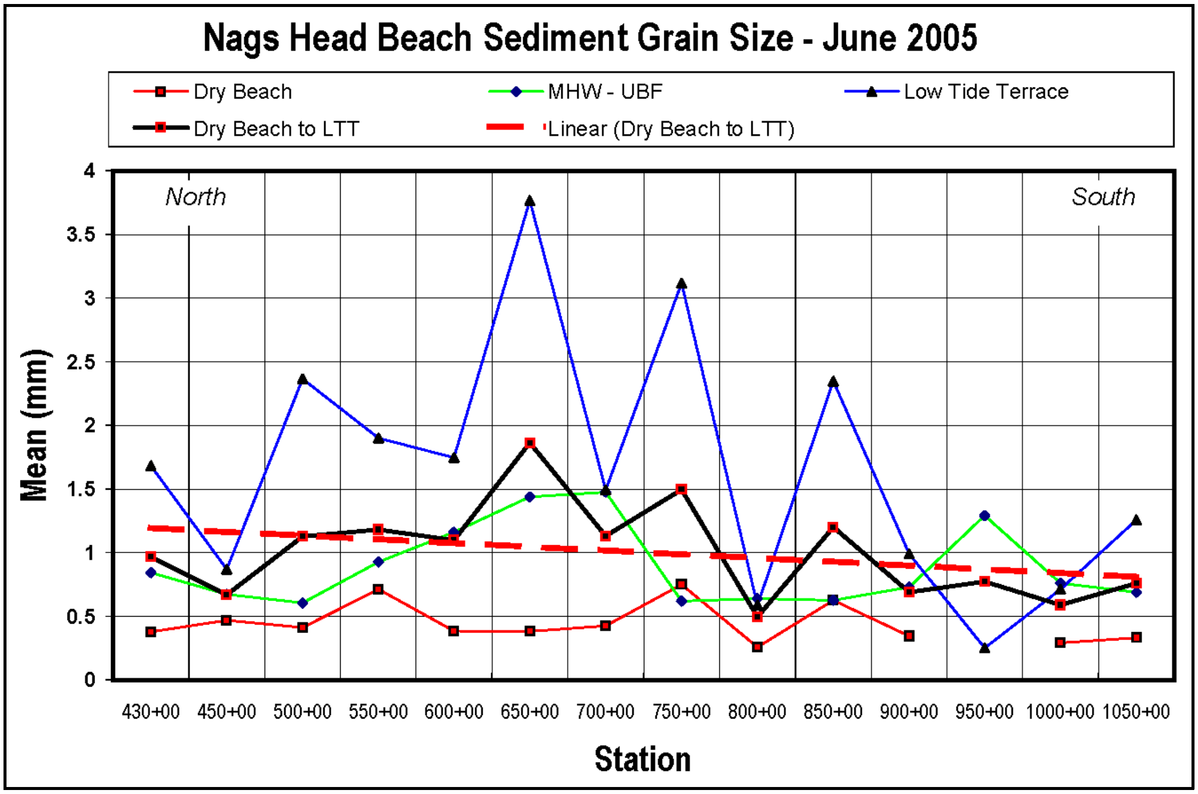


FIGURE 16. Mean grain size by station for dune samples (upper) and active beach zone (lower) along with trend lines.

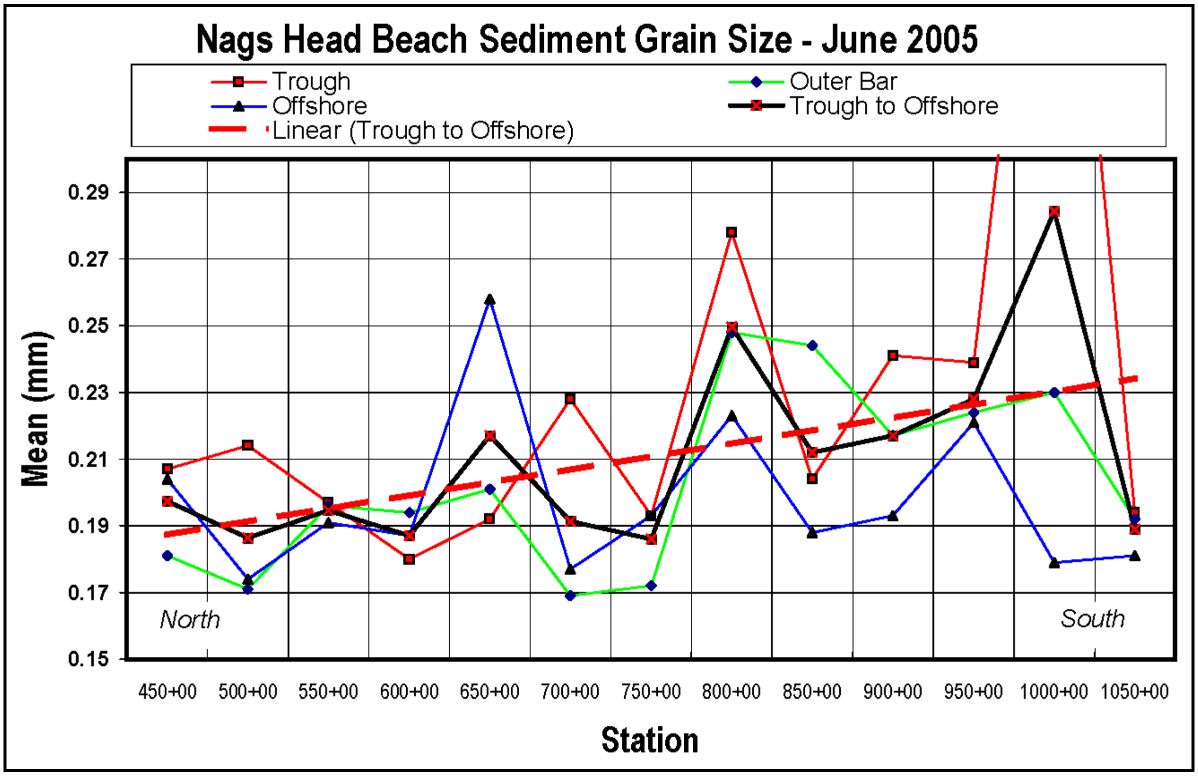
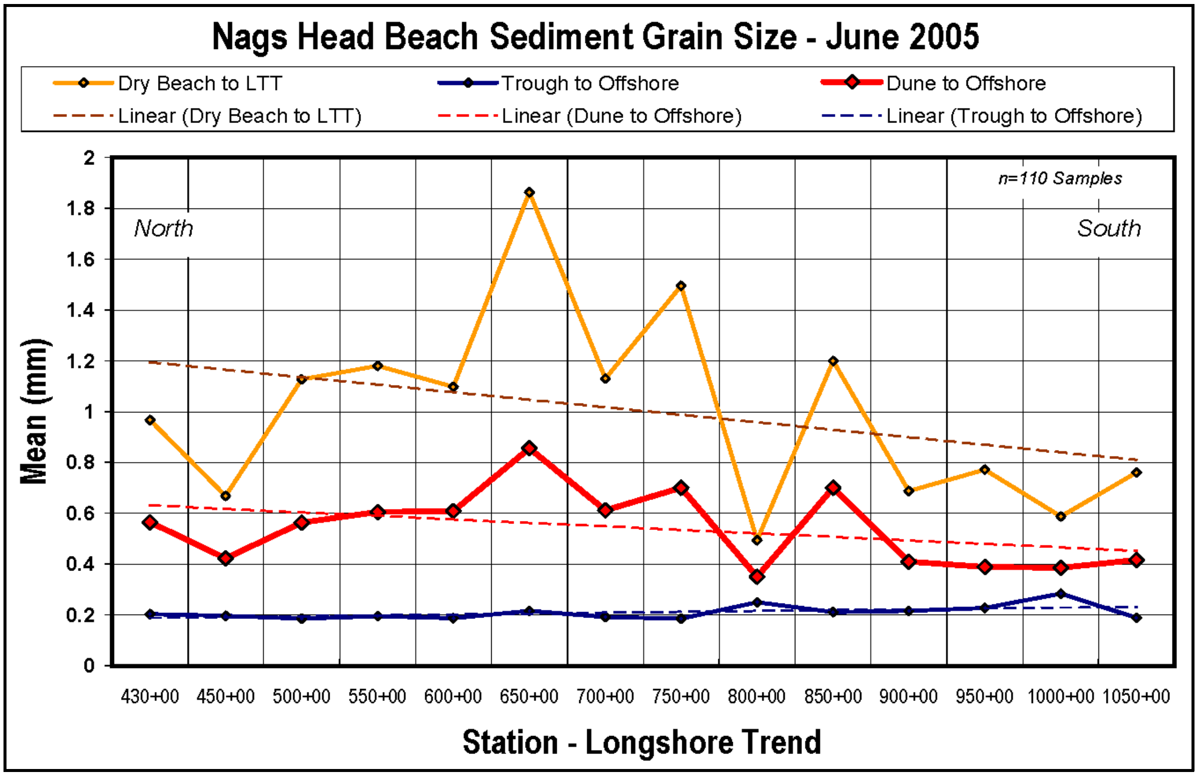


FIGURE 17. Mean grain size by station for underwater samples. Note the scale change compared with Figure 16.



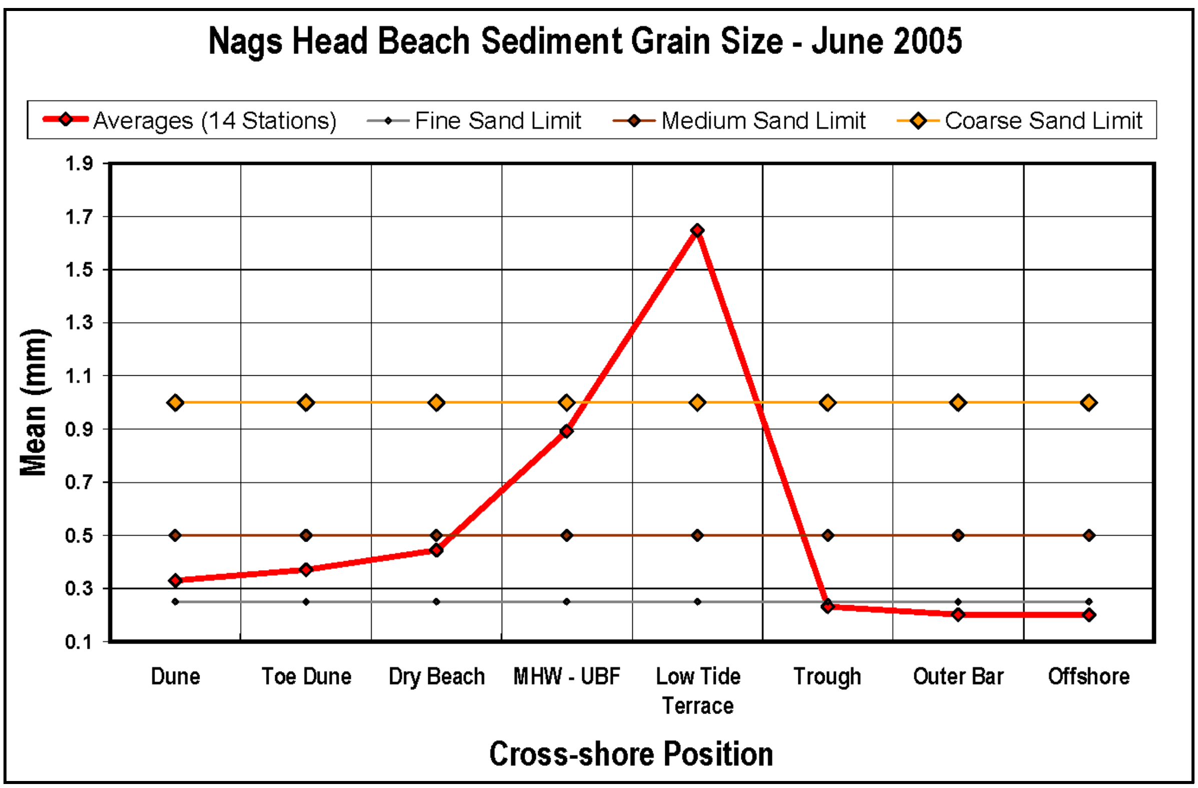


FIGURE 18. Overall trends in mean grain size by station and position across the profile. Red lines pool all samples. Trend line (dashed red line in upper graph) shows decrease in mean grain size from north to south.

3.3 Selection of the Native Grain-Size Distribution

Beaches tend to have well sorted (poorly graded) sediments with a major portion of sand falling within a narrow size range. Sediments having graphs similar in form to Figures 15 and 19 would be found on many US beaches (Komar 1998). The frequency curve provides a visual gauge of the dominant size range in a sample. In Figure 19, nearly 80 percent of the sample falls between 2.0 phi and 3.0 phi (0.125 mm and 0.25 mm), with the mean equaling 0.20 mm. Approximately 15 percent of the sample (by volume) has grain sizes >0.25 mm, and a little less than 5 percent of the sample is comprised of grains smaller than 0.125 mm. Figure 19 is a composite of 14 offshore samples from Nags Head taken from around the 15-ft depth contour. While this size distribution is characteristic of sand on other beaches, many of Nags Heads' samples are not.

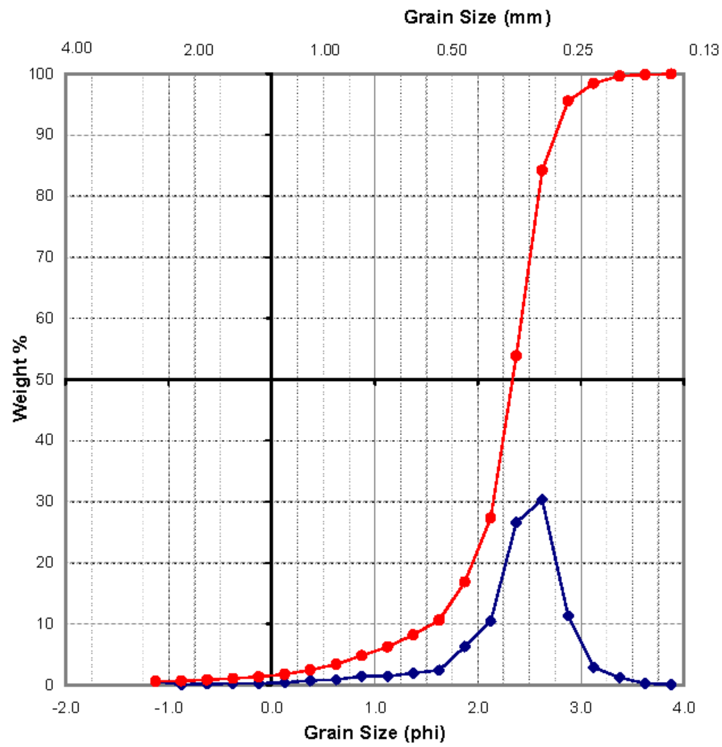
Figure 20 shows the result for station 550+00, near the mean high-tide line (swash zone). Here, the frequency curve shows a highly skewed distribution with a peak around –1.0 phi (2 mm). Eighty percent of this sample (by volume) falls between about –1.5 phi and 1.5 phi (ie, 0.35 mm to 2.8 mm – or medium sand to granules). A significant part of the sample (~15 percent) is finer than 0.3 mm. In this case, the sand in the swash zone is poorly sorted (well graded) and much coarser than the Nags Head offshore samples. The photographs in Figure 21 illustrate the wide range of grain sizes found on Nags Head beaches.

Because of these differences in the shape of curves from one part of the beach to another, it is generally preferable to create composite size distributions using averages of individual size intervals. That is, all samples retained on a particular sieve size are averaged, and so on with each sieve, to yield the composite size distribution. Then the distribution of mean weights (percentages) is analyzed by the method of moments to compute a truer mean and standard deviation. The resulting values are "weighted" means in comparison to "arithmetic" means given at the bottom of Table 2.

