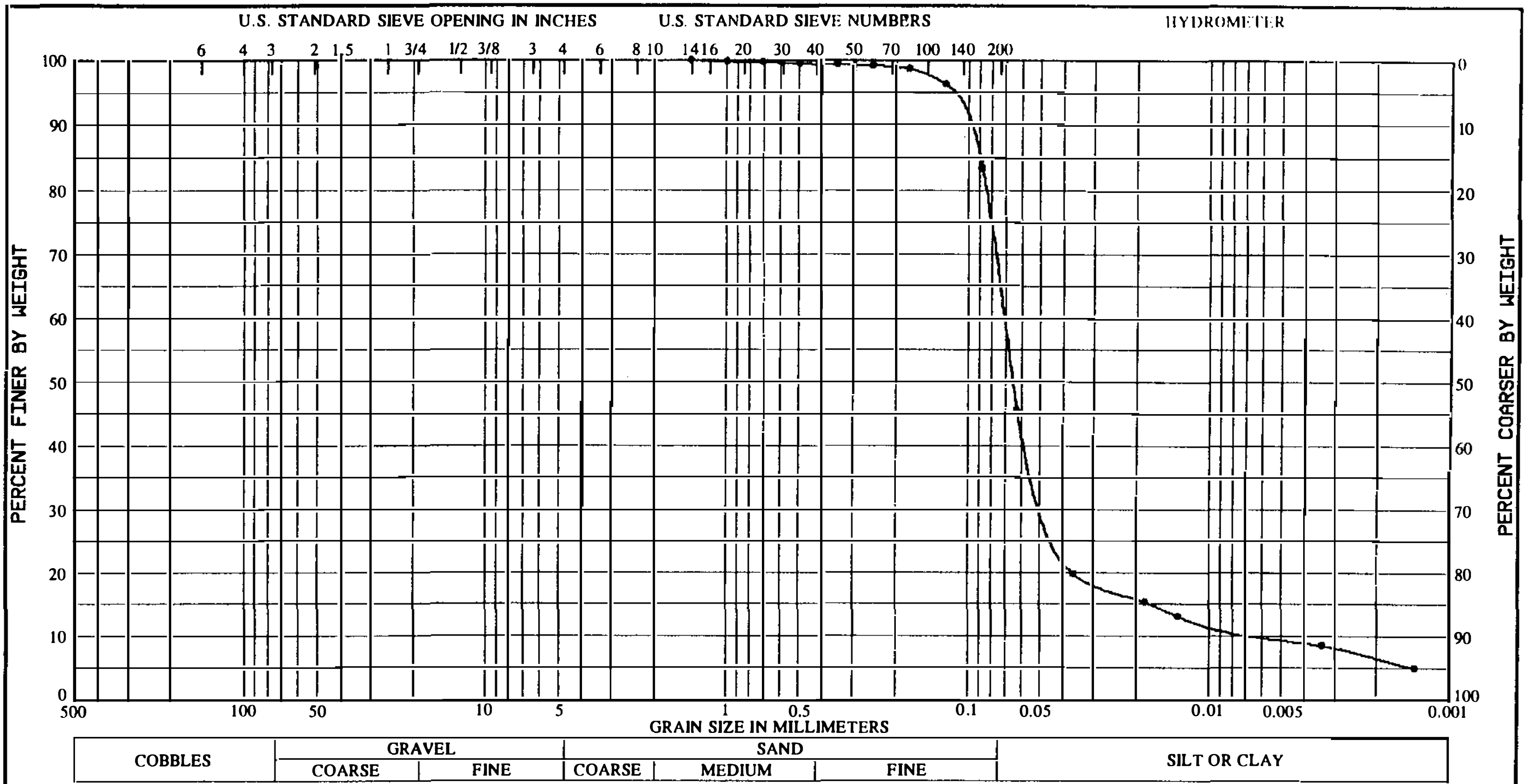
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



Sample No.	Depth	Classification	Nat w%	LL	PL	PI
D-1	2.0-2.5'	(VISUAL) GRAY, SANDY INORGANIC SILT	36.4			
		LOW LL (ML).				
		SP. GRAVITY = 2.67				
		WET DENSITY = 109.0 PCF.				
		DRY DENSITY = 79.9 PCF.				

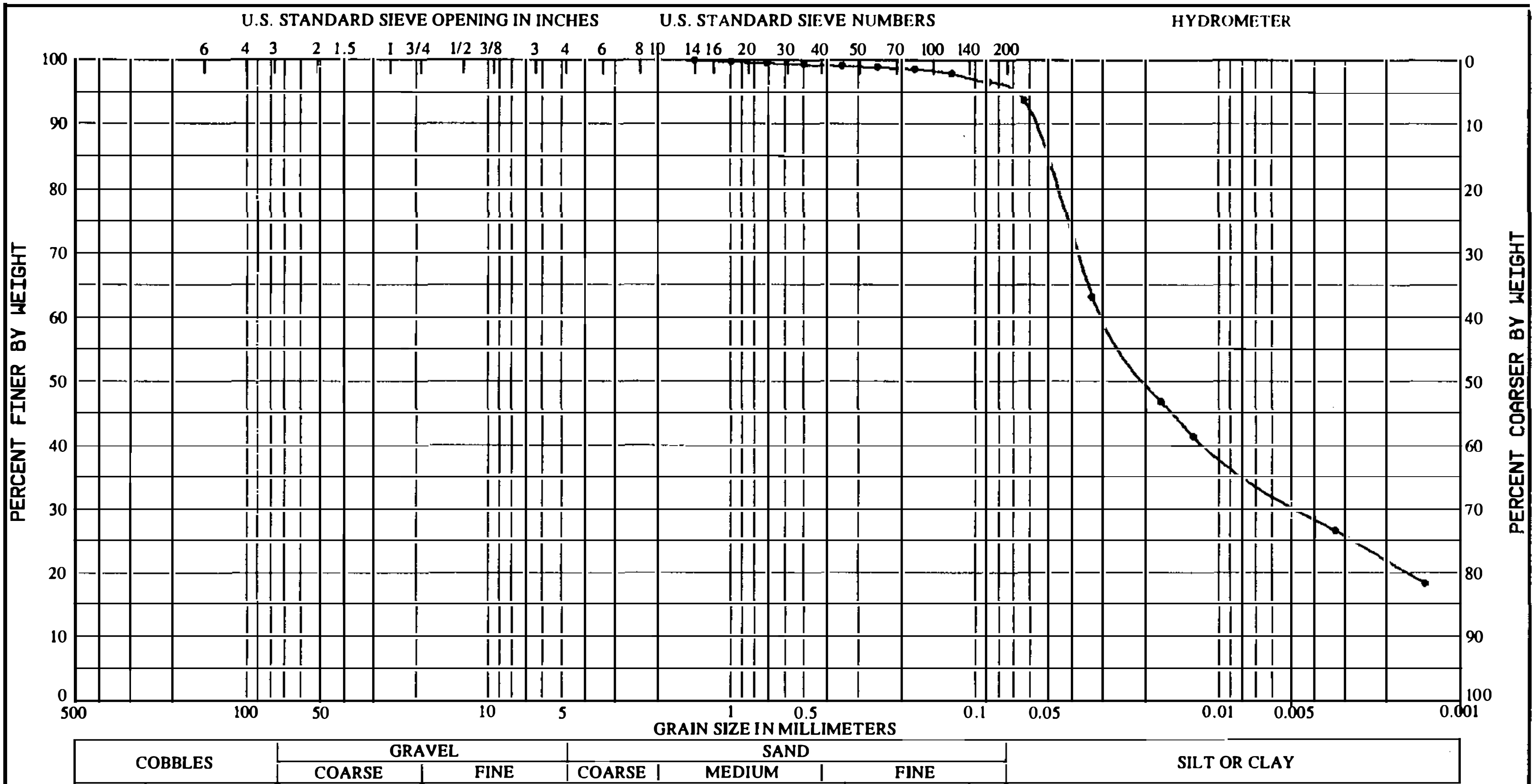
Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/936
Boring No. KAV-29
Date 02/07/95