Table 3 gives results of composites calculated by the method described above. Results were obtained for each position across the beach and for select groups of sample positions. Data sheets are given at the end of Appendix B. As Table 3 shows, the composite (weighted) means for particular positions across the profile (ie, dune, toe of dune, etc) range from 0.20 mm to 0.86 mm in diameter. When groups (eg, dune and toe dune) are combined, the resulting means show values ranging from 0.21 mm (underwater samples) to 0.65 mm (berm, MHW, and LTT samples). A further grouping of 69 samples encompassing the toe of dune, dry berm, MHW, LTT, and trough averaged 0.47 mm in mean diameter. When all 110 samples are combined, mean size is 0.36 mm. The latter mean is in the medium sand size range, whereas the mean for 69 samples is categorized as nearly coarse sand. All samples (combined) average ~12 percent coarser than 2 mm (ie, gravel) and ~3 percent shell material.

The draft NC CRC (2005) sediment sampling guidelines suggest that a composite of all samples (in this case) be used to establish the "native sediment" size and percentages of coarse and fine materials. In previous projects, CSE has preferred to use composites based on a more limited sampling zone encompassing the dune to low-tide terrace (eg, CSE–Stroud 2001). This is the primary zone of sediment transport and, therefore, contains the type of sediment that will be "stable" under the incident wave energy. The USACE, by comparison, has used composited samples from the foredune to the –30-ft contour, based on the assumption that this broad zone represents the entire littoral profile (eg, USACE 2000). The draft NC CRC sampling guidelines fall somewhere between USACE's practice and CSE's practice.

For purposes of preliminary project planning, CSE elected to adopt two "native beach" size distributions (bold values in Table 3). Figure 22 shows the characteristic size distribution curves for the two composites. The top graph shows a composite native size distribution based on toe of dune and trough samples consistent with CSE's prior practice. The lower graph shows a composite based on dune to outer (offshore) samples, consistent with draft NC CRC (2005) sampling guidelines.



Nags Head '05
Beach Samples
Date 15-May-05

STA # NH Comp
Location Out

Mean 0.198 mm
Std. Deviation 0.659 mm
Skewness -0.986

Sediment Type
FINE SAND
Well Sorted
Strongly Coarse-Skewed
Very Leptokurtic

Total weight (gram)	99.97
% finer than 4.00 phi	0.04
% coarser than -1.00 phi	0.57

Class Limits (phi)	Mid Point (phi)	Weight (gram)	Weight %	Cumm. Wt %
-1.000	-1.125	0.569	0.569	0.569
-0.750	-0.875	0.106	0.106	0.675
-0.500	-0.625	0.192	0.192	0.867
-0.250	-0.375	0.209	0.209	1.076
0.000	-0.125	0.271	0.271	1.347
0.250	0.125	0.386	0.386	1.733
0.500	0.375	0.732	0.732	2.465
0.750	0.625	0.905	0.905	3.370
1.000	0.875	1.446	1.446	4.817
1.250	1.125	1.421	1.421	6.238
1.500	1.375	1.976	1.976	8.214
1.750	1.625	2.398	2.399	10.613
2.000	1.875	6.267	6.269	16.882
2.250	2.125	10.421	10.425	27.307
2.500	2.375	26.565	26.574	53.881
2.750	2.625	30.300	30.310	84.191
3.000	2.875	11.330	11.334	95.525
3.250	3.125	2.909	2.910	98.435
3.500	3.375	1.203	1.203	99.638
3.750	3.625	0.248	0.248	99.886
4.000	3.875	0.071	0.071	99.957
>4.00		0.043	0.043	100.000

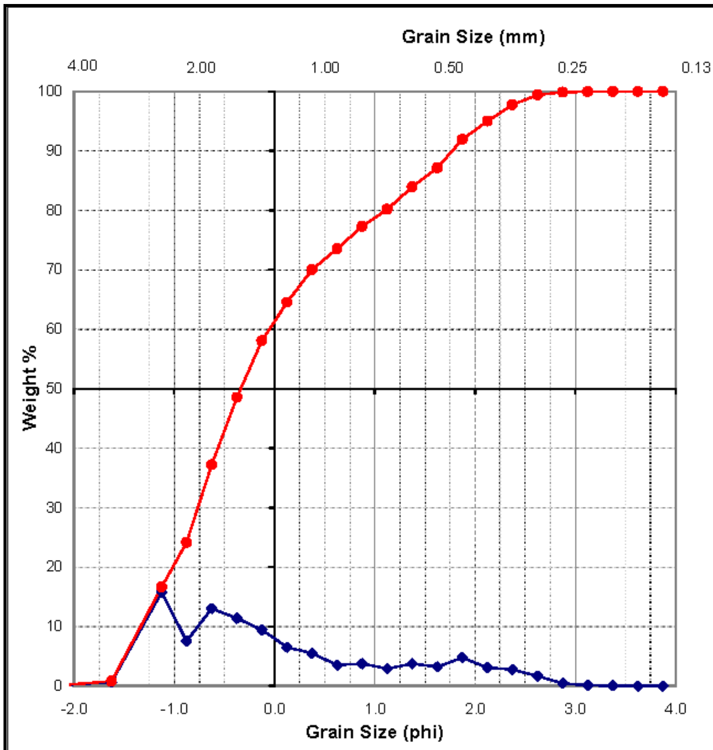
Percentiles

1	5	16	25	50
-0.341	1.032	1.965	2.195	2.463
75	**84**	**95**	**99**	
2.674	2.748	2.988	3.367	

Moment Measures	(phi)	(mm)
Mean	**2.335**	**0.198**
Standard Deviation	**0.602**	**0.659**
Skewness	**-0.986**	
Kurtosis	**5.410**	
Dispersion	0.271	
Standard Deviation	0.452	0.731
Deviation from Normal	-24.87%	

Graphic phi parameter	Inman (1952)	Folk & Ward (1957)
Mean	2.357	2.392
Standard Deviation	0.392	0.492
Skewness (1)	-0.273	-0.368
Skewness (2)	-1.157	
Kurtosis	1.496	1.672

FIGURE 19. Composite grain-size distribution data sheet for Nags Head offshore samples (at –15 ft NGVD) showing narrow size range (well sorted), which is characteristic of many US beaches.



Nags Head '05
Beach Samples

Date	15-May-05
STA #	NH 55+000
Location	MHW
Mean	0.928 mm
Std. Deviation	0.467 mm
Skewness	0.374

Sediment Type
COARSE SAND
Poorly Sorted
Strongly Fine-Skewed
Platykurtic

Total weight (gram)	100.72
% finer than 4.00 phi	0.00
% coarser than -1.00 phi	16.63

Class Limits (phi)	Mid Point (phi)	Weight (gram)	Weight %	Cumm. Wt %
-4.000	-4.125	0.000	0.000	0.000
-3.000	-3.125	0.000	0.000	0.000
-2.000	-2.125	0.150	0.149	0.149
-1.500	-1.625	0.680	0.675	0.824
-1.000	-1.125	15.920	15.806	16.630
-0.750	-0.875	7.580	7.526	24.156
-0.500	-0.625	13.140	13.046	37.202
-0.250	-0.375	11.440	11.358	48.560
0.000	-0.125	9.540	9.472	58.032
0.250	0.125	6.540	6.493	64.525
0.500	0.375	5.520	5.481	70.006
0.750	0.625	3.540	3.515	73.521
1.000	0.875	3.790	3.763	77.284
1.250	1.125	2.940	2.919	80.203
1.500	1.375	3.760	3.733	83.936
1.750	1.625	3.250	3.227	87.162
2.000	1.875	4.810	4.776	91.938
2.250	2.125	3.090	3.068	95.006
2.500	2.375	2.770	2.750	97.756
2.750	2.625	1.670	1.658	99.414
3.000	2.875	0.460	0.457	99.871
3.250	3.125	0.090	0.089	99.960
3.500	3.375	0.030	0.030	99.990
3.750	3.625	0.010	0.010	100.000

Percentiles				
1	**5**	**16**	**25**	**50**
-1.247	-1.184	-1.010	-0.734	-0.212
75	**84**	**95**	**99**	
0.848	1.505	2.250	2.688	

Moment Measures	(phi)	(mm)
Mean	**0.107**	**0.928**
Standard Deviation	**1.100**	**0.467**
Skewness	**0.374**	
Kurtosis	**-0.507**	
Dispersion	0.542	
Standard Deviation	0.842	0.558
Deviation from Normal	-23.45%	

Graphic phi parameter	Inman (1952)	Folk & Ward (1957)
Mean	0.248	0.094
Standard Deviation	1.257	1.149
Skewness (1)	0.365	0.400
Skewness (2)	0.592	
Kurtosis	0.365	0.889

FIGURE 20. Grain-size distribution data sheet for a sample from station 550+00 (aka 55+000) taken from around mean high water in the swash zone. Note the flatter frequency curve and broader range of sizes (poorly sorted) in this case.

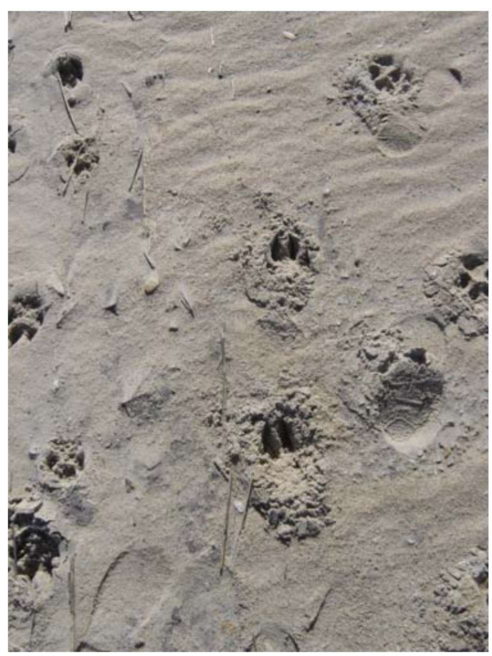


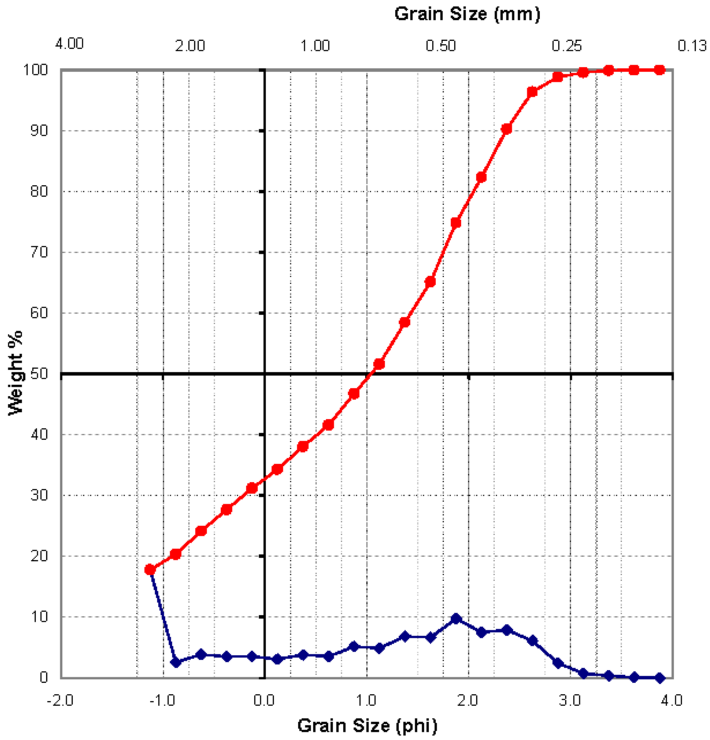
FIGURE 21. Nags Head beach samples span a wide range of sizes both cross-shore and alongshore, making selection of the "native sediment" size subjective.

[UPPER LEFT] Station 469+88 (overview)
[UPPER RIGHT] Station 518+96 (beach face)
[CENTER LEFT] Station 469+88 (beach face)
[CENTER RIGHT] Station 705+00 (overview)
[LOWER LEFT] Station 755+00 (beach face)
[LOWER RIGHT] Station 850+11 (toe of dune)

TABLE 3. Nags Head native beach sediment quality. Mathematical (weighted by sieve size) composite grain-size distributions.

Locality	Sample	Typical	Applicable	Grain Size Distributions		
Group	**ID**	**Elev (ft-NGVD)**	**# Samples**	**Mean (mm)**	***Std Dev. (mm)***	***Skewness***
Dune	Comp Dune	~15	14	0.312	0.590	-0.311
Toe of Dune	Comp Toe Dune	~10	14	0.350	0.541	-0.237
Dry Berm	Comp Dry Berm	~8	13	0.421	0.581	-0.250
MHW-Beach Face	Comp MHW	~3	14	0.759	0.551	0.396
LTT - Low Tide Terrace	Comp LTT	~-3	14	0.859	0.574	0.741
Trough	Comp Trou	~-8 to -10	13	0.249	0.532	-0.776
Outer Bar	Comp Bar	~-6	14	0.200	0.648	-0.873
Offshore (-15 ft)	Comp Out	~-15	14	0.198	0.659	-0.986
Dune & Toe of Dune	Comp Dune-Toe28		28	0.330	0.562	-0.286
Beach Face (Dry Berm,MHW,LTT)	Comp BeachFace41		41	0.650	0.525	0.223
Inshore (Trou, Bar, Outer)	Comp Inshore42		42	0.208	0.628	-0.923
ToeDune-Trough (Toe to Trou)	Comp Toe-Trou69		**69**	**0.474**	**0.471**	-0.001
All Samples	Comp All		**110**	**0.362**	**0.469**	-0.225

Locality	Sample	%Coarser	% Finer Than	%	Sediment	
Group	**ID**	***Than 2 mm***	***.0625 mm***	***Carbonate***	**Description***	
Dune	Comp Dune	4.6	0.02	1.9	MS,ms,s-cs	
Toe of Dune	Comp Toe Dune	10.3	0.03	2.0	MS,ps,s-cs	
Dry Berm	Comp Dry Berm	5.2	0.00	2.5	MS,ms,s-cs	
MHW-Beach Face	Comp MHW	24.3	0.00	4.0	VCS,ps,ns	
LTT - Low Tide Terrace	Comp LTT	45.3	0.00	5.4	VCS,ps,ns	
Trough	Comp Trou	3.6	0.02	2.5	FS,ms,s-cs	
Outer Bar	Comp Bar	0.7	0.07	1.4	MS,mws,s-cs	
Offshore (-15 ft)	Comp Out	0.6	0.04	2.4	FS,ws,s-cs	
Dune & Toe of Dune	Comp Dune-Toe28	7.5	0.02	2.0	MS,ps,s-cs	
Beach Face (Dry Berm,MHW,LTT)	Comp BeachFace41	24.9	0.00	4.0	CS,ps,cs	
Inshore (Trou, Bar, Outer)	Comp Inshore42	0.6	0.04	2.1	FS,mws,s-cs	
ToeDune-Trough (Toe to Trou)	Comp Toe-Trou69	**17.8**	**0.01**	**3.3**	**CS,ps,s-cs**	
All Samples	Comp All	**11.8**	**0.02**	**2.8**	**MS,ps,s-cs**	



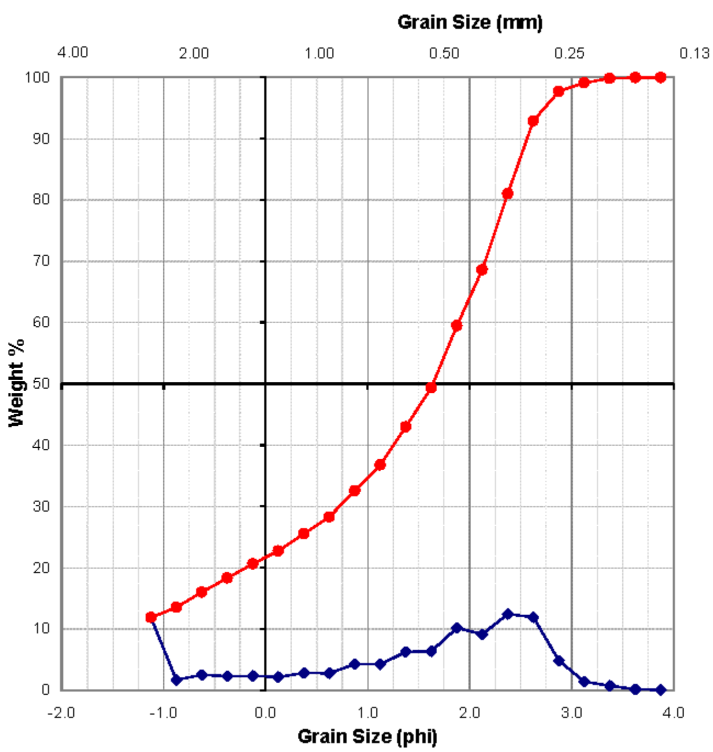
Nags Head '05
Beach Samples
Date 20-May-05

STA # NH Comp
Location ToeDune-Trough69

Mean 0.474 mm
Std. Deviation 0.471 mm
Skewness -0.001

Sediment Type
COARSE SAND
Poorly Sorted
Strongly Coarse-Skewed
Platykurtic

Total weight (gram)	100.15
% finer than 4.00 phi	0.01
% coarser than -1.00 phi	17.77



Nags Head '05
Beach Samples
Date 19-May-05

STA # NH Comp
Location All110

Mean 0.362 mm
Std. Deviation 0.469 mm
Skewness -0.225

Sediment Type
MEDIUM SAND
Poorly Sorted
Strongly Coarse-Skewed
Mesokurtic

Total weight (gram)	100.09
% finer than 4.00 phi	0.02
% coarser than -1.00 phi	11.84

FIGURE 22. Nags Head composite grain-size distributions for the "native beach" as adopted herein. The lower graph, based on all samples, follows the draft NC CRC (2005) sampling protocols. The upper graph shows the result for a more limited zone of sampling between the toe of dune and trough.

4.0 BORROW AREA INVESTIGATIONS

Two potential borrow areas for nourishment (Fig 23) are considered in the present study:

1) Offshore area “S1" as delineated by USACE (2000) for the Dare County project.
2) Oregon Inlet channels and shoals.

Offshore Area “S1"

Area S1 was chosen because of previous studies and recommendations by USACE (2000) as well as the fact that there is an existing EIS for the area which should facilitate permitting should the town elect to pursue a locally funded nourishment project.

Borrow area S1 is strategically located 1–3 miles offshore of south Nags Head (Fig 23). The USACE (2000) delineated a nearly ten-square-mile area based on ~32 borings. The Corps estimated that S1 contains as much as 100 million cubic yards of beach-quality sand within the upper 10 ft of the bottom. Water depths in S1 range from 30 ft to 60 ft and are therefore considered well outside the normal limits of the beach zone. Because the density of prior cores in S1 (~1 per 200 acres) is relatively low, CSE was contracted to collect 60 additional borings and further evaluate its sediment quality. In anticipation of an ~4 million cubic yard project for Nags Head, only a small fraction of S1 would be required.

Oregon Inlet

Oregon Inlet was considered as a potential borrow area for Nags Head because of ongoing federal dredging of the channel and the possibility of piggy-backing on the federal project via Section 933, or some other funding means. Section 933 projects, under federal regulations, allow a local sponsor to obtain dredged material for the difference in cost between what the federal government would pay for nearby disposal and what it costs to place the spoil on the local beach.

Oregon Inlet is dredged on a regular basis, and material is usually disposed along Pea Island about one-half mile downcoast of the channel. Because of these ongoing activities and the fact that the inlet is situated less than 5 miles from Nags Head, it may provide an economic source of sand. As part of the present study, CSE obtained sediment samples and short borings from sites in the inlet and on the Pea Island disposal area for purposes of evaluating sediment quality. The next two sections of the report summarize the results.

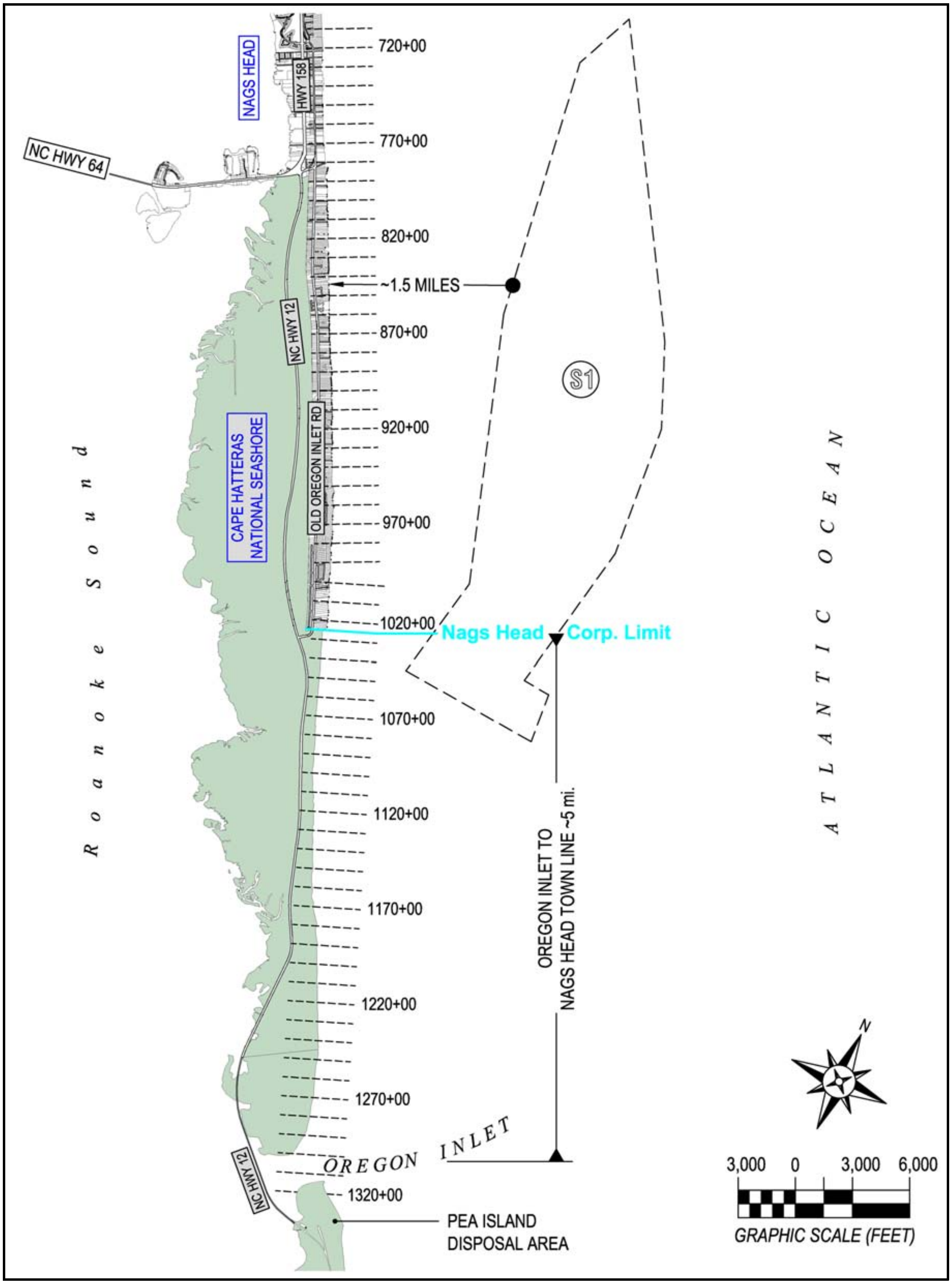


FIGURE 23. The present study investigated potential borrow sources in borrow area S1 (delineated by USACE 2000) and Oregon Inlet (and the Pea Island disposal area for Oregon Inlet).

4.1 Offshore Area S1

CSE reviewed the borings obtained by USACE (2000) and delineated several subareas for further investigation. The present work included a preliminary bathymetric survey of S1 using transects by boat at ~500-ft spacing. Digital bathymetry data from the survey are available on CSE's web site (www.coastalscience.com). Figure 24 shows the resulting contours in area S1, confirming the presence of oblique trending ridges and swales as described by others (eg, Swift et al 1973). Ridges tend to contain coarser sediments and have lower concentrations of fines than the swales, although that is not always the case. Riggs et al (1995) discuss the importance of underlying geology on the distribution and thickness of surficial sediments. The northern Outer Banks tends to have a more plentiful supply of Holocene (recent) sediments, whereas southern portions of the North Carolina coast are sediment-starved.

Drawing on work by others, CSE delineated a search grid in S1 focusing on three subareas (W–C, E–C, S). Cores were collected on a grid inside and adjacent to these subareas. Later analyses of sediment quality identified other subareas (N, C, S) which tend to have sediments most closely matching the native beach. Figure 25 shows the location of various subareas and the grid of cores obtained in the present study. Also shown are the cores obtained by USACE in connection with the federal Dare County project.

Cores were obtained by divers using CSE's proprietary coring system which utilizes a suction pump to create a differential pressure that facilitates penetration of the core barrel into the substrate. Sixty cores averaging ~8 ft long were obtained using 3-inch-diameter aluminum core tubes. Cores were capped underwater and sealed for transport to CSE's sediment testing lab. Each core was split, logged, photographed, and sampled for sediment quality analysis. Half-core sections were sealed in plastic and retained for archives or later use. The other half was sampled and discarded. Sampling was continuous over the indicated interval measured from the top of the core. Samples were then processed and sieved by the same methods used for the beach samples (cf, Section 3.0).

Figure 26 presents one of the cores (NG-05). For the most part, sediments in each core were tan in color and consisted of various mixtures of medium to coarse sand with minor amounts of shell material. Granules and "pea" gravel also occurred in significant amounts in some cores. Core logs and photos of each core are provided in Appendix C. Sample intervals varied according to lithology but with the intent of establishing size and quality information for the upper few feet. Recent experience indicates that shallow excavations by hopper dredge are likely to be more feasible in this setting than deep cuts by cutterhead dredge.

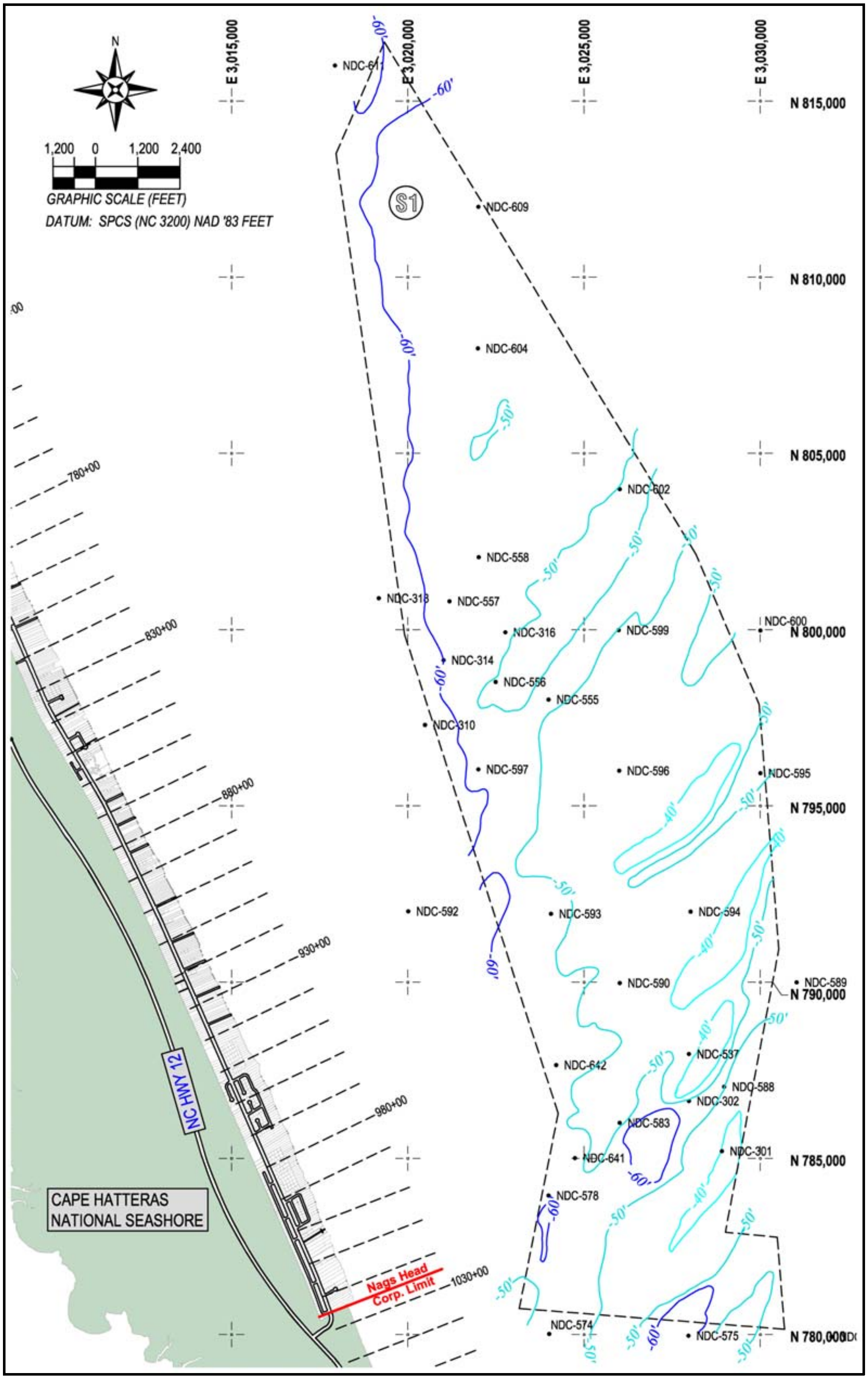


FIGURE 24. Bathymetric contours in offshore area S1 based on a survey by CSE in April 2005. Digital data are available at www.coastalscience.com or from the Town of Nags Head. USACE (2000) boring locations shown (points inside S1).

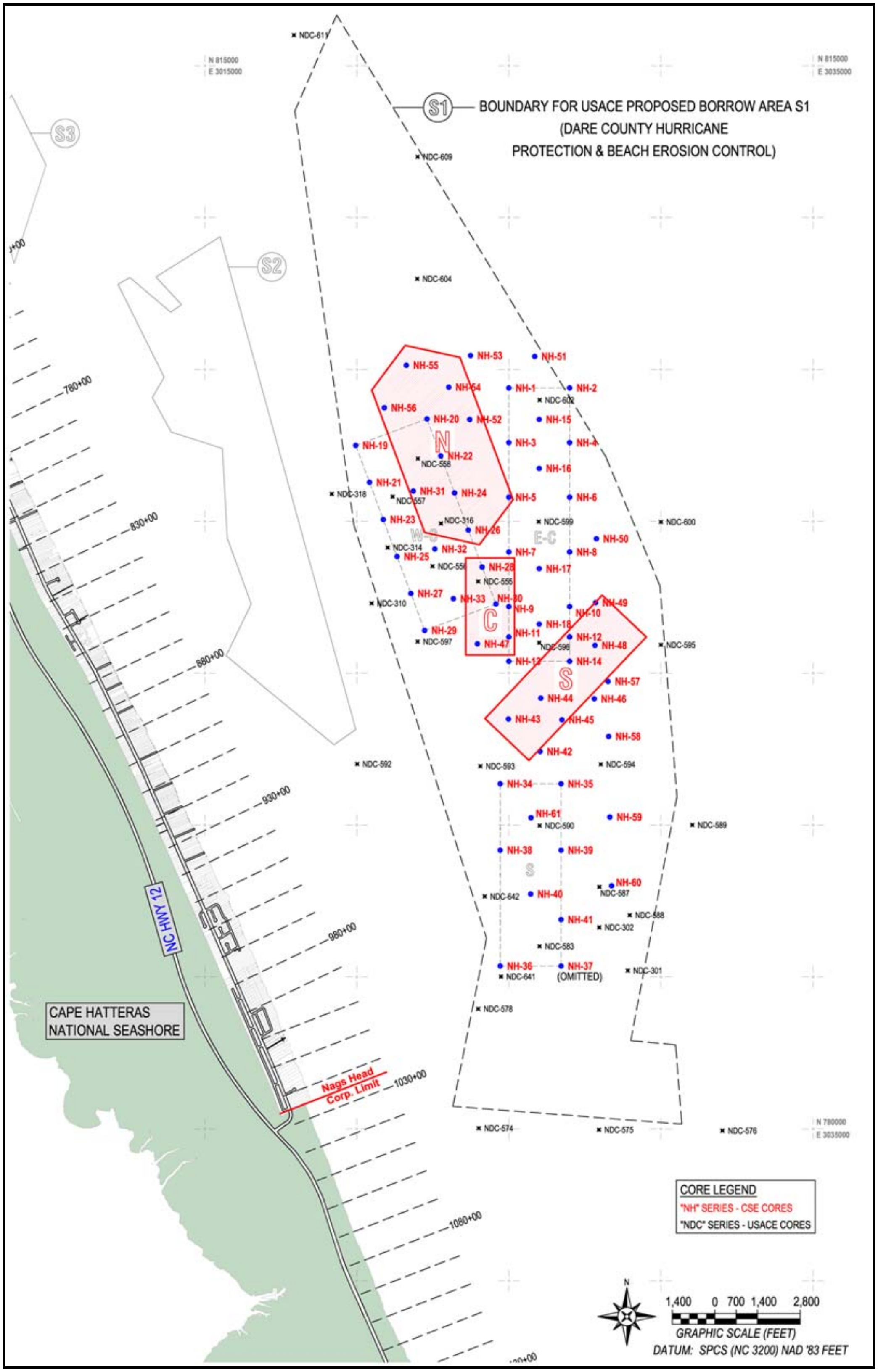


FIGURE 25. Location of various subareas and the grid of cores obtained in the present study. Subareas W–C, E–C, and S were the basis of CSE's survey grid. Subgroups N, C, and S (red) were delineated based on sediment test results.