GRADATION CURVES

108

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



Sample No.	Depth	Classification	Nat w%	LL	PL	PI
D-2	7.6-8.1'	(VISUAL) GRAY, FAT CLAY (CH), WITH A	63.5			
		TRACE OF SAND SIZES.				
		SP. GRAVITY = 2.62				
		WET DENSITY = 99.6 PCF.				
		DRY DENSITY = 61.0 PCF.				

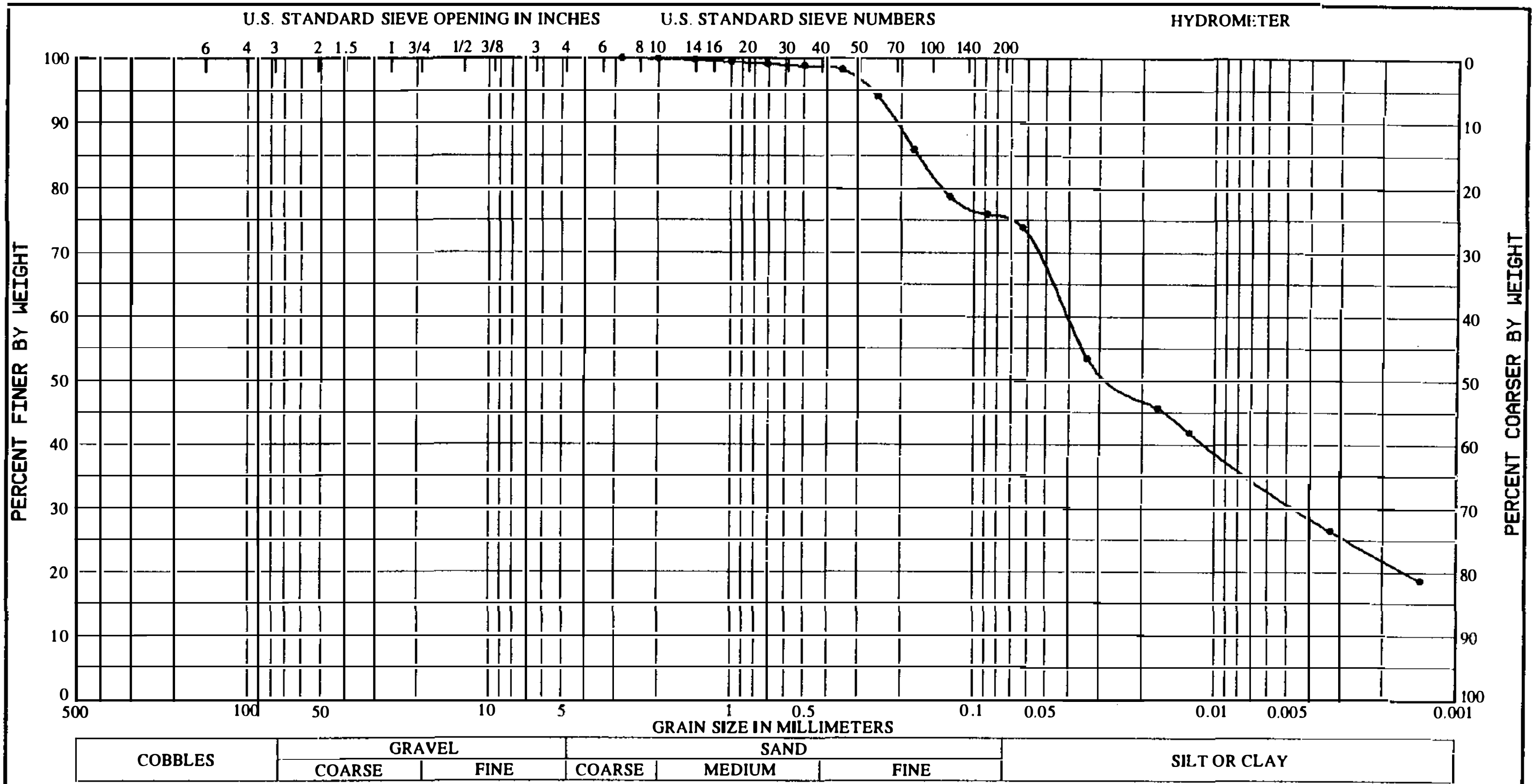
Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/936
Boring No. KAV-29
Date 02/07/95

GRADATION CURVES

109

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



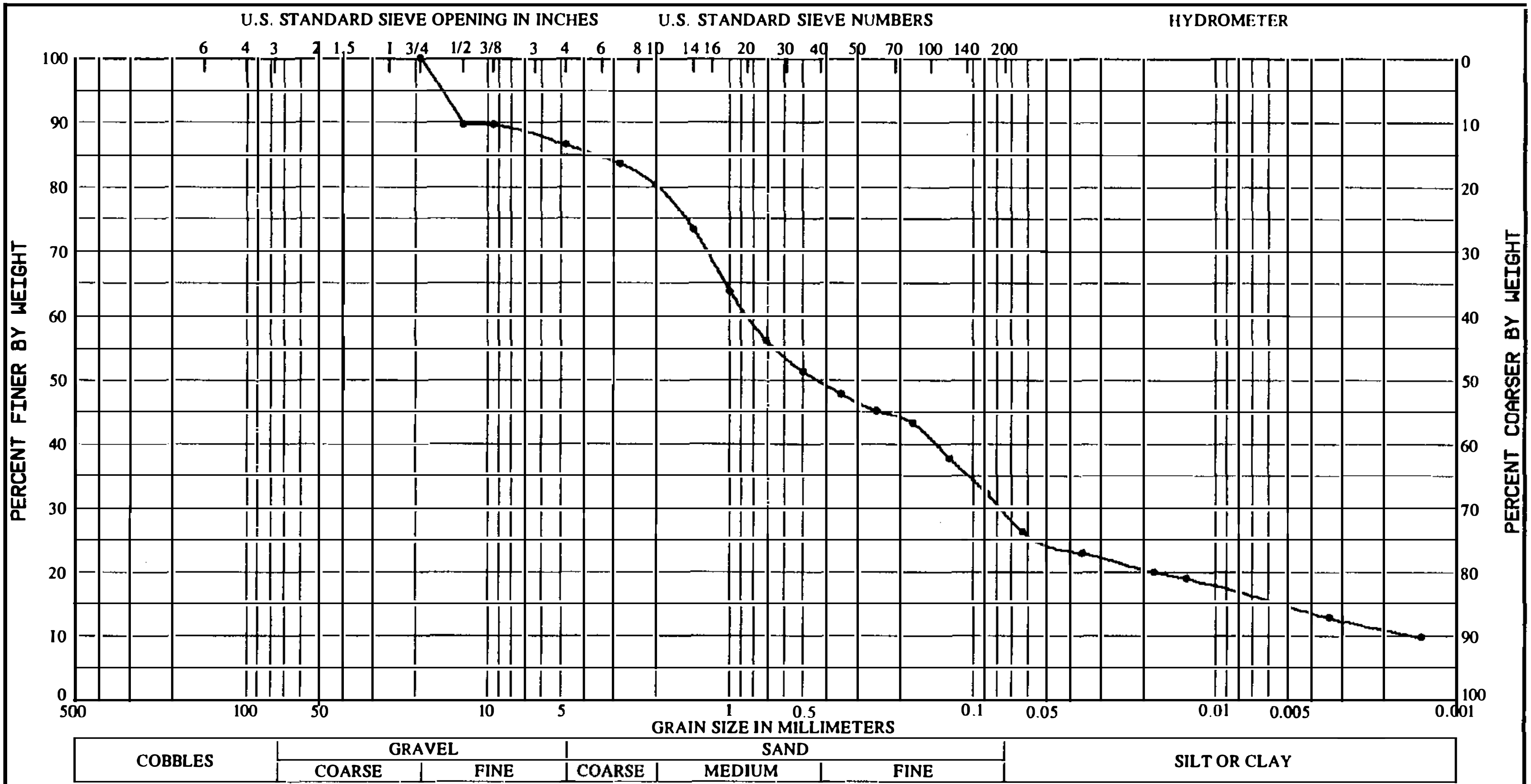
Sample No.	Depth	Classification	Nat w%	LL	PL	PI
D-3	13.6-14.1'	(VISUAL) GRAY, FAT CLAY (CH), WITH	55.1			
		SOME SAND SIZES.				
		SP. GRAVITY = 2.60				
		WET DENSITY = 101.3 PCF.				
		DRY DENSITY = 65.3 PCF.				

Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/936
Boring No. KAV-29
Date 02/07/95

GRADATION CURVES

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



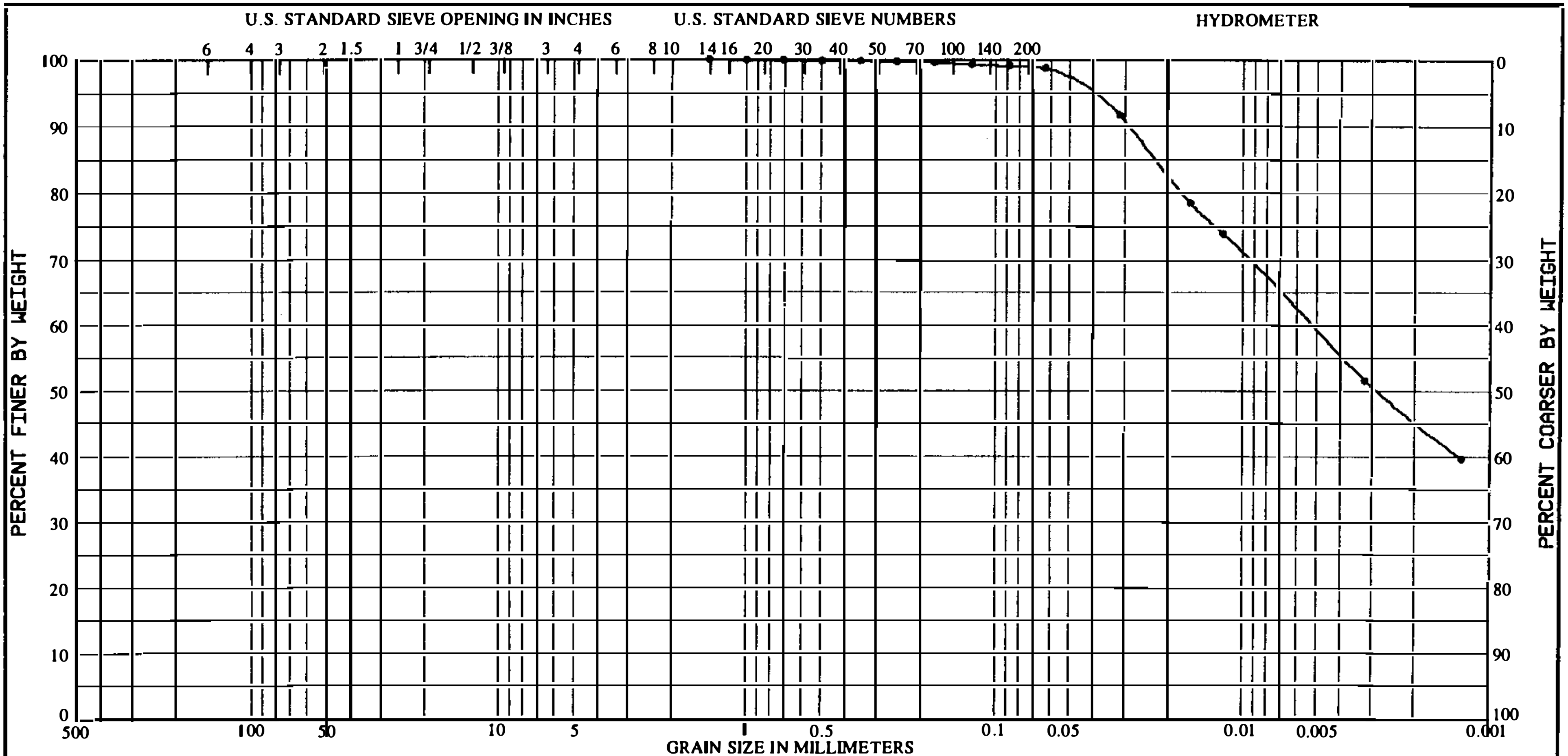
Sample No.	Depth	Classification	Nat w%	LL	PL	PI
A	4.0-4.3'	(VISUAL) GRAY, CLAYEY SAND (SC), WITH A LITTLE GRAVEL SIZES.				

Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/936A
Boring No. KAV-29
Date 02/08/95