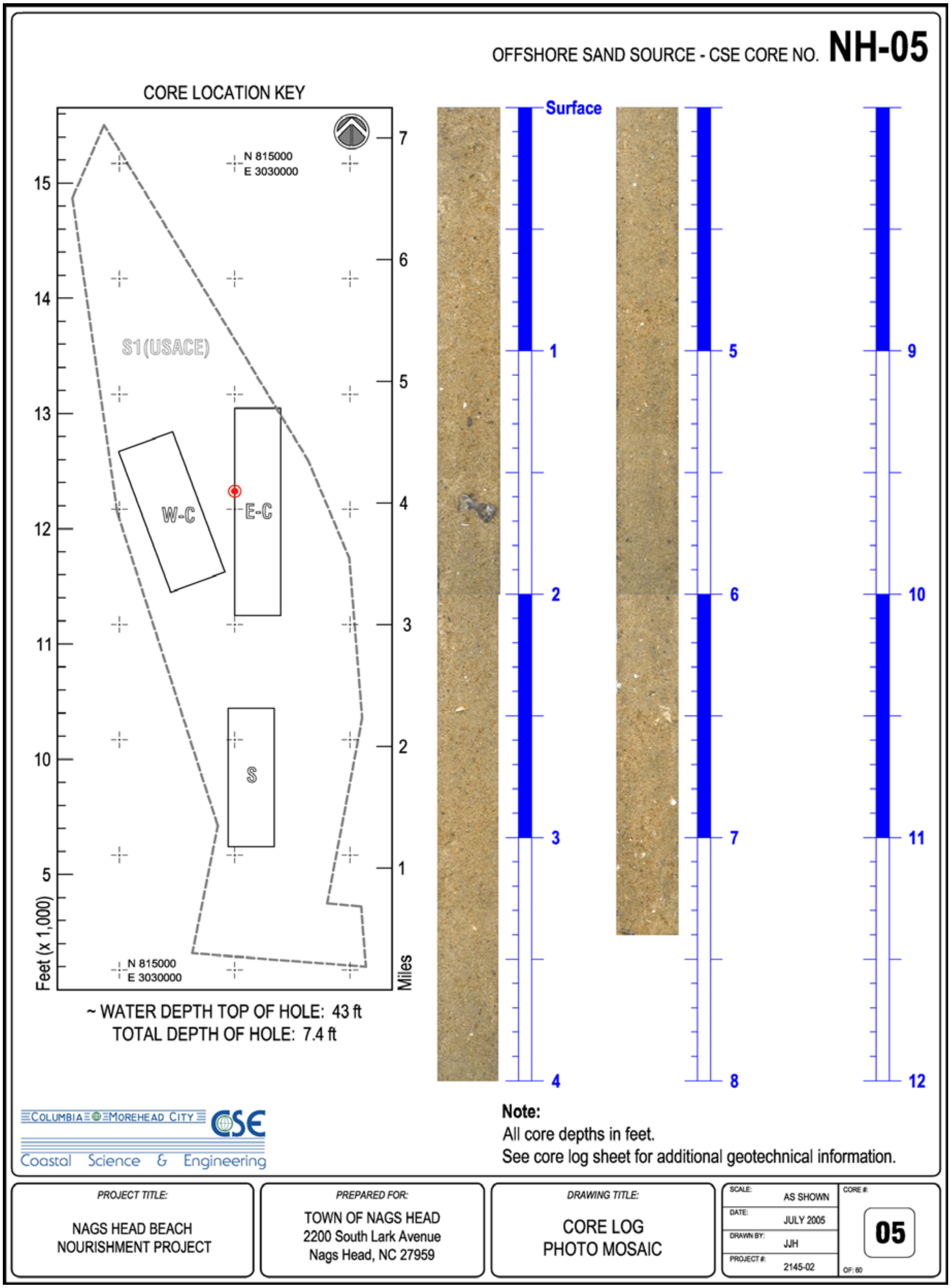


FIGURE 26. Representative core from offshore area S1 which was originally delineated by USACE (2000) and reviewed by regulatory and resource agencies as part of the Dare County project federal EIS. This core contained clean, moderately sorted medium to coarse sand with ~5 percent gravel and negligible fines. Shell content is ~1 percent. Appendix C contains the set of core logs and photos collected for the present study.

The core logs in Appendix C document visual breaks in sediment type. In general, the CSE cores tend to have only trace amounts of mud. Some cores terminated in muddy layers, particularly sites close to the western side of area S1 or in deeper water. Visually, the appearance of a majority of core sediments was exceedingly similar to the beach. Cores contained the same admixtures of sand, granules, pea gravel, and shell fragments found on the beach at Nags Head with only trace fines except an occasional mud lens as noted. (See Appendix C.)

Table 4 lists the key descriptive statistics for each core sample. The table is organized by subgroup within S1 as illustrated on Figure 25. The arithmetic mean grain size for all samples is 0.42 mm (medium sand size comparable to the overall average mean grain size for the beach as discussed in Section 3.3)

Because only a small part of area S1 is needed to provide ~4 million cubic yards, CSE further subdivided the sand search area on the basis of grain size in the upper 2–4 ft. A hopper dredging operation will excavate the topmost layer before reaching deeper sections of the deposit. Using ~0.5 mm-diameter sand as the target, CSE identified 23 cores having somewhat coarser material than the overall average. The locations of these samples are inside the prominent subareas (N, C, S) shown on Figure 25 and listed at the bottom of Table 4. Arithmetic mean grain sizes for the *north, central*, and *south* groups range from 0.51 mm to 0.54 mm. Gravel (percentage >2 mm) ranges from 4.6 percent to 13.1 percent. Shell content is less than 4 percent for all samples. Subgroups *north, central*, and *south* comprise ~800 acres, which if fully excavated by an average of 3 ft would yield ~4 million cubic yards. Obviously, a larger borrow area should be considered if excavations are by hopper dredge. However, the point here is to illustrate the relatively small area within S1 required to provide an initial large-scale project for Nags Head. Subgroup areas *north, central*, and *south* represent only ~12.5 percent of area S1. Furthermore, the assumed average excavation depth (~3 ft) is one-third the potential excavation depth projected in the Dare County project (USACE 2000).

4.2 Oregon Inlet Channel Maintenance for Possible Borrow Source

As part of the present study, CSE obtained a limited number of samples and cores from the Oregon Inlet channel, adjacent spit, and the Pea Island disposal area. One alternative under consideration for Nags Head beach restoration is use of Oregon Inlet dredge spoils (CSE 2004a).

TABLE 4. Nags Head offshore sediment characteristics – area USACE S1 (June-July 2005 survey). [*Sediment Description provided in Table 2 or Table 5.] (Page 1 of 2)

Locality	Core	~Water	Recovery	Sample	Interval	Grain Size Distributions			*% Coarser*	*%*	%	Sediment
(Borrow Area)	ID	Depth (ft)	Length (ft)	ID	(ft)	Mean (mm)	*Std Dev (mm)*	*Skewness*	*Than 2 mm*	*<0.0625 mm*	*Carbonate*	Description*
USACE-S1	NH-19	-60.0	5.1	NH-19-01	0-2.7	0.383	0.500	-0.246	9.2	0.06	1.9	MS,ps,sc-s
Sub Area				NH-19-02	2.8-4.1	0.590	0.455	0.228	19.3	0.06	13.3	CS,ps,ns
W-C	NH-20	-53.3	10.4	NH-20-01	0-3	0.496	0.553	-0.142	9.3	0.02	0.8	CS,ps,sc-s
				NH-20-02	3-5	0.363	0.600	-0.335	1.2	0.03	0.7	MS,ms,c-s
				NH-20-03	5-10.4	0.236	0.623	-0.371	0.5	0.65	2.4	FS,mws,c-s
	NH-21	-60.3	3	NH-21-01	0-0.8	ND	ND	ND	ND	ND	ND	ND
				NH-21-02	0.8-2.8	0.328	0.570	-0.518	6.8	0.07	2.8	MS,ps,sc-s
	NH-22	-51.7	9.7	NH-22-01	0-2.1	0.631	0.591	0.017	13.8	0.01	3.0	CS,ps,sc-s
				NH-22-02	2.1-4.7	0.431	0.617	-0.307	2.1	0.04	1.5	MS,ms,c-s
				NH-22-03	4.7-7.1	0.369	0.589	-0.363	2.1	0.06	0.8	MS,ms,s-c
				NH-22-04	7.1-9.7	0.300	0.655	-0.468	0.6	0.00	0.8	MS,mws,c-s
	NH-23	-56.0	5.6	NH-23-01	0-3.25	0.418	0.551	-0.255	8.8	0.02	1.9	MS,ps,sc-s
				NH-23-02	3.25-5.6	0.249	0.638	-0.649	0.4	0.17	2.1	FS,mws,sc-s
	NH-24	-51.0	9.3	NH-24-01	0-3	0.514	0.591	-0.165	7.7	0.00	1.3	CS,ms,sc-s
				NH-24-02	3-5	0.430	0.615	-0.274	1.5	0.05	1.4	MS,ms,c-s
				NH-24-03	5-9.3	0.303	0.654	-0.492	0.5	0.03	0.6	MS,mws,c-s
	NH-25	-56.2	8	NH-25-01	0-2.8	0.371	0.582	-0.338	5.3	0.04	0.8	MS,ms,sc-s
				NH-25-02	2.8-5	0.294	0.658	-0.433	0.9	0.10	0.9	MS,mws,c-s
				NH-25-03	5-8	0.210	0.605	-0.618	0.6	2.12	-2.3	FS,mws,ns
	NH-26	-47.7	8.6	NH-26-01	0-4	0.484	0.579	-0.171	7.0	0.01	4.0	MS,ps,sc-s
				NH-26-02	4-8.6	0.480	0.593	-0.209	5.0	0.01	4.4	MS,ms,c-s
	NH-27	-54.2	7.1	NH-27-01	0-2.2	0.460	0.550	-0.238	9.8	0.02	2.1	CS,ps,sc-s
				NH-27-02	2.2-4.8	0.231	0.648	-0.737	1.2	0.52	2.5	FS,ws,c-s
				NH-27-03	4.8-7.1	0.430	0.439	0.068	12.5	2.22	6.7	MS,ps,c-s
	NH-28	-52.1	9.2	NH-28-01	0-1.2	0.450	0.563	-0.172	8.7	0.05	1.5	MS,ps,sc-s
				NH-28-02	1.2-7.2	0.221	0.703	-0.304	0.1	0.36	0.8	FS,ws,c-s
	NH-29	-53.8	3.9	NH-29-01	0-2.6	0.425	0.531	-0.278	12.3	0.04	1.4	MS,ps,sc-s
				NH-29-02	2.6-3.65	0.308	0.552	-0.271	0.8	1.17	1.2	MS,ms,c-s
	NH-30	-48.1	8.6	NH-30-01	0-3	0.483	0.587	-0.196	4.7	0.04	1.2	MS,ms,c-s
				NH-30-02	3-5.8	0.486	0.601	-0.162	1.5	0.02	1.9	MS,ms,c-s
				NH-30-03	5.8-8.6	0.358	0.619	-0.308	0.7	0.05	0.6	MS,mws,c-s
	NH-31	-52.4	8.5	NH-31-01	0-2.7	0.609	0.557	0.118	22.5	0.00	1.0	CS,ps,sc-s
				NH-31-02	2.7-8.5	0.355	0.603	-0.367	5.0	0.06	1.1	MS,ms,sc-s
	NH-32	-50.7	6.6	NH-32-01	0-1.9	0.324	0.636	-0.468	1.4	0.02	1.2	MS,mws,c-s
				NH-32-02	1.9-6.6	0.362	0.622	-0.420	1.5	0.06	2.8	MS,mws,sc-s
	NH-33	-50.9	10	NH-33-01	0-1.1	0.493	0.582	-0.153	6.2	0.02	1.4	CS,ms,c-s
				NH-33-02	1.1-3.9	0.360	0.604	-0.363	2.5	0.18	0.7	MS,ms,sc-s
				NH-33-03	4.1-7.9	0.408	0.563	-0.222	10.0	0.04	3.4	MS,ps,sc-s
Sub Area W-C Averages		***-53.2***				***0.396***	*0.589*	*-0.286*	*5.5*	*0.23*	*2.0*	
USACE-S1	NH-1	-53.1	7.7	NH-1-01	0-6	0.349	0.625	-0.402	1.0	0.01	2.6	MS,mws,c-s
Sub Area				NH-1-02	6-7.7	0.295	0.541	-0.557	6.1	0.04	9.3	MS,ms,sc-s
E-C	NH-2	-54.0	9.3	NH-2-01	0-5.5	0.359	0.611	-0.373	0.6	0.01	1.4	MS,mws,c-s
				NH-2-02	5.5-9.3	0.307	0.611	-0.514	0.7	0.03	0.8	MS,mws,sc-s
	NH-3	-50.0	6.3	NH-3-01	0-2	0.464	0.609	-0.229	3.7	0.00	0.6	MS,ms,c-s
				NH-3-02	2-5	0.349	0.602	-0.513	2.2	0.00	1.0	MS,ms,sc-s
				NH-3-03	5-6.3	0.244	0.728	-0.498	0.1	0.05	0.8	FS,ws,ns
	NH-4	-57.4	7.4	NH-4-01	0-3	0.387	0.571	-0.223	1.8	0.03	1.5	MS,ms,c-s
				NH-4-02	3-6.2	0.307	0.597	-0.350	0.6	0.06	1.3	MS,ms,c-s
	NH-5	-46.6	7.4	NH-5-01	0-4	0.480	0.586	-0.214	4.2	0.00	0.4	MS,ms,c-s
				NH-5-02	4-7.4	0.505	0.583	-0.181	5.9	0.00	1.8	CS,ms,sc-s
	NH-6	-52.0	8.6	NH-6-01	0-4.2	0.461	0.593	-0.182	3.6	0.02	1.3	MS,msc-s
				NH-6-02	4.2-8.6	0.323	0.616	-0.469	0.8	0.03	0.5	MS,mws,sc-s
	NH-7	-52.1	7.5	NH-7-01	0-7.5	0.228	0.660	-0.507	0.1	0.18	1.5	FS,mws,c-s
	NH-8	-45.6	8.8	NH-8-01	0-4.4	0.486	0.606	-0.212	3.2	0.00	2.2	MS,ms,c-s
				NH-8-02	4.4-8.8	0.331	0.618	-0.444	1.4	0.03	3.4	MS,mws,sc-s
	NH-9	-46.6	7.5	NH-9-01	0-4	0.584	0.588	-0.035	12.8	0.00	0.5	CS,ps,sc-s
				NH-9-02	4-7.5	0.605	0.575	-0.030	11.0	0.00	7.0	CS,ps,sc-s
	NH-10	-45.0	8.8	NH-10-01	0-3	0.469	0.593	-0.239	2.8	0.00	0.7	MS,ms,c-s
	NH-11	-45.5	10	NH-11-01	0-3.3	0.606	0.587	-0.018	8.6	0.01	1.1	CS,ms,c-s
				NH-11-02	3.3-8.2	0.473	0.587	-0.218	3.1	0.01	0.7	MS,ms,c-s
				NH-11-03	8.2-10	0.194	0.725	-0.589	0.2	0.29	1.0	FS,ws,ns
	NH-12	-42.8	9.3	NH-12-01	0-3.1	0.559	0.597	-0.131	4.9	0.01	2.9	CS,ms,c-s
				NH-12-02	3.1-6	0.516	0.579	-0.122	8.2	0.01	0.9	CS,ps,sc-s
				NH-12-03	6-9.3	0.417	0.615	-0.278	1.2	0.00	1.0	MS,ms,c-s
	NH-13	-44.8	9.3	NH-13-01	0-4.5	0.356	0.593	-0.380	1.5	0.03	0.8	MS,ms,c-s
				NH-13-02	4.5-9.3	0.262	0.660	-0.355	0.0	0.07	2.0	MS,mws,c-s
	NH-14	-43.4	9.1	NH-14-01	0-5	0.526	0.573	-0.182	4.2	0.00	2.3	CS,ms,c-s
				NH-14-02	5-9.1	0.333	0.643	-0.481	0.9	0.00	3.0	MS,mws,c-s
	NH-15	-50.1	7.7	NH-15-01	0-2.3	0.342	0.629	-0.455	1.0	0.01	2.7	MS,mws,c-s
				NH-15-02	2.3-5.6	0.372	0.608	-0.360	1.4	0.03	1.2	MS,ms,c-s
				NH-15-03	5.6-6.6	0.533	0.574	-0.035	3.7	0.00	1.5	CS,ms,c-s
	NH-16	-46.9	8.3	NH-16-01	0-3	0.466	0.599	-0.215	4.0	0.01	0.5	MS,ms,c-s
				NH-16-02	3-8.3	0.479	0.575	-0.198	7.0	0.02	1.0	MS,ps,sc-s
	NH-17	-47.7	6.5	NH-17-01	0-3.9	0.431	0.580	-0.248	2.6	0.00	2.5	MS,ms,c-s
				NH-17-02	3.9-6.5	0.295	0.663	-0.426	0.7	0.05	0.7	MS,mws,c-s
	NH-18	-45.2	10	NH-18-01	0-2.2	0.265	0.699	-0.531	0.2	0.08	0.8	MS,ws,ns
				NH-18-02	2.2-10.0	0.438	0.576	-0.244	0.3	0.01	1.4	MS,ms,c-s
Sub Area E-C Averages		***-48.3***				***0.405***	*0.610*	*-0.306*	*3.1*	*0.03*	*1.8*	
USACE-S1	NH-34	-49.4	8.9	NH-34-01	0-2	0.575	0.563	0.019	25.2	0.00	9.3	CS,ps,sc-s
Sub Area				NH-34-02	2-8.9	0.303	0.730	-0.301	0.2	0.02	1.5	MS,ws,c-s
S	NH-35	-44.3	5.9	NH-35-01	0-1.8	0.464	0.597	-0.273	3.9	0.01	0.8	MS,ms,c-s
				NH-35-02	1.8-5.9	0.364	0.659	-0.100	0.5	0.05	0.6	MS,mws,c-s
	NH-36	-51.8	9.4	NH-36-01	0-2	0.425	0.580	-0.279	3.6	0.01	1.6	MS,ms,sc-s
				NH-36-02	2-5	0.289	0.685	-0.435	0.5	0.04	1.6	MS,ws,c-s
				NH-36-03	5-9.4	0.272	0.637	-0.192	0.2	0.37	1.0	MS,mws,ns
	NH-38	-50.7	5.9	NH-38-01	0-5.8	0.424	0.606	-0.376	4.1	0.01	1.3	MS,ms,sc-s
	NH-39	-42.4	8.3	NH-39-01	0-2.4	0.471	0.603	-0.263	3.7	0.02	0.9	MS,ms,sc-s
				NH-39-02	2.4-8.3	0.422	0.610	-0.378	3.5	0.04	0.9	MS,ms,sc-s
	NH-40	-50.0	8.9	NH-40-01	0-4	0.426	0.618	-0.346	2.0	0.02	0.7	MS,ms,c-s
				NH-40-02	4-8.8	0.359	0.622	-0.497	1.4	0.01	1.4	MS,mws,sc-s
	NH-41	-52.4	9.1	NH-41-01	0-4	0.329	0.692	-0.145	0.2	0.00	0.4	MS,mws,ns
				NH-41-02	4-9.1	0.298	0.719	-0.190	0.1	0.03	0.5	MS,ws,c-s
	NH-61	-47.6	6.3	NH-61-01	0-4	0.428	0.592	-0.349	2.9	0.02	0.7	MS,ms,sc-s
				NH-61-02	4-6.3	0.369	0.639	-0.433	1.3	0.03	1.3	MS,mws,c-s
Sub Area S Averages		***-48.6***				***0.389***	*0.635*	*-0.284*	*3.3*	*0.04*	*1.5*	

TABLE 4. Nags Head offshore sediment characteristics – area USACE S1 (June-July 2005 survey). [*Sediment Description provided in Table 2 or Table 5.] (Page 2 of 2)

Locality	Core	~Water	Recovery	Sample	Interval	Grain Size Distributions			% Coarser	%	%	Sediment
(Borrow Area)	ID	Depth (ft)	Length (ft)	ID	(ft)	Mean (mm)	***Std Dev (mm)***	***Skewness***	***Than 2 mm***	***<0.0625 mm***	***Carbonate***	Description*
USACE-S1	NH-42	-48.4	9.1	NH-42-01	0-2.6	0.409	0.609	-0.362	3.1	0.01	0.5	MS,ms,sc-s
Other Cores				NH-42-02	2.6-5.7	0.304	0.675	-0.449	0.2	0.03	0.5	MS,mws,c-s
				NH-42-03	5.7-9.1	0.280	0.647	-0.502	1.0	0.29		MS,mws,c-s
	NH-43	-44.0	9.6	NH-43-01	0-2.7	0.533	0.591	-0.135	8.0	0.01		CS,ms,sc-s
				NH-43-02	2.7-4.15	0.380	0.633	-0.502	2.4	0.00		MS,mws,sc-s
				NH-43-03	4.15-4.7	0.782	0.600	0.231	18.8	0.01		CS,ps,c-s
				NH-43-04	4.7-7.2	0.479	0.593	-0.219	4.8	0.02		MS,ms,c-s
				NH-43-05	7.2-8.2	0.605	0.572	0.041	17.0	0.00		CS,ps,sc-s
				NH-43-06	8.2-9.6	0.387	0.644	-0.399	0.9	0.01		MS,mws,c-s
	NH-44	-42.8	11.4	NH-44-01	0-3	0.511	0.593	-0.115	3.7	0.01	0.9	CS,ms,c-s
				NH-44-02	3-8	0.388	0.662	-0.299	0.5	0.02	0.7	MS,mws,c-s
				NH-44-03	8-11.4	0.494	0.668	-0.229	0.6	0.00	0.6	MS,mws,c-s
	NH-45	-39.5	9.1	NH-45-01	0-4	0.478	0.611	-0.265	2.4	0.00	0.6	MS,ms,c-s
				NH-45-02	4-9.1	0.294	0.745	-0.187	0.0	0.04	0.3	MS,ws,ns
	NH-46	-34.6	8	NH-46-01	0-4	0.441	0.631	-0.325	3.0	0.00		MS,mws,c-s
				NH-46-02	4-8	0.509	0.581	-0.200	5.7	0.00		CS,ms,sc-s
	NH-47	-48.7	8.3	NH-47-01	0-4	0.511	0.582	-0.136	5.7	0.01	0.9	CS,ms,c-s
				NH-47-02	4-8.3	0.334	0.643	-0.507	0.9	0.02	1.2	MS,mws,sc-s
	NH-48	-45.0	7.8	NH-48-01	0-3.6	0.434	0.612	-0.295	1.4	0.01	1.1	MS,ms,c-s
				NH-48-02	3.6-6.7	0.530	0.570	-0.100	5.8	0.00	1.0	CS,ms,c-s
	NH-49	-47.1	8	NH-49-01	0-2.8	0.493	0.591	-0.171	5.7	0.02	0.9	CS,ms,sc-s
				NH-49-02	2.8-8.0	0.388	0.609	-0.654	1.5	0.03	3.1	MS,ms,c-s
	NH-50	-47.2	9.7	NH-50-01	0-3	0.468	0.605	-0.213	3.9	0.01	2.2	MS,ms,c-s
				NH-50-02	3-8.3	0.472	0.589	-0.220	3.5	0.01	0.8	MS,ms,c-s
	NH-51	-55.3	6.3	NH-51-01	0-0.8	0.303	0.641	-0.474	0.8	0.08	1.4	MS,mws,c-s
				NH-51-02	0.8-5.2	0.555	0.526	-0.017	6.6	0.01	4	CS,ps,c-s
	NH-52	-51.1	9.7	NH-52-01	0-4.3	0.542	0.572	-0.080	10.3	0.00		CS,ps,sc-s
				NH-52-02	4.3-9.7	0.273	0.744	-0.035	0.1	0.06		MS,ws,ns
	NH-53	-53.9	9.6	NH-53-01	0-3.4	0.408	0.589	-0.323	3.9	0.00	1.6	MS,ms,sc-s
				NH-53-02	3.4-9.6	0.230	0.562	-0.781	2.1	0.69	13.8	FS,ms,sc-s
	NH-54	-53.1	9.6	NH-54-01	0-1.6	0.483	0.572	-0.200	6.0	0.02		MS,ms,sc-s
				NH-54-02	1.6-8.5	0.332	0.665	-0.322	0.5	0.10		MS,mws,c-s
	NH-55	-51.6	9.5	NH-55-01	0-2	0.754	0.604	0.220	26.0	0.01	14.3	VC,ps,c-s
				NH-55-02	2-4	0.623	0.587	0.045	20.1	0.02	6.1	CS,ps,sc-s
				NH-55-03	4-6.2	0.709	0.590	0.197	26.3	0.02	2.7	VC,ps,sc-s
				NH-55-04	6.2-7	0.500	0.601	-0.177	4.6	0.01	0.8	CS,ms,c-s
				NH-55-05	7-8.6	0.693	0.569	0.212	25.3	0.01	1.1	CS,ps,c-s
				NH-55-06	8.6-9.5	0.346	0.642	-0.405	1.2	0.02	6.1	MS,mws,c-s
	NH-56	-55.4	8.7	NH-56-01	0-4	0.545	0.528	0.054	24.7	0.01	5.4	CS,ps,sc-s
				NH-56-02	4-5.6	0.619	0.539	0.238	39.3	0.01	2.1	VC,vps,sc-s
				NH-56-03	5.6-6.4	0.416	0.465	-0.094	32.0	0.05	0.8	VC,vps,sc-s
				NH-56-04	6.4-8.7	0.315	0.561	-0.471	7.1	0.05	0.9	MS,ps,sc-s
	NH-57	-36.0	9.4	NH-57-01	0-3.3	0.582	0.608	-0.141	7.9	0.00	0.6	CS,ms,sc-s
				NH-57-02	3.3-7	0.449	0.644	-0.296	1.1	0.01	0.8	MS,mws,c-s
				NH-57-03	7-9.4	0.432	0.616	-0.372	1.7	0.00	1.5	MS,ms,c-s
	NH-58	-44.9	7.8	NH-58-01	0-4.4	0.456	0.619	-0.252	1.8	0.01	0.9	MS,ms,c-s
				NH-58-02	4.4-7.8	0.351	0.657	-0.372	0.8	0.10	1.5	MS,mws,c-s
	NH-59	-36.8	9	NH-59-01	0-1.2	0.448	0.643	-0.311	0.7	0.00	0.5	MS,mws,c-s
				NH-59-02	1.2-5	0.373	0.656	-0.397	0.9	0.01	0.5	MS,mws,c-s
				NH-59-03	5-9	0.428	0.619	-0.339	1.3	0.02	0.8	MS,mws,c-s
	NH-60	-38.3	6.9	NH-60-01	0-3	0.349	0.696	-0.423	0.3	0.01	0.4	MS,ws,c-s
				NH-60-02	3-6.9	0.324	0.718	-0.419	0.3	0.01	1.3	MS,ws,c-s
Other Core Averages		***-46.0***				***0.457***	*0.613*	*-0.230*	*6.8*	*0.04*	*2.2*	
All Sample Averages		-48.9	8.2			0.419	0.608	-0.271	5.1	0.1	1.9	

Locality	Core	~Water	Recovery	Sample	Interval	Grain Size Distributions			%Coarser	%	%	Sediment
(Borrow Area S1)	ID	Depth (Ft)	Lgth (Ft)	ID	(Ft)	Mean (mm)	***Std Dev. (mm)***	***Skewness***	***Than 2 mm***	***<0.0625mm***	***Carbonate***	Description*
Group	NH-20	-53.3	10.4	NH-20-01	0-3	0.496	0.553	-0.142	9.3	0.02	0.8	CS,ps,sc-s
North	NH-22	-51.7	9.7	NH-22-01	0-2.1	0.631	0.591	0.017	13.8	0.01	3.0	CS,ps,sc-s
	NH-24	-51.0	9.3	NH-24-01	0-3	0.514	0.591	-0.165	7.7	0.00	1.3	CS,ms,sc-s
	NH-26	-47.7	8.6	NH-26-01	0-4	0.484	0.579	-0.171	7.0	0.01	4.0	MS,ps,sc-s
	NH-31	-52.4	8.5	NH-31-01	0-2.7	0.609	0.557	0.118	22.5	0.00	1.0	CS,ps,sc-s
	NH-5	-46.6	7.4	NH-5-01	0-4	0.480	0.586	-0.214	4.2	0.00	0.4	MS,ms,c-s
	NH-52	-51.1	9.7	NH-52-01	0-4.3	0.542	0.572	-0.080	10.3	0.00		CS,ps,sc-s
	NH-54	-53.1	9.6	NH-54-01	0-1.6	0.483	0.572	-0.200	6.0	0.02		MS,ms,sc-s
	NH-55	-51.6	9.5	NH-55-01	0-2	0.754	0.604	0.220	26.0	0.01	14.3	VC,ps,c-s
	NH-56	-55.4	8.7	NH-56-01	0-4	0.545	0.528	0.054	24.7	0.01	5.4	CS,ps,sc-s
Group	NH-28	-52.1	9.2	NH-28-01	0-1.2	0.450	0.563	-0.172	8.7	0.05	1.5	MS,ps,sc-s
Central	NH-30	-48.1	8.6	NH-30-01	0-3	0.483	0.587	-0.196	4.7	0.04	1.2	MS,ms,c-s
	NH-11	-45.5	10.0	NH-11-01	0-3.3	0.606	0.587	-0.018	8.6	0.01	1.1	CS,ms,c-s
	NH-47	-48.7	8.3	NH-47-01	0-4	0.511	0.582	-0.136	5.7	0.01	0.9	CS,ms,c-s
Group	NH-12	-42.8	9.3	NH-12-01	0-3.1	0.559	0.597	-0.131	4.9	0.01	2.9	CS,ms,c-s
South	NH-14	-43.4	9.1	NH-14-01	0-5	0.526	0.573	-0.182	4.2	0.00	2.3	CS,ms,c-s
	NH-43	-44.0	9.6	NH-43-01	0-2.7	0.533	0.591	-0.135	8.0	0.01		CS,ms,sc-s
	NH-44	-42.8	11.4	NH-44-01	0-3	0.511	0.593	-0.115	3.7	0.01	0.9	CS,ms,c-s
	NH-45	-39.5	9.1	NH-45-01	0-4	0.478	0.611	-0.265	2.4	0.00	0.6	MS,ms,c-s
	NH-46	-34.6	8.0	NH-46-01	0-4	0.441	0.631	-0.325	3.0	0.00		MS,mws,c-s
	NH-48	-45.0	7.8	NH-48-01	0-3.6	0.434	0.612	-0.295	1.4	0.01	1.1	MS,ms,c-s
	NH-49	-47.1	8.0	NH-49-01	0-2.8	0.493	0.591	-0.171	5.7	0.02	0.9	CS,ms,sc-s
	NH-57	-36.0	9.4	NH-57-01	0-3.3	0.582	0.608	-0.141	7.9	0.00	0.6	CS,ms,sc-s
					0-3.5							
Sub Group	~Area	*~Volume to 3 ft*										
North	427 Ac.	*2.2 million cy*		10 Samples	0-3.1	0.554	0.573	-0.056	13.1	0.01	3.8	CS,ps,sc-s
Central	117.5 Ac.	*0.6 million cy*		4 Samples	0-2.9	0.513	0.580	-0.131	6.9	0.03	1.2	CS,ms,sc-s
South	257 Ac.	*1.2 million cy*		9 Samples	0-3.5	0.506	0.601	-0.196	4.6	0.01	1.3	CS,ps,c-s
All Sub Groups	~800 Ac	*4.0 million cy*		23 Samples	0-3.2	0.528	0.585	-0.124	8.7	0.01	2.3	CS,ps,sc-s

Under USACE Section 933, it is possible for communities to cost-share navigation projects, such as inlet maintenance, and place the spoil directly on the beach. This practice is encouraged to make "best use" of dredged material. If the cost of disposal onshore exceeds the least-cost disposal option (such as offshore disposal), a community has the option of paying the difference to the federal government and receiving the spoil. Such 933 projects have been implemented at Indian Beach and Pine Knoll Shores (NC) (cf, CSE 2004b and www.protectthebeach.com).