GRADATION CURVES

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

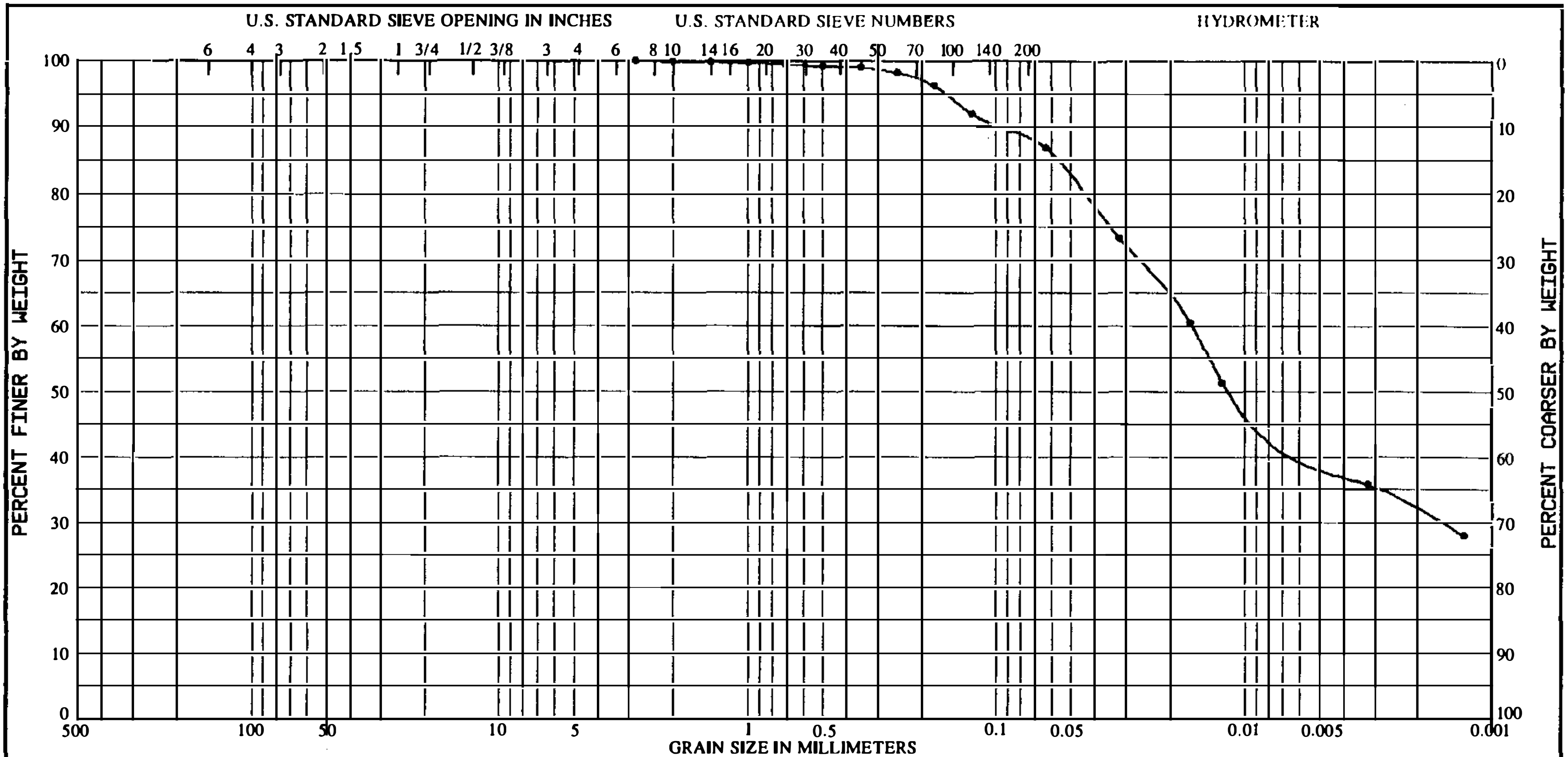
Sample No.	Depth	Classification	Nat w %	LL	PL	PI
B	6.7-6.9'	(VISUAL) FAT CLAY (CH), WITH A TRACE OF SAND SIZES.				

Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/936B
Boring No. KAV-29
Date 02/08/95

GRADATION CURVES

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Depth	Classification	Nat w%	LL	PL	PI
C	11.0-11.3'	(VISUAL) GRAY, FAT CLAY (CH), WITH A LITTLE SAND SIZES.				

Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/936C
Boring No. KAV-29
Date 02/08/95

GRADATION CURVES

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DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

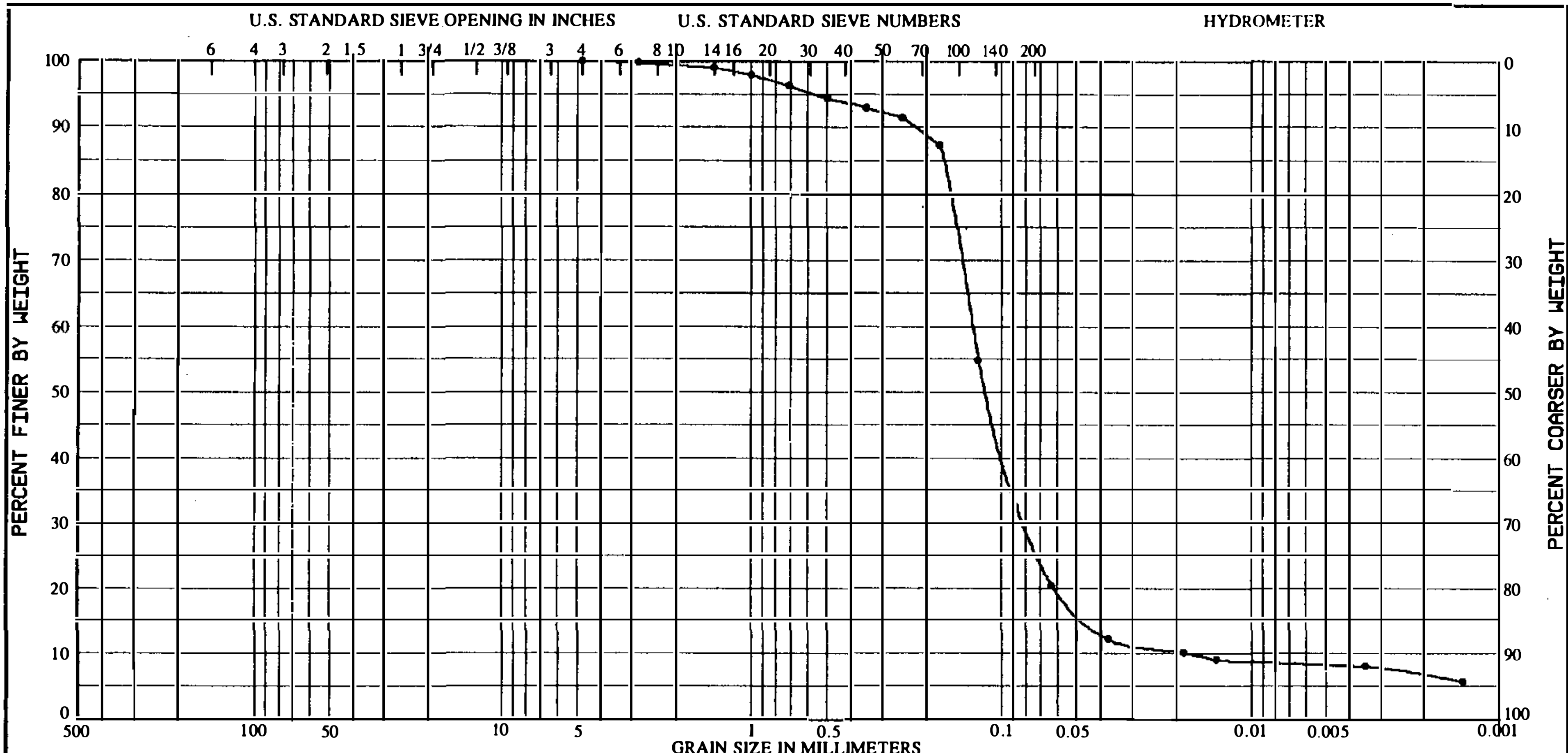
Project: *DELAWARE BAY*		Boring No. *KAV-32*
Location: *VIBRA CORE SAMPLES*		Lab No. *184/939*
Boring Depth (ft): *15.40*	Elevation:	Work order: *7476*
Datum/Notes: *See grain size data on enclosed gradation curves.*		Requisition: *CENAP-95-707*

Elev. (feet)	Depth (feet)	Leg-end	Material Description	Comments
	1			
	2		BROWNISH GRAY, SILTY SAND (SM).	MA D-1 2.0 - 2.5' WET DEN = 122.3. DRY DENSITY = 98.4 MC = 24.4 %.
	3		--	
	4		BROWNISH GRAY, SILTY SAND (SM), WITH POCKETS AND LAYERS OF INORGANIC SILT LOW (ML).	MA (A) 4.1 - 4.4'
	5		--	
	6		BROWNISH GRAY, SILTY SAND (SM).	
	7			MA D-2 6.9 - 7.4' WET DEN = 113.3. DRY DEN = 81.3, MC = 39.4 %.
	8		--	
	9			SA (B) 8.9 - 9.6'
	10		LT. GRAY, POORLY GRADED SAND (SP), WITH SOME GRAVEL SIZES.	
	11			
	12		--	SA D-3 12.0 - 12.5' WET DEN = 135.4, DRY DEN = 122.7, MC = 10.3 %.
	13			
	14		TAN & LT. GRAY, POORLY GRADED SAND (SP), WITH A TRACE OF GRAVEL SIZES.	
	15		--	

Date: *02/21/95* **LABORATORY LOG AND SAMPLE DATUM** Sheet No. *1* of *1*

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Sample No.	Depth	Classification	Nat w%	LL	PL	PI
D-1	2.0-2.5'	(VISUAL) BROWNISH GRAY, SILTY SAND (SM).	24.4			
		SP. GRAVITY = 2.67				
		WET DENSITY = 122.3 PCF.				
		DRY DENSITY = 98.4 PCF.				

Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/939
Boring No. KAV-32
Date 02/15/95

GRADATION CURVES

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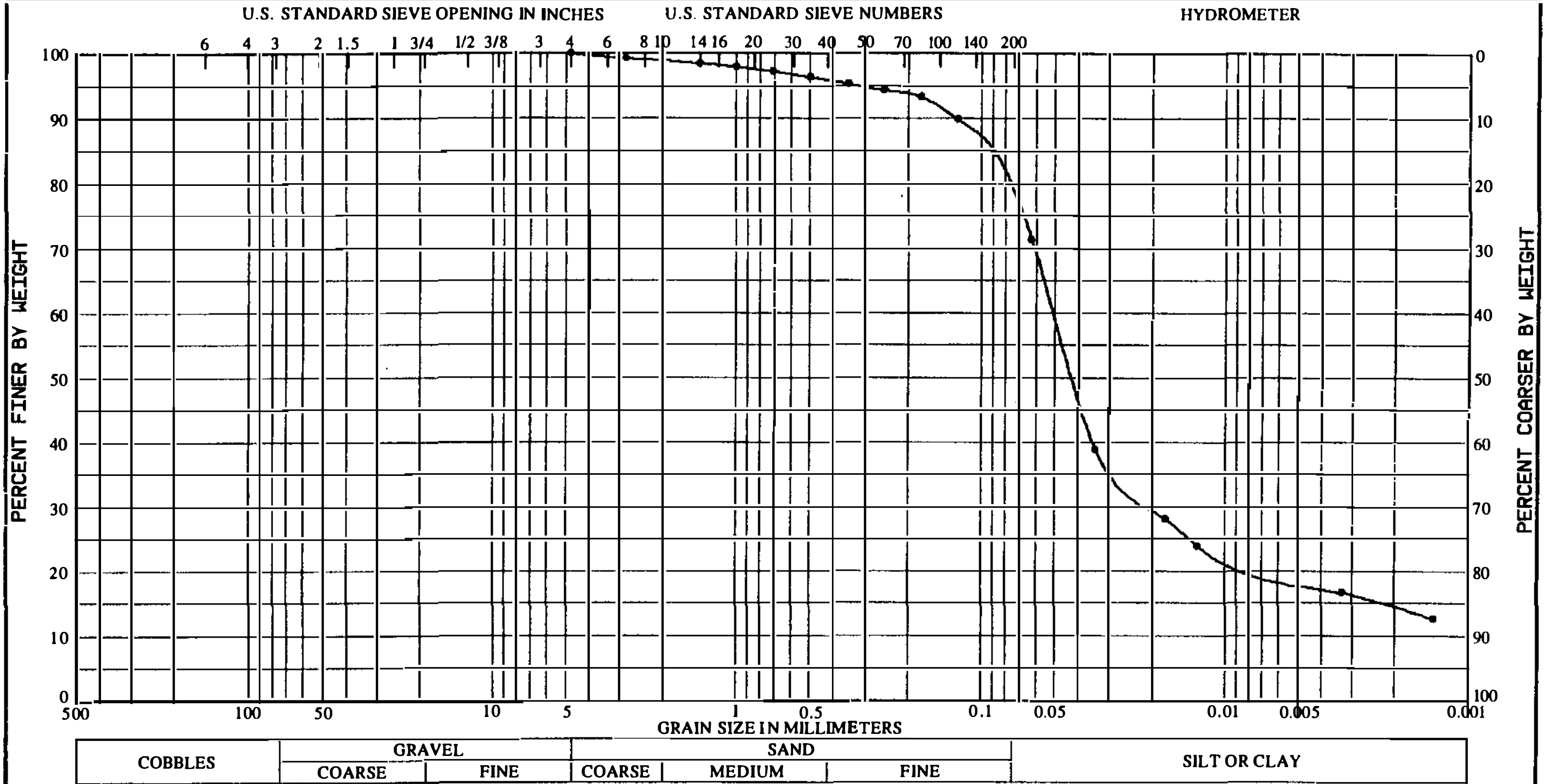
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