A 933 project for Nags Head would require running a pipeline ~5 miles north to the town line, then pumping along the beach from south to north up to 15 miles total distance from the inlet. Presently, USACE disposes spoil from the inlet about 0.5 mile south along Pea Island. It is not considered feasible to perform maintenance in the inlet via hopper dredge because of depth limitations. Consequently, spoil would have to be pumped from cutterhead dredges via one or more booster pumps to reach Nags Head.

For a 933 project to be cost effective, the difference in costs between Pea Island disposal and Nags Head disposal would have to be less than the cost of using offshore area S1. Furthermore, the quality of sediment in the inlet would have to be comparable to S1 and the native beach. Otherwise, a larger volume of Oregon Inlet spoil would be required to achieve the same performance as S1 sediment (NRC 1995).

As per the scope of services, CSE obtained a limited number of sediment samples from Oregon Inlet and tested them in the laboratory using the same techniques described for native beach samples. Figure 27 shows localities in the inlet and on the Pea Island disposal area sampled in the present study. Short cores were obtained on Pea Island to sample through a section of spoil material from recent inlet maintenance projects. The sediment test results are given in Table 5 and Appendix C.

A glance at Table 5 shows that the typical grain size in Oregon Inlet and on Pea Island (disposal area) averages ~0.3 mm (medium sand) with low percentages of gravel. This is considerably finer than the native beach or the majority of samples tested from USACE offshore area S1. While the present sampling was by no means exhaustive, the general lack of coarse sand is not surprising and likely represents conditions for much of the inlet. The trend for the beach at Nags Head is a general fining from north to south. The results for Oregon Inlet simply reinforce that trend.

The next section compares potential borrow sediments with the Nags Head native beach sediment.

FIGURE 27. Oregon Inlet and Pea Island showing general location of sediment samples obtained for the present study.

TABLE 5. Oregon Inlet sediment characteristics (June-July 2005 survey). [*P–pebble; G–granule; VCS–very coarse sand; CS–coarse sand; MS–medium sand; FS–fine sand; ms–moderately sorted; mws–moderately well sorted; ws–well sorted; ps–poorly sorted; c-s–coarse skewed; sc-s–strongly coarse skewed; f-s–fine skewed; sym–symmetrical size distribution; ns–nearly symmetrical.]

Locality	Core	Sample	Interval	Grain Size Distributions			%Coarser	%	%	Sediment
(Borrow Area)	ID	ID	(ft)	Mean (mm)	*Std Dev (mm)*	*Skewness*	*Than 2 mm*	*<0.0625 mm*	*Carbonate*	Description*
Oregon Inlet	**OR-1**	Grab	N/A	**0.420**	0.570	-0.276	11.9	0.00	2.8	MS,ps,sc-s
Shoals & Channel	**OR-2**	Grab	N/A	**0.314**	0.747	-0.237	0.3	0.00	0.4	MS,ws,ns
	OR-3	Grab	N/A	**0.231**	0.710	-0.548	0.0	0.01	0.6	FS,ws,c-s
	OR-4	Grab	N/A	**0.311**	0.461	-0.397	20.5	0.00	18.0	CS,vps,sc-s
	OR-5	Grab	N/A	**0.688**	0.579	0.199	19.0	0.00	2.6	CS,ps,c-s
	OR-6	Grab	N/A	**0.192**	0.793	-0.393	0.1	0.01	0.4	FS,vws,ns
	OR-7	Grab	N/A	**0.233**	0.699	-0.506	0.5	0.01	0.5	FS,ws,c-s
	OR-8	Grab	N/A	**0.359**	0.602	-0.206	1.0	0.00	2.9	MS,ms,ns
	OR-9	Grab	N/A	**0.255**	0.671	-0.784	1.7	0.00	0.7	FS,mws,c-s
	Averages			**0.334**	0.648	-0.350	6.1	0.00	3.2	MS,ms,c-s
Oregon Inlet	**OR-10**	OR-10-A	Surface	**0.247**	0.775	0.086	0.0	0.00	0.3	FS,vws.f-s
Pea Island		OR-10-B	0-1'	**0.244**	0.785	-0.139	0.0	0.00	0.3	FS,vws,f-s
Disposal Area		OR-10-C	1-2'	**0.227**	0.737	0.171	0.0	0.00	0.4	FS,ws,f-s
	OR-11	OR-11-A	Surface	**0.177**	0.732	-0.218	0.0	0.01	0.3	FS,ws,ns
		OR-11-B	0-1'	**0.223**	0.776	0.008	0.0	0.02	2.7	FS,vws.ns
		OR-11-C	1-2'	**0.242**	0.773	-0.336	0.4	0.01	0.4	FS,vws,f-s
	OR-12	OR-12-A	Surface	**0.375**	0.545	-0.425	2.6	0.00	2.6	MS,ms.sc-s
		OR-12-B	0-1'	**0.324**	0.691	-0.346	0.5	0.00	0.7	MS,mws,ns
		OR-12-C	1-2'	**0.397**	0.654	-0.189	0.5	0.01	1.2	MS,mws,ns
	OR-13	OR-13-A	Surface	**0.310**	0.709	0.031	0.2	0.01	0.4	MS,ws,ns
		OR-13-B	0-1'	**0.282**	0.734	-0.050	0.0	0.00	0.2	MS,ws,ns
		OR-13-C	1-2'	**0.278**	0.686	-0.236	0.0	0.00	0.2	MS,mws,c-s
	Averages			**0.290**	0.700	-0.196	0.5	0.00	1.0	MS,ws,ns

4.3 Comparison of Potential Borrow and Native Sediments

CSE analyzed each sediment sample from offshore area S1 and Oregon Inlet for compatibility as nourishment material. Compatibility was measured by means of the overfill factor R_A (CERC 1984), which provides a measure of how a particular sediment will perform as beach nourishment. R_A's of less than 1.5 are generally preferred, with ideal being equal to 1.0.

To apply the method, a native sediment size must be assumed. In this case, two possible native size distributions were applied:

1) "Composite 69" representing the sediments found between the toe of dune and trough.
2) "Composite 110" representing all available beach samples (dune to offshore) following draft recommendations and criteria of the NC CRC (2005).

In the first case, the mean grain size (Mz) is 0.474 mm. In the second case, Mz=0.362 mm.

Table 6 provides the R_A's for each sample using CSE's preferred coarser native size. (Because mud was only found in trace amounts, it is not considered here.) The bottom of Table 6 shows alternate R_A's (using composite 110 for the native size distribution) for selected samples. Table 6 also sorts the USACE area S1 samples into CSE's initial subareas (cf, Fig 25). Upon inspection of results, CSE further subdivided S1 samples into three subgroups (S, C, N) meeting the following approximate criteria:

- Coarse sand (mean grain size ~0.5 mm or greater)
- Represents upper 2 ft or deeper substrate
- Similar sediment quality in adjacent cores

Table 6 color-codes the subgroups and repeats applicable samples at the bottom of the table. The table includes the input values for estimation of R_A's using the required phi values for native mean (M_n), borrow mean (M_b), and sorting parameter (Sd_n and Sd_b) for standard deviation native and borrow (respectively). R_A's were determined graphically after the method of James 1975 (CERC 1984). Inspection of Table 6 shows that R_A's range from ~1.0 to >10. Approximately 50 percent of the samples have R_A's less than 2.0. CSE then identified 23 samples from the uppermost substrate having the lowest R_A's. These samples were flagged on the search area map and used to delineate the three polygons (subgroups) in Figure 25 (N, C, S).

TABLE 6. Nags Head sediment compatibility comparing offshore area S1 with the native beach by the method of James 1975 (CERC 1984). [Page 1 of 3]

Scenario 1: Overfill Ratios Based On Native Beach Equals Composite of Samples from Toe of Dune to Trough

									MzNative=	1.077	phi ***(0.474 mm)***
									StdDevNat=	1.086	phi ***(0.471 mm)***
Borrow	Core	Sample	Recovery	Interval	Sediment	Moment Measures		X	Y	Overfill Ratio (R_A)	%
Area	ID	Number	Length (ft)	(ft)	Description**	M-phi-b	Sigma-b	(Mb-Mn)/SDn	(SDb/SDn)	(R_A) on Comp69	Carbonate
	NH-19	NH-19-01	5.1	0-2.7	MS,ps,sc-s	1.384	1.000	0.28	0.92	1.75	1.9
USACE-S1		NH-19-02		2.8-4.1	CS,ps,ns	0.761	1.137	-0.29	1.05	1.00	13.3
Sub Area	NH-20	NH-20-01	10.4	0-3	CS,ps,sc-s	1.013	0.855	-0.06	0.79	1.25	0.8
W-C		NH-20-02		3-5	MS,ms,c-s	1.461	0.738	0.35	0.68	4.00	0.7
		NH-20-03		5-10.4	FS,mws,c-s	2.085	0.684	0.93	0.63	6.80	2.4
	NH-21	NH-21-01	3	0-0.8	MS,ps,ns	1.389	1.434	0.29	1.32	1.41	9.2
		NH-21-02		0.8-2.8	MS,ps,sc-s	1.608	0.810	0.49	0.75	4.0	2.8
	NH-22	NH-22-01	9.7	0-2.1	CS,ps,sc-s	0.665	0.759	-0.38	0.70	1.1	3.0
		NH-22-02		2.1-4.7	MS,ms,c-s	1.215	0.697	0.13	0.64	2.4	1.5
		NH-22-03		4.7-7.1	MS,ms,c-s	1.440	0.764	0.33	0.70	3.5	0.8
		NH-22-04		7.1-9.7	MS,mws,c-s	1.736	0.611	0.61	0.56	>10	0.8
	NH-23	NH-23-01	5.6	0-3.25	MS,ps,sc-s	1.260	0.859	0.17	0.79	1.8	1.9
		NH-23-02		3.25-5.6	FS,mws,sc-s	2.004	0.649	0.85	0.60	>10	2.1
	NH-24	NH-24-01	9.3	0-3	CS,ms,sc-s	0.960	0.759	-0.11	0.70	1.24	1.3
		NH-24-02		3-5	MS,ms,c-s	1.217	0.701	0.13	0.65	2.5	1.4
		NH-24-03		5-9.3	MS,mws,c-s	1.723	0.612	0.59	0.56	>10	0.6
	NH-25	NH-25-01	8	0-2.8	MS,ms,sc-s	1.430	0.781	0.33	0.72	3.45	0.8
		NH-25-02		2.8-5	MS,mws,c-s	1.767	0.605	0.64	0.56	>10	0.9
		NH-25-03		5-8	FS,mws,ns	2.249	0.725	1.08	0.67	16	-2.3
	NH-26	NH-26-01	8.6	0-4	MS,ps,sc-s	1.048	0.789	-0.03	0.73	1.49	4.0
		NH-26-02		4-8.6	MS,ms,c-s	1.059	0.755	-0.02	0.70	1.5	4.4
	NH-27	NH-27-01	7.1	0-2.2	CS,ps,sc-s	1.122	0.863	0.04	0.79	1.5	2.1
		NH-27-02		2.2-4.8	FS,ws,c-s	2.112	0.625	0.95	0.58	>10	2.5
		NH-27-03		4.8-7.1	MS,ps,c-s	1.219	1.189	0.13	1.09	1.21	6.7
	NH-28	NH-28-01	9.2	0-1.2	MS,ps,sc-s	1.152	0.830	0.07	0.76	1.6	1.5
		NH-28-02		1.2-7.2	FS,ws,c-s	2.176	0.508	1.01	0.47	20	0.8
	NH-29	NH-29-01	3.9	0-2.6	MS,ps,sc-s	1.235	0.915	0.15	0.84	1.6	1.4
		NH-29-02		2.6-3.65	MS,ms,c-s	1.700	0.858	0.57	0.79	4.2	1.2
	NH-30	NH-30-01	8.6	0-3	MS,ms,c-s	1.051	0.768	-0.02	0.71	1.49	1.2
		NH-30-02		3-5.8	MS,ms,c-s	1.040	0.735	-0.03	0.68	1.48	1.9
		NH-30-03		5.8-8.6	MS,mws,c-s	1.480	0.693	0.37	0.64	5.0	0.6
	NH-31	NH-31-01	8.5	0-2.7	CS,ps,sc-s	0.717	0.843	-0.33	0.78	1.24	1.0
		NH-31-02		2.7-8.5	MS,ms,sc-s	1.496	0.731	0.39	0.67	4.5	1.1
	NH-32	NH-32-01	6.6	0-1.9	MS,mws,c-s	1.628	0.652	0.51	0.60	>10	1.2
		NH-32-02		1.9-6.6	MS,mws,sc-s	1.467	0.685	0.36	0.63	5.0	2.8
	NH-33	NH-33-01	10	0-1.1	CS,ms,c-s	1.020	0.780	-0.05	0.72	1.41	1.4
		NH-33-02		1.1-3.9	MS,ms,sc-s	1.474	0.729	0.37	0.67	4.0	0.7
		NH-33-03		4.1-7.9	MS,ps,sc-s	1.295	0.828	0.20	0.76	2.1	3.4
USACE-S1	NH-1	NH-1-01	7.7	0-6	MS,mws,c-s	1.517	0.678	0.41	0.62	7.00	2.6
Sub Area		NH-1-02		6-7.7	MS,ps,sc-s	1.763	0.886	0.63	0.82	4.50	9.3
E-C	NH-2	NH-2-01	9.3	0-5.5	MS,mws,c-s	1.478	0.711	0.37	0.65	5.00	1.4
		NH-2-02		5.5-9.3	MS,mws,sc-s	1.704	0.711	0.58	0.65	>10	0.8
	NH-3	NH-3-01	6.3	0-2	MS,ms,c-s	1.108	0.715	0.03	0.66	2.00	0.6
		NH-3-02		2-5	MS,ms,sc-s	1.517	0.732	0.41	0.67	5.00	1.0
		NH-3-03		5-6.3	FS,ws,ns	2.038	0.458	0.88	0.42	>10	0.8
	NH-4	NH-4-01	7.4	0-3	MS,ms,c-s	1.368	0.807	0.27	0.74	2.32	1.5
		NH-4-02		3-6.2	MS,ms,c-s	1.705	0.744	0.58	0.69	7.0	1.3
	NH-5	NH-5-01	7.4	0-4	MS,ms,c-s	1.060	0.772	-0.02	0.71	1.48	0.4
		NH-5-02		4-7.4	MS,ms,sc-s	0.984	0.778	-0.09	0.72	0.6	1.8
	NH-6	NH-6-01	8.6	0-4.2	MS,ms,c-s	1.118	0.754	0.04	0.69	1.75	1.3
		NH-6-02		4.2-8.6	MS,mws,sc-s	1.628	0.698	0.51	0.64	2.15	0.5
	NH-7	NH-7-01	7.5	0-7.5	FS,mws,c-s	2.134	0.598	0.97	0.55	13	1.5
	NH-8	NH-8-01	8.8	0-4.4	MS,ms,c-s	1.041	0.722	-0.03	0.66	1.52	2.2
		NH-8-02		4.4-8.8	MS,mws,sc-s	1.594	0.694	0.48	0.64	6.8	3.4
	NH-9	NH-9-01	7.5	0-4	CS,ps,sc-s	0.777	0.765	-0.28	0.70	1.08	0.5
		NH-9-02		4-7.5	CS,ps,sc-s	0.726	0.799	-0.32	0.74	1.02	7.0
	NH-10	NH-10-01	8.8	0-3	MS,ms,c-s	1.093	0.755	0.01	0.70	1.75	0.7
	NH-11	NH-11-01	10	0-3.3	CS,ms,c-s	0.724	0.770	-0.33	0.71	1.03	1.1
		NH-11-02		3.3-8.2	MS,ms,c-s	1.080	0.769	0.00	0.71	1.5	0.7
		NH-11-03		8.2-10	FS,ws,ns	2.365	0.464	1.19	0.43	20	1.0
	NH-12	NH-12-01	9.3	0-3.1	CS,ms,c-s	0.838	0.744	-0.22	0.69	1.1	2.9
		NH-12-02		3.1-6	CS,ps,sc-s	0.955	0.788	-0.11	0.73	1.24	0.9
		NH-12-03		6-9.3	MS,ms,c-s	1.263	0.702	0.17	0.65	2.75	1.0
	NH-13	NH-13-01	9.3	0-4.5	MS,ms,c-s	1.488	0.755	0.38	0.70	3.75	0.8
		NH-13-02		4.5-9.3	MS,mws,c-s	1.931	0.600	0.79	0.55	>10	2.0
	NH-14	NH-14-01	9.1	0-5	CS,ms,c-s	0.927	0.804	-0.14	0.74	1.15	2.3
		NH-14-02		5-9.1	MS,mws,c-s	1.585	0.636	0.47	0.59	10.0	3.0
	NH-15	NH-15-01	7.7	0-2.3	MS,mws,c-s	1.550	0.668	0.44	0.62	7.0	2.7
		NH-15-02		2.3-5.6	MS,ms,c-s	1.426	0.718	0.32	0.66	6.0	1.2
		NH-15-03		5.6-6.6	CS,ms,c-s	0.908	0.801	-0.16	0.74	1.15	1.5
	NH-16	NH-16-01	8.3	0-3	MS,ms,c-s	1.103	0.740	0.02	0.68	1.8	0.5
		NH-16-02		3-8.3	MS,ps,sc-s	1.062	0.798	-0.01	0.73	1.47	1.0
	NH-17	NH-17-01	6.5	0-3.9	MS,ms,c-s	1.214	0.785	0.13	0.72	2	2.5
		NH-17-02		3.9-6.5	MS,mws,c-s	1.762	0.593	0.63	0.55	>10	0.7
	NH-18	NH-18-01	10	0-2.2	MS,ws,ns	1.918	0.516	0.77	0.48	>10	0.8
		NH-18-02		2.2-10.0	MS,ms,c-s	1.192	0.797	0.11	0.73	1.8	1.4

TABLE 6. Nags Head sediment compatibility comparing offshore area S1 with the native beach by the method of James 1975 (CERC 1984). [Page 2 of 3]

Scenario 1:	***Overfill Ratios Based On Native Beach Equals Composite of Samples from Toe of Dune to Trough***								MzNative=	1.077	phi ***(0.474 mm)***
									StdDevNat=	1.086	phi ***(0.471 mm)***
Borrow	Core	Sample	Recovery	Interval	Sediment	Moment Measures		X	Y	Overfill Ratio (R_A)	%
Area	ID	Number	Length (ft)	(ft)	Description**	M-phi-b	Sigma-b	(Mb-Mn)/SDn	(SDb/SDn)	(R_A) on Comp69	Carbonate
USACE-S1	NH-34	NH-34-01	8.9	0-2	CS,ps,sc-s	0.798	0.830	-0.26	0.76	1.05	9.3
Sub Area		NH-34-02		2-8.9	MS,ws,c-s	1.724	0.454	0.60	0.42	>10	1.5
S	NH-35	NH-35-01	5.9	0-1.8	MS,ms,c-s	1.109	0.745	0.03	0.69	1.78	0.8
		NH-35-02		1.8-5.9	MS,mws,c-s	1.459	0.601	0.35	0.55	10	0.6
	NH-36	NH-36-01	9.4	0-2	MS,ms,sc-s	1.234	0.786	0.14	0.72	1.9	1.6
		NH-36-02		2-5	MS,ws,c-s	1.789	0.546	0.66	0.50	>10	1.6
		NH-36-03		5-9.4	MS,mws,ns	1.878	0.652	0.74	0.60	>10	1.0
	NH-38	NH-38-01	5.9	0-5.9	MS,ms,sc-s	1.239	0.722	0.15	0.66	2.24	1.3
	NH-39	NH-39-01	8.3	0-2.4	MS,ms,sc-s	1.087	0.731	0.01	0.67	1.90	0.9
		NH-39-02		2.4-8.3	MS,ms,sc-s	1.244	0.713	0.15	0.66	2.50	0.9
	NH-40	NH-40-01	8.9	0-4	MS,ms,c-s	1.231	0.694	0.14	0.64	2.60	0.7
		NH-40-02		0-8.9	MS,mws,sc-s	1.480	0.684	0.37	0.63	5.00	1.4
	NH-41	NH-41-01	9.1	0-4	MS,mws,ns	1.605	0.532	0.49	0.49	>10	0.4
		NH-41-02		4-9.1	MS,ws,c-s	1.747	0.475	0.62	0.44	>10	0.5
	NH-61	NH-61-01	6.3	0-4	MS,ms,sc-s	1.225	0.756	0.14	0.70	2.10	0.7
		NH-61-02		4-6.3	MS,mws,c-s	1.440	0.647	0.33	0.60	6.00	1.3
USACE-S1	NH-42	NH-42-01	9.1	0-2.6	MS,ms,sc-s	1.290	0.715	0.20	0.66	2.75	0.5
Other Cores		NH-42-02		2.6-5.7	MS,mws,c-s	1.716	0.567	0.59	0.52	>10	0.5
		NH-42-03		5.7-9.1	MS,mws,c-s	1.834	0.628	0.70	0.58	>10	
	NH-43	NH-43-01	9.6	0-2.7	CS,ms,sc-s	0.907	0.758	-0.16	0.70	1.24	
		NH-43-02		2.7-4.15	MS,mws,sc-s	1.397	0.661	0.29	0.61	4.50	
		NH-43-03		4.15-4.7	CS,ps,c-s	0.355	0.736	-0.66	0.68	<1.02	
		NH-43-04		4.7-7.2	MS,ms,c-s	1.063	0.754	-0.01	0.69	1.5	
		NH-43-05		7.2-8.2	CS,ps,sc-s	0.726	0.805	-0.32	0.74	1.02	
		NH-43-06		8.2-9.6	MS,mws,c-s	1.371	0.635	0.27	0.58	6	
	NH-44	NH-44-01	11.4	0-3	CS,ms,c-s	0.969	0.755	-0.10	0.70	1.25	0.9
		NH-44-02		3-8	MS,mws,c-s	1.367	0.596	0.27	0.55	6.8	0.7
		NH-44-03		8-11.4	MS,mws.cs	1.016	0.582	-0.06	0.54	2.15	0.6
	NH-45	NH-45-01	9.1	0-4	MS,ms,c-s	1.065	0.711	-0.01	0.65	1.74	0.6
		NH-45-02		4-9.1	MS,ws,ns	1.765	0.424	0.63	0.39	>10	0.3
	NH-46	NH-46-01	8	0-4	MS,mws,c-s	1.180	0.665	0.09	0.61	2.25	
		NH-46-02		4-8	CS,ms,sc-s	0.975	0.782	-0.09	0.72	1.4	
	NH-47	NH-47-01	8.3	0-4	CS,ms,c-s	0.969	0.780	-0.10	0.72	1.25	0.9
		NH-47-02		4-8.3	MS,mws,sc-s	1.583	0.637	0.47	0.59	10	1.2
	NH-48	NH-48-01	7.8	0-3.6	MS,ms,c-s	1.205	0.709	0.12	0.65	2.25	1.1
		NH-48-02		3.6-6.7	CS,ms,c-s	0.915	0.811	-0.15	0.75	1.1	1.0
	NH-49	NH-49-01	8	0-2.8	CS,ms,sc-s	1.022	0.759	-0.05	0.70	1.49	0.9
		NH-49-02		2.8-8.0	MS,ms,c-s	1.367	0.717	0.27	0.66	3.25	3.1
	NH-50	NH-50-01	9.7	0-3	MS,ms,c-s	1.096	0.725	0.02	0.67	1.78	2.2
		NH-50-02		3-8.3	MS,ms,c-s	1.083	0.764	0.01	0.70	1.6	0.8
	NH-51	NH-51-01	6.3	0-0.8	MS,mws,c-s	1.722	0.643	0.59	0.59	>10	1.4
		NH-51-02		0.8-5.2	CS,ps,c-s	0.851	0.928	-0.21	0.85	<1.02	4
	NH-52	NH-52-01	9.7	0-4.3	CS,ps,sc-s	0.883	0.807	-0.18	0.74	1.15	
		NH-52-02		4.3-9.7	MS,ws,ns	1.875	0.427	0.73	0.39	>10	
	NH-53	NH-53-01	9.6	0-3.4	MS,ms,sc-s	1.294	0.763	0.20	0.70	2.5	1.6
		NH-53-02		3.4-9.6	FS,ms,sc-s	2.121	0.832	0.96	0.77	>10	13.8
	NH-54	NH-54-01	9.6	0-1.6	MS,ms,sc-s	1.049	0.806	-0.03	0.74	1.25	
		NH-54-02		1.6-8.5	MS,mws,c-s	1.592	0.589	0.47	0.54	>10	
	NH-55	NH-55-01	9.5	0-2	VC,ps,c-s	0.406	0.727	-0.62	0.67	<1.02	14.3
		NH-55-02		2-4	CS,ps,sc-s	0.683	0.769	-0.36	0.71	1.05	6.1
		NH-55-03		4-6.2	VC,ps,sc-s	0.497	0.762	-0.53	0.70	<1.02	2.7
		NH-55-04		6.2-7	CS,ms,c-s	1.001	0.734	-0.07	0.68	1.49	0.8
		NH-55-05		7-8.6	CS,ps,c-s	0.528	0.815	-0.51	0.75	<1.02	1.1
		NH-55-06		8.6-9.5	MS,mws,c-s	1.533	0.639	0.42	0.59	1.05	6.1
	NH-56	NH-56-01	8.7	0-4	CS,ps,sc-s	0.876	0.920	-0.19	0.85	1.02	5.4
		NH-56-02		4-5.6	VC,vps,sc-s	0.693	0.892	-0.35	0.82	<1.02	2.1
		NH-56-03		5.6-6.4	VC,vps,sc-s	1.265	1.103	0.17	1.02	1.25	0.8
		NH-56-04		6.4-8.7	MS,ps,sc-s	1.667	0.833	0.54	0.77	4.5	0.9
	NH-57	NH-57-01	9.4	0-3.3	CS,ms,sc-s	0.782	0.718	-0.27	0.66	1.15	0.6
		NH-57-02		3.3-7	MS,mws,c-s	1.157	0.635	0.07	0.58	2.8	0.8
		NH-57-03		7-9.4	MS,ms,c-s	1.211	0.699	0.12	0.64	2.5	1.5
	NH-58	NH-58-01	7.8	0-4.4	MS,ms,c-s	1.132	0.693	0.05	0.64	2.1	0.9
		NH-58-02		4.4-7.8	MS,mws,c-s	1.509	0.606	0.40	0.56	>10	1.5
	NH-59	NH-59-01	9	0-1.2	MS,mws,c-s	1.159	0.638	0.08	0.59	2.75	0.5
		NH-59-02		1.2-5	MS,mws,c-s	1.423	0.609	0.32	0.56	10	0.5
		NH-59-03		5-9	MS,mws,c-s	1.225	0.691	0.14	0.64	2.75	0.8
	NH-60	NH-60-01	6.9	0-3	MS,ws,c-s	1.518	0.523	0.41	0.48	>10	0.4
		NH-60-02		3-6.9	MS,ws,c-s	1.625	0.477	0.50	0.44	>10	1.3

TABLE 6. Nags Head sediment compatibility. [Page 3 of 3]

Scenario 2: ***Revised Overfill Ratios Based On Using NC-CRC Draft Sampling Portocols for Native Beach***
(ie, all beach samples composited)

MzNative= **1.465** **phi** ***(.362 mm)***
StdDevNat= **1.091** **phi** ***(.469 mm)***

Borrow Area	Core ID	Sample Number	Recovery Length (ft)	Interval (ft)	Sediment Description**	Moment Measures M-phi-b	Moment Measures Sigma-b	X (Mb-Mn)/SDn	Y (SDb/SDn)	Overfill Ratio (R_A) On Comp69	Overfill Ratio (R_A) On Comp All	% Carbonate
Sub Group		NH-20-01	10.4	0-3	CS,ps,sc-s	1.013	0.855	-0.41	0.78	1.25	**1.00**	0.8
North	NH-22	NH-22-01	9.7	0-2.1	CS,ps,sc-s	0.665	0.759	-0.73	0.70	1.05	**1.00**	3.0
Central	NH-24	NH-24-01	9.3	0-3	CS,ms,sc-s	0.960	0.759	-0.46	0.70	1.24	**1.00**	1.3
South	NH-26	NH-26-01	8.6	0-4	MS,ps,sc-s	1.048	0.789	-0.38	0.72	1.49	**1.00**	4.0
	NH-28	NH-28-01	9.2	0-1.2	MS,ps,sc-s	1.152	0.830	-0.29	0.76	1.02	**1.02**	1.5
	NH-30	NH-30-01	8.6	0-3	MS,ms,c-s	1.051	0.768	-0.38	0.70	1.49	**1.00**	1.2
	NH-31	NH-31-01	8.5	0-2.7	CS,ps,sc-s	0.717	0.843	-0.69	0.77	1.24	**1.00**	1.0
	NH-5	NH-5-01	7.4	0-4	MS,ms,c-s	1.060	0.772	-0.37	0.71	1.02	**1.02**	0.4
	NH-11	NH-11-01	10	0-3.3	CS,ms,c-s	0.724	0.770	-0.68	0.71	1.03	**1.00**	1.1
	NH-12	NH-12-01	9.3	0-3.1	CS,ms,c-s	0.838	0.744	-0.57	0.68	1.10	**1.00**	2.9
	NH-14	NH-14-01	9.1	0-5	CS,ms,c-s	0.927	0.804	-0.49	0.74	1.15	**1.00**	2.3
	NH-43	NH-43-01	9.6	0-2.7	CS,ms,sc-s	0.907	0.758	-0.51	0.69	1.24	**1.00**	
	NH-44	NH-44-01	11.4	0-3	CS,ms,c-s	0.969	0.755	-0.45	0.69	1.25	**1.00**	0.9
	NH-45	NH-45-01	9.1	0-4	MS,ms,c-s	1.065	0.711	-0.37	0.65	1.74	**1.03**	0.6
	NH-46	NH-46-01	8	0-4	MS,mws,c-s	1.180	0.665	-0.26	0.61	2.25	**1.24**	
	NH-47	NH-47-01	8.3	0-4	CS,ms,c-s	0.969	0.780	-0.45	0.71	1.25	**1.00**	0.9
	NH-48	NH-48-01	7.8	0-3.6	MS,ms,c-s	1.205	0.709	-0.24	0.65	2.25	**1.12**	1.1
	NH-49	NH-49-01	8	0-2.8	CS,ms,sc-s	1.022	0.759	-0.41	0.70	1.49	**1.00**	0.9
	NH-52	NH-52-01	9.7	0-4.3	CS,ps,sc-s	0.883	0.807	-0.53	0.74	1.15	**1.00**	
	NH-54	NH-54-01	9.6	0-1.6	MS,ms,sc-s	1.049	0.806	-0.38	0.74	1.25	**1.00**	
	NH-55	NH-55-01	9.5	0-2	VC,ps,c-s	0.406	0.727	-0.97	0.67	1.00	**1.00**	14.3
	NH-56	NH-56-01	8.7	0-4	CS,ps,sc-s	0.876	0.920	-0.54	0.84	1.02	**1.00**	5.4
	NH-57	NH-57-01	9.4	0-3.3	CS,ms,sc-s	0.782	0.718	-0.63	0.66	1.15	**1.00**	0.6
									Averages	**1.31**	**1.02**	

***CS-Coarse Sand; MS-Medium Sand; FS-fine sand*
ms-moderately sorted; mws-moderately well sorted; ws-well sorted; ps-poorly sorted
c-s coarse skewed; sc-s strongly coarse skewed; f-s fine skewed; sym - symmetrical size distribution
** These samples have a limiting acceptable depth for excavation based on recovered cores*
(ie. Underlying material is considered less suitable for nourishment).