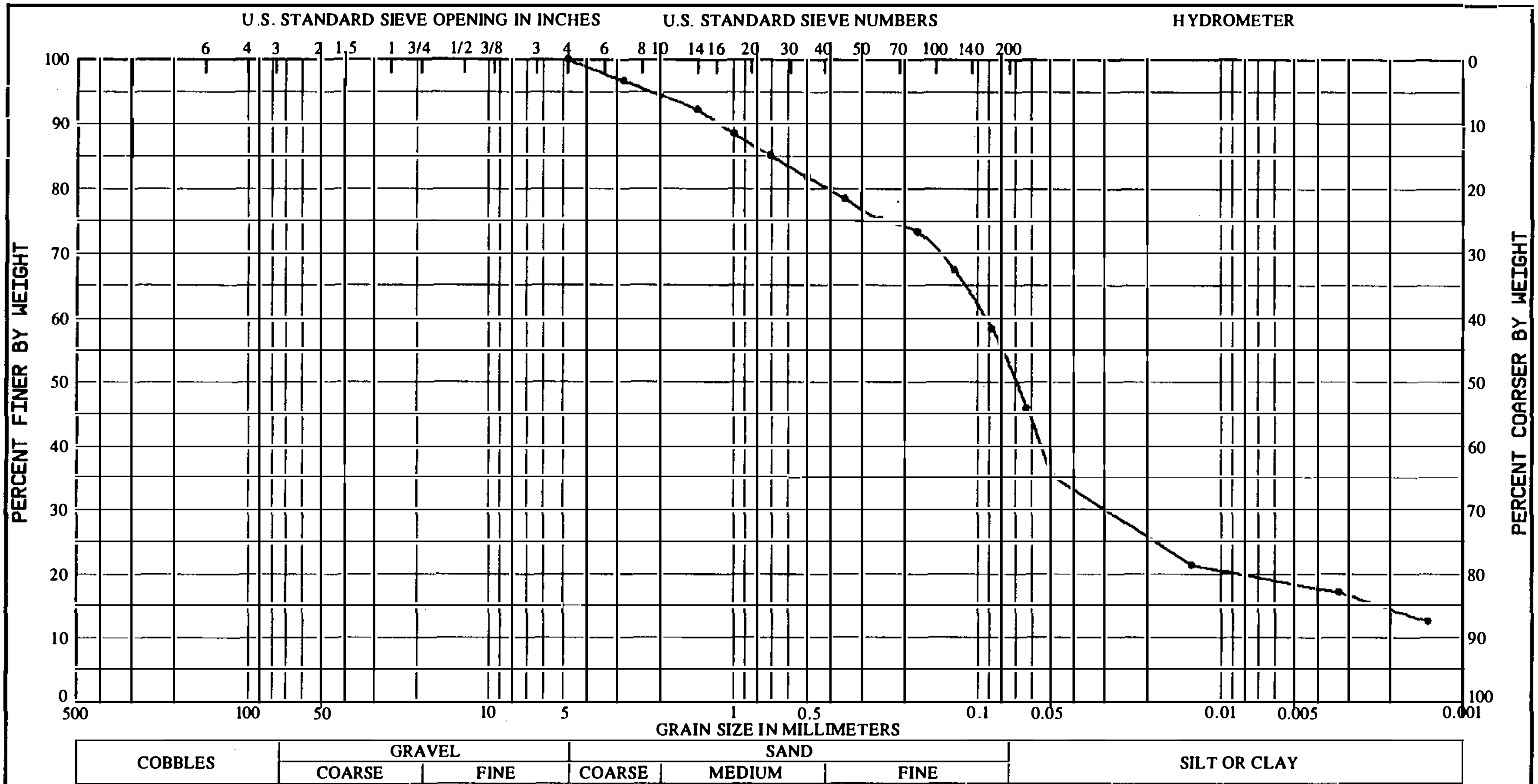
Sample No.	Depth	Classification	Nat w%	LL	PL	PI
A	4.1-4.4'	(VISUAL) BROWNISH GRAY, INORGANIC SILT				
		LOW LL (ML), WITH SOME SAND SIZES.				

Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/939A
Boring No. KAV-32
Date 02/15/95

GRADATION CURVES

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



Sample No.	Depth	Classification	Nat w%	LL	PL	PI
D-2	6.9-7.4'	(VISUAL) BROWNISH GRAY, SANDY INORGANIC	39.4			
		SILT LOW LL (ML).				
		SP. GRAVITY = 2.67				
		WET DENSITY = 113.3 PCF.				
		DRY DENSITY = 81.3 PCF.				

Project DELAWARE BAY
VIBRA CORE SAMPLES

Lab No. 184/939

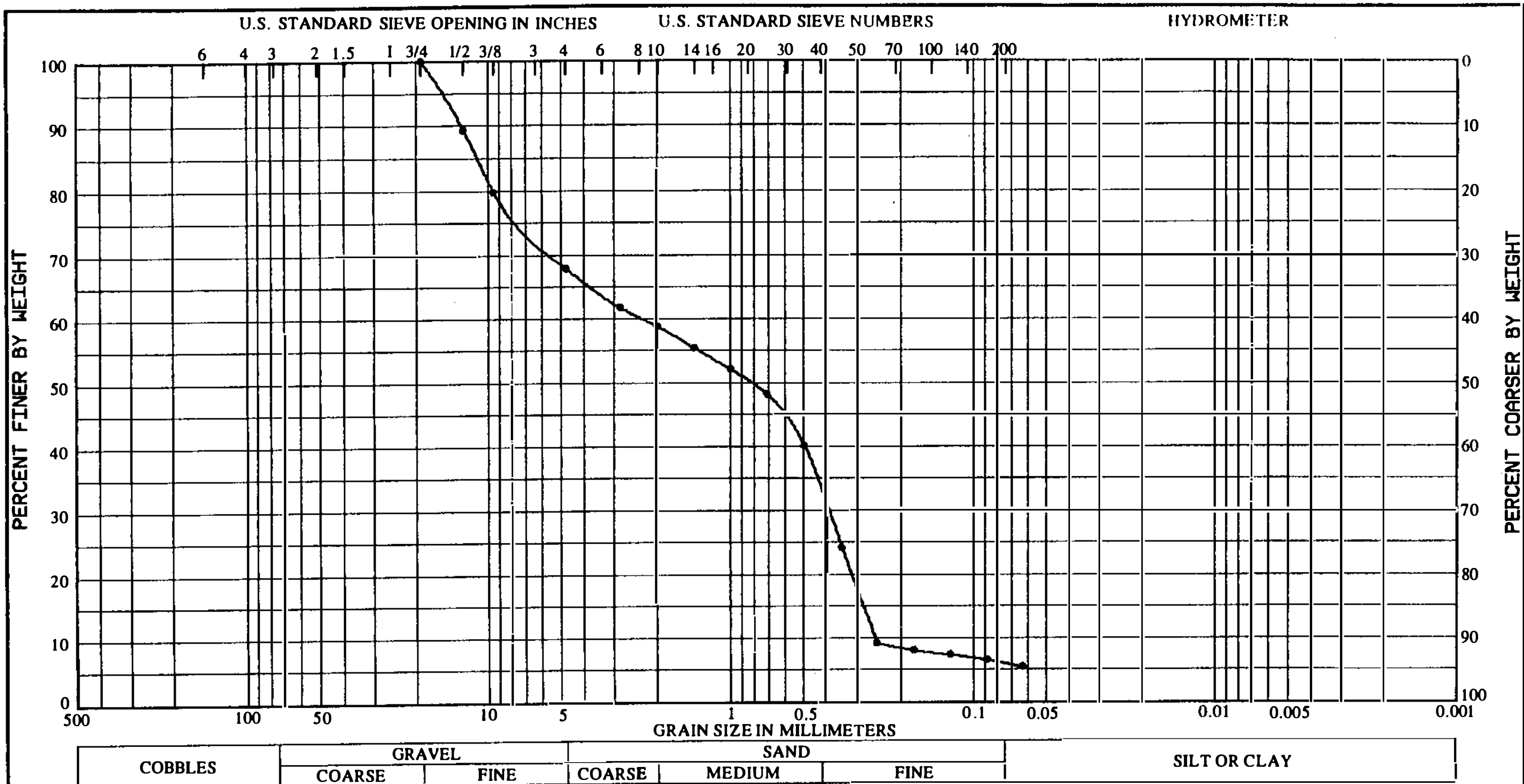
Boring No. KAV-32

Date 02/15/95

GRADATION CURVES

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



Sample No.	Depth	Classification	Nat w%	LL	PL	PI
B	8.9-9.6'	(VISUAL) LT. GRAY, POORLY GRADED SILTY SAND (SP-SM), WITH SOME GRAVEL SIZES.				