As the list at the bottom of Table 6 shows, the average R_A for samples in the subgroups is 1.31 when comparing against native "Comp 69". This same subgroup of samples was compared against "Comp All 110" to obtain alternate R_A's. The result in Table 6 (bottom) shows an average R_A equals 1.02 when the select group is compared against the native composite derived using the draft NC CRC (2005) criteria. In simple terms, the subgroup samples compare very well with the native beach using either the NC CRC criteria or CSE's compatibility criteria.

Oregon Inlet sediment was found to be significantly finer than the native beach. Table 7 shows that 14 of 21 samples had a mean grain size of less than 0.31 mm. When compared against a native mean grain size of 0.36 or 0.47, the Oregon Inlet sediments were found to have high R_A's (>7.0). This means that at least seven times more sediment would be required to yield the same performance as sediments with R_A's $\cong$1.0.

TABLE 7. Nags Head sediment compatibility comparing Oregon Inlet sediment with the native beach (using draft NC CRC criteria – "Comp 110").

Overfill Ratios Based On Native Beach Equals Composite of All Samples (Comp 110)						MzNative=	1.465	phi *(0.362 mm)*
						StdDevNat=	1.091	phi *(0.469 mm)*
Borrow	**Core**	**Sample**	**Sediment**	**Moment Measures**		**X**	**Y**	**Overfill Ratio (R_A)**
Area	**ID**	**Number**	**Description****	**M-phi-b**	**Sigma-b**	**(Mb-Mn)/SDn**	**(SDb/SDn)**	(R_A) on Comp 110
Oregon Inlet	**OR-1**	N/A	MS,ps,sc-s	1.252	0.812	-0.20	0.74	**1.24**
Channel	**OR-2**	N/A	MS,ws,ns	1.672	0.421	0.19	0.39	**>10**
Spit	**OR-3**	N/A	FS,ws,c-s	2.113	0.493	0.59	0.45	**>10**
& Pea Island	**OR-4**	N/A	CS,vps,sc-s	1.687	1.118	0.20	1.02	**1.2**
	OR-5	N/A	CS,ps,c-s	0.540	0.788	-0.85	0.72	**1.02**
	OR-6	N/A	FS,vws,ns	2.377	0.334	0.84	0.31	**>10**
	OR-7	N/A	FS,ws,c-s	2.103	0.516	0.58	0.47	**>10**
	OR-8	N/A	MS,ms,ns	1.479	0.733	0.01	0.67	**1.7**
	OR-9	N/A	FS,mws,c-s	1.974	0.576	0.47	0.53	**>10**
	OR-10	OR-10-A	FS,vws.f-s	2.015	0.367	0.50	0.34	**>10**
		OR-10-B	FS,vws,f-s	2.037	0.348	0.52	0.32	**>10**
		OR-10-C	FS,ws,f-s	2.139	0.441	0.62	0.40	**>10**
	OR-11	OR-11-A	FS,ws,ns	2.495	0.451	0.94	0.41	**>10**
		OR-11-B	FS,vws.ns	2.163	0.366	0.64	0.34	**>10**
		OR-11-C	FS,vws,f-s	2.047	0.371	0.53	0.34	**>10**
	OR-12	OR-12-A	MS,ms.sc-s	1.413	0.875	-0.05	0.80	**1.24**
		OR-12-B	MS,mws,ns	1.626	0.534	0.15	0.49	**5.0**
		OR-12-C	MS,mws,ns	1.333	0.613	-0.12	0.56	**2.0**
	OR-13	OR-13-A	MS,ws,ns	1.691	0.495	0.21	0.45	**>10**
		OR-13-B	MS,ws,ns	1.824	0.446	0.33	0.41	**>10**
		OR-13-C	MS,mws,c-s	1.848	0.543	0.35	0.50	**>10**
							Average	**>7.0**

A measure of the difference in grain size distribution among selected groups of borrow and native samples is given in Figures 28 and 29.

Figure 28 compares the NC CRC-criteria native (Comp 110) against area S1 (subgroups N, C, S – composite) and native Comp 110 against Oregon Inlet sediments (Comp 21). The comparison shows that area S1 subgroup (Group 23) would be significantly coarser but would contain less gravel than the native beach. Borrow sediment from area S1 under this criteria would tend to be stable and would provide a wider recreational beach.

Figure 28 (right) compares Oregon Inlet with the NC CRC-criteria native. In this case, mean grain size (d_{50}) is similar but finer than native. Significantly, a major part of the size distribution curve falls under the native in the coarse sand range. This means that Oregon Inlet would be less stable for nourishment and would result in a narrower dry beach for a given volume of fill. R_A's for Oregon Inlet sediment are in the unacceptable range for 80 percent of the samples, because the sediments tend to be well sorted (poorly graded) and lack the coarse fraction that would make them more compatible with the native beach.

Figure 29 compares area S1 (subgroup 23) and Oregon Inlet sediments against CSE's native beach (Comp 69). In this case (Fig 29, left), area S1 (subgroups N, C, S) provide a fairly close match with native (Comp 69). Parameter d_{50} is nearly equal for native and borrow, and the proportion of coarse material closely matches.

Figure 29 (right), comparing Oregon Inlet sediment with CSE Comp 69, shows a large difference in d_{50}'s. The native beach (Comp 69) is nearly 1.0 phi unit coarser than Oregon Inlet sediment. More importantly, only a small fraction of the Oregon Inlet sediment is coarse. [Note how each red line in Figure 29 (lower) falls well below the corresponding curve for native (Comp 69).] This supports CSE's finding from the analysis of R_A's that much more Oregon Inlet sand would be required to provide the same performance as area S1.

Kana and Mohan (1998) documented the role of the coarse fraction of a borrow material on nourishment longevity. A coarse-skewed size distribution such as area S1 (subgroup 23) can increase fill longevity by 25 percent or greater as was the case for a project at Hunting Island (SC).

Given the size of area S1, there are many potential subareas that could provide sufficient nourishment volume. These preliminary results using one subgroup (Comp 23) simply indicate the likelihood that offshore area S1 has areas that will provide a good match with the native beach. The results for Oregon Inlet, while cursory, suggest that these sediments would likely perform poorly as nourishment along Nags Head.

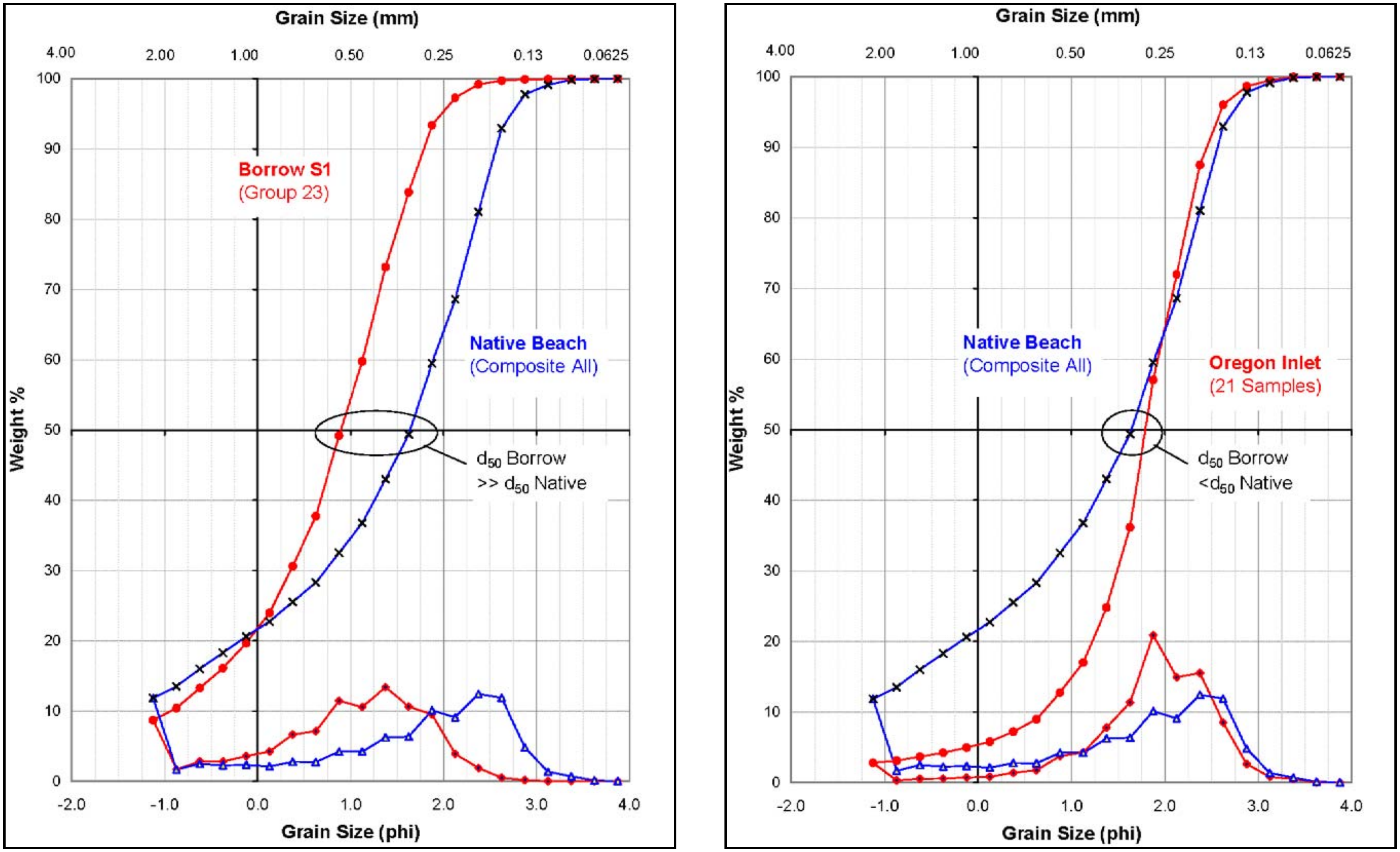
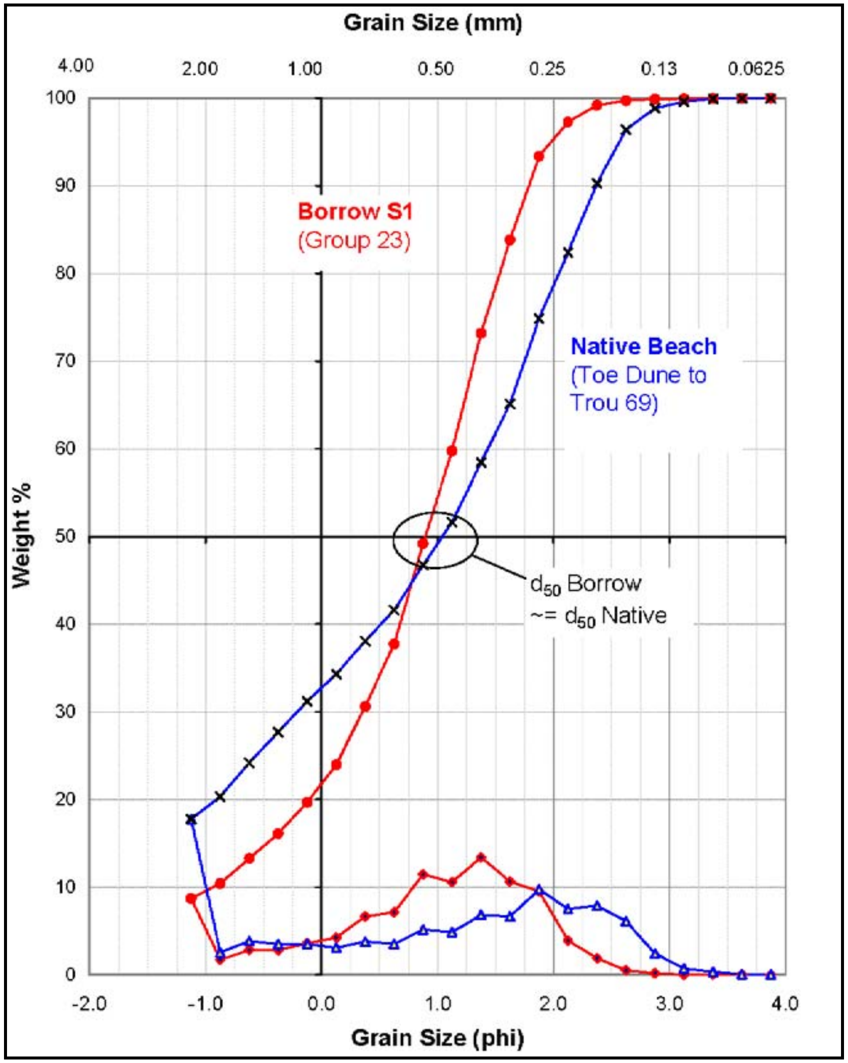


FIGURE 28. [LEFT] Comparison of borrow area S1 (subgroup 23) composite versus Nags Head native beach (Comp 110) (ie, NC CRC native criteria). [RIGHT] Comparison of Oregon Inlet sediments versus native (Comp 110).



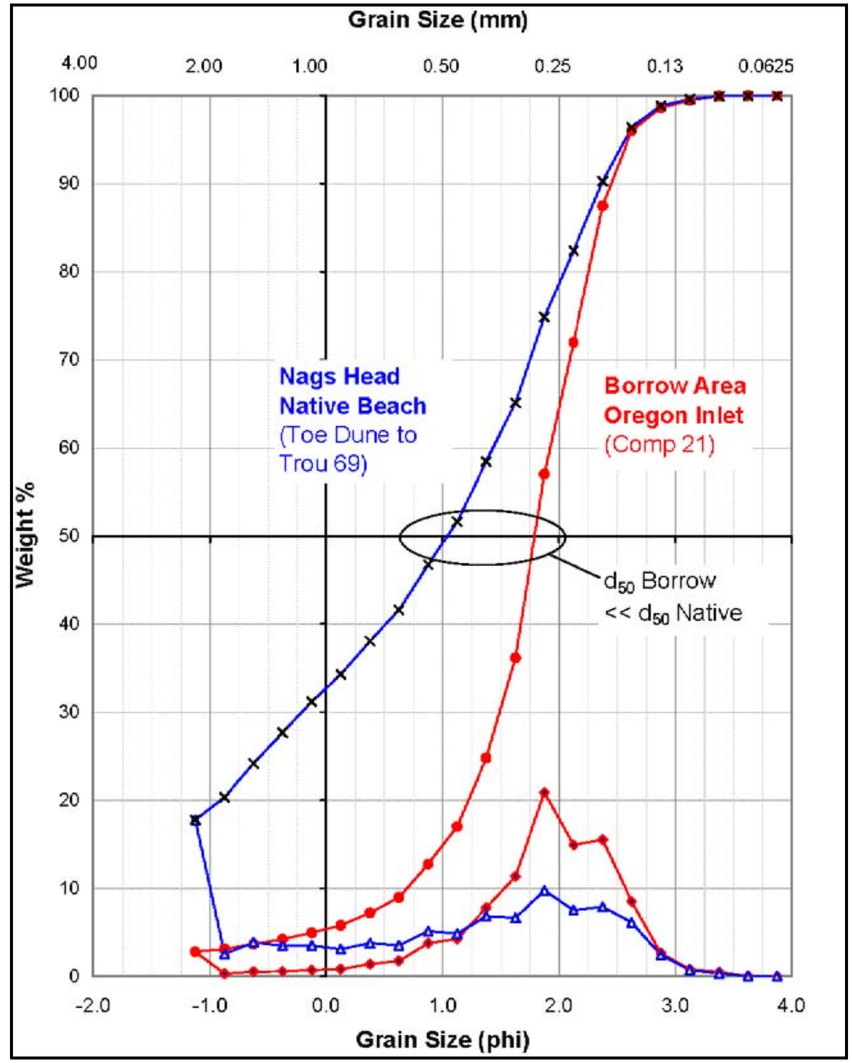


FIGURE 29. [LEFT] Comparison of borrow area S1 (subgroup 23) composite versus Nags Head native beach (Comp 69) (ie, CSE recommended criteria). [RIGHT] Comparison of Oregon Inlet sediments versus native (Comp 69).