Project DELAWARE BAY
VIBRA CORE SAMPLES

Lab No. 184/939B

Boring No. KAV-32

Date 02/15/95

GRADATION CURVES

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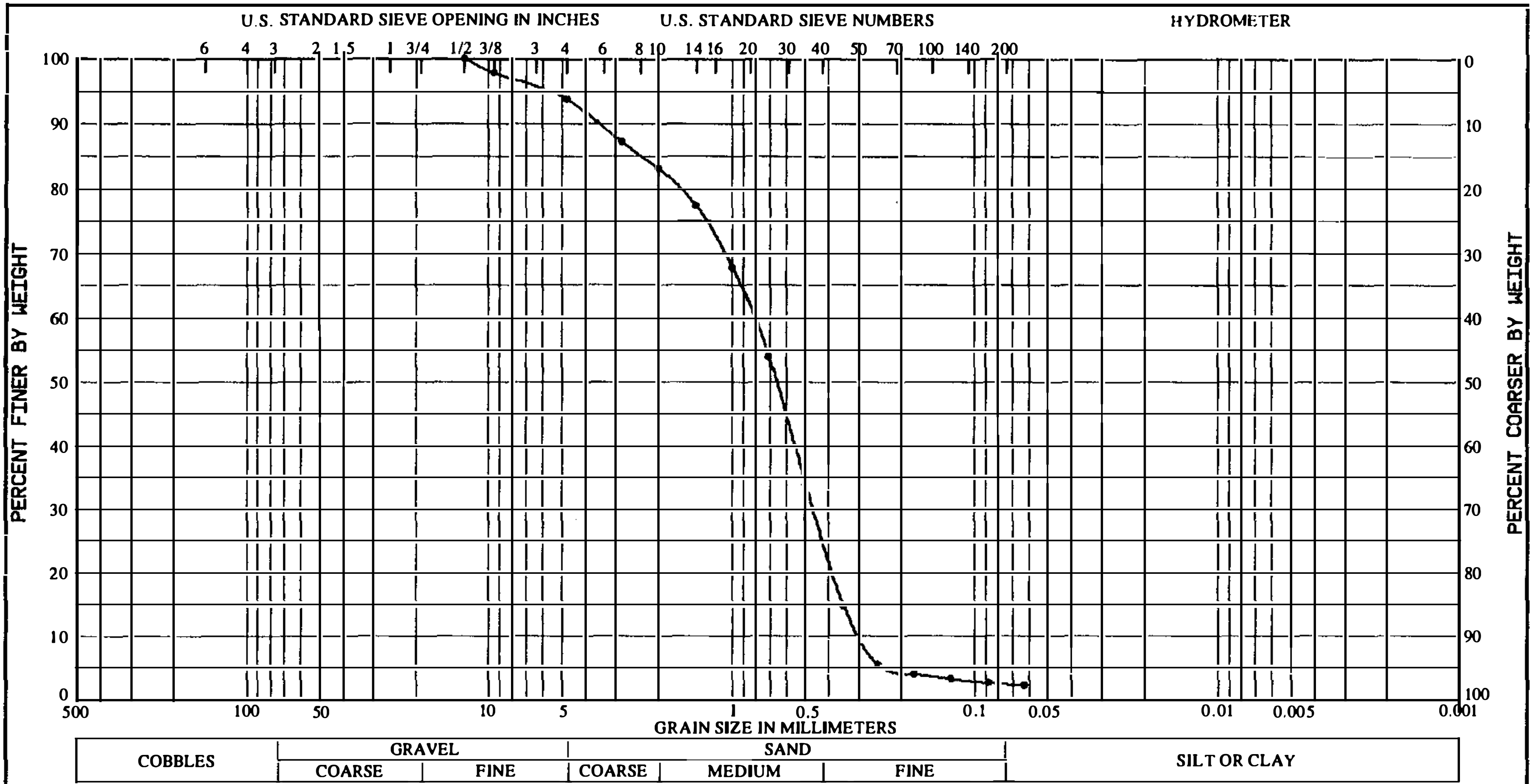
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE , MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



Sample No.	Depth	Classification	Nat w%	LL	PL	PI
D-3	12.0-12.5'	(VISUAL) TAN & LT. GRAY, POORLY GRADED	10.3			
		SAND (SP), WITH A TRACE OF GRAVEL SIZES.				
		SP. GRAVITY = 2.65				
		WET DENSITY = 135.4 PCF.				
		DRY DENSITY = 122.7 PCF.				

Project DELAWARE BAY
VIBRA CORE SAMPLES
Lab No. 184/939
Boring No. KAV-32
Date 02/15/95

GRADATION CURVES

Hole No.KAV-41

DRILLING LOG

DIVISION: North Atlantic	INSTALLATION: Philadelphia District — SHEET 1 OF 1
1. PROJECT: Broadkill Beach	10. SIZE AND TYPE OF BIT
2. LOCATION (EASTING AND NORTHING) *(or sta.)*: Easting=N 306,275 Northing=E 722,094	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
3. DRILLING AGENCY: TEI Oceanographic Services	12. MANUFACTURER'S DESIGNATION OF DRILL: Vibracore
4. HOLE NO. *(As shown on drawing title and file number)*: KAV-41	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: undisturbed:
5. NAME OF DRILLER	14. TOTAL NUMBER OF CORE BOXES
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 10-95 COMPLETED 10-95
7. THICKNESS OF BURDEN: 18.5 Ft.	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK: 0 Ft.	18. TOTAL CORE RECOVERY FOR BORIN
9. TOTAL DEPTH OF HOLE: 18.5 Ft.	19. SIGNATURE OF

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC ft	SAMPLE NUMBER	REMARKS
n/a	0.0					
	1.0		(SP-SM) Dark Gray medium SAND, Trace Fines			
	4.5		(SP) Dark Gray medium-to-coarse SAND			Note: Coordinates are NAD83 Delaware State Plane
	9.5		(SP) Dark Gray fine-to-medium SAND			
	11.5		(SP) Gray/Brown fine-to-medium SAND			
	15.0		(SP) Light Brown medium-to-coarse Gravelly SAND			
	18.5		(SP) Brown medium SAND			
			BOH @ 18.5 Soils are field visually classified and laboratory corrected in accordance with the Unified Soils Classification System.			

Scale: 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5

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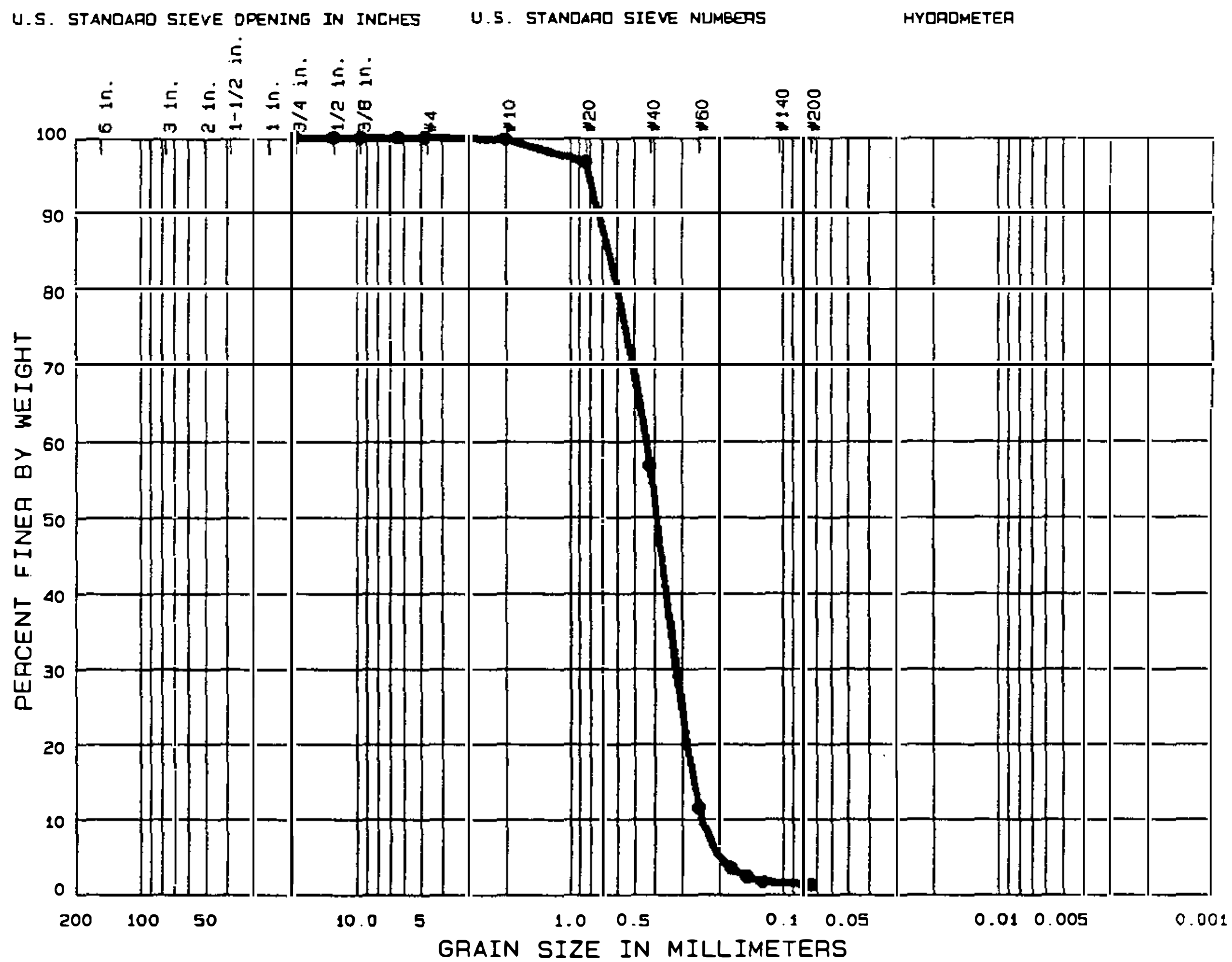
ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT	HOLE NUMBER
Broadkill Beach	KAV-41

W.O. No. Broadkill Beach
Req. No. KAV-41
Contract No. KAV-41



% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
● 0.0	0.0	98.7	1.3

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-1						0.96	1.8

CLASSIFICATION

●

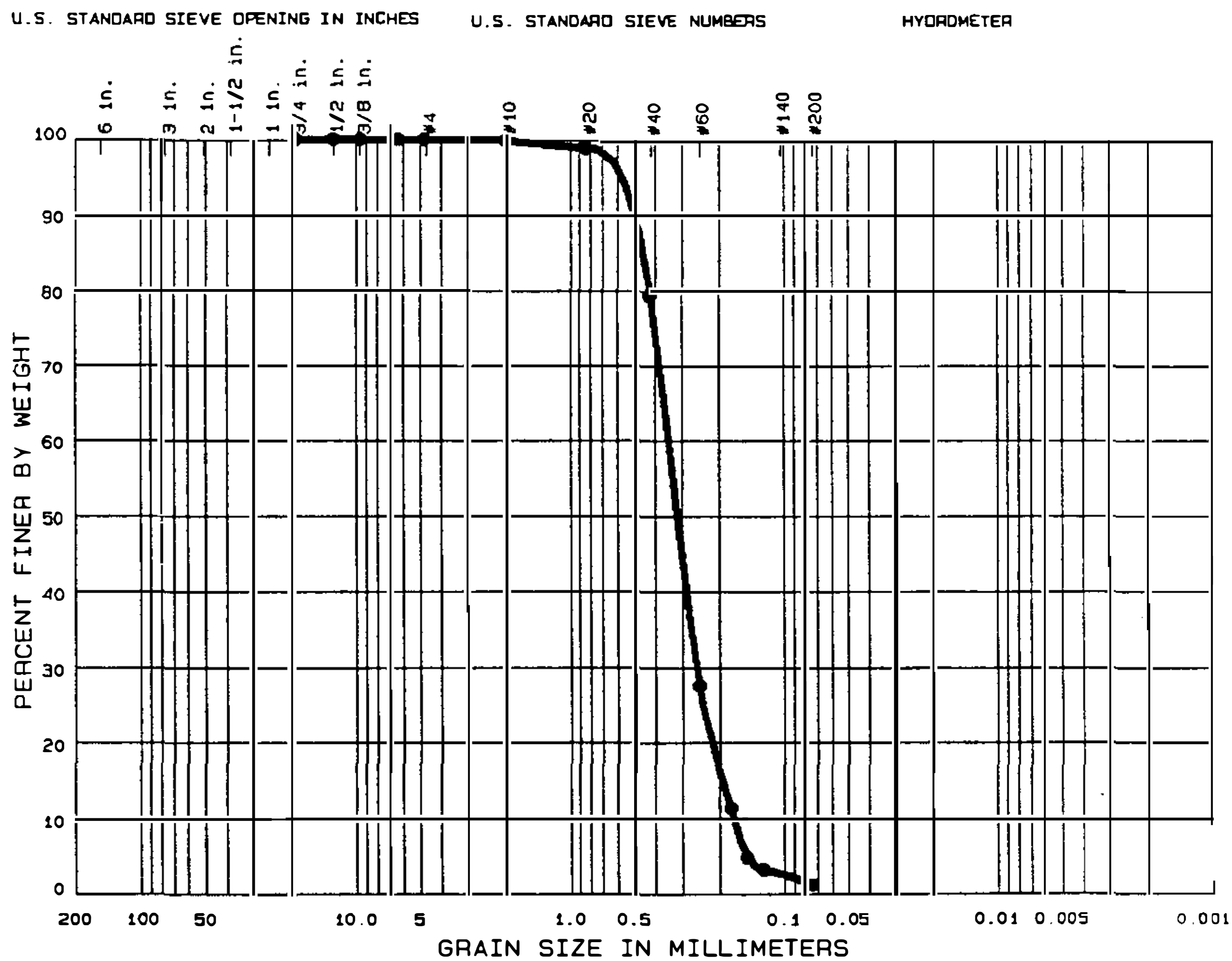
Remarks:

Project Broadkill Beach
Feasibility Study
Lab No.
Area
Boring No. KAV-41 Date 12 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. Broadkill Beach
Req. No. KAV-41
Contract No. KAV-41



% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
● 0.0	0.0	98.8	1.2

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-2						1.12	2.0

CLASSIFICATION

●

Remarks:

Project Broadkill Beach
Feasibility Study
Lab No.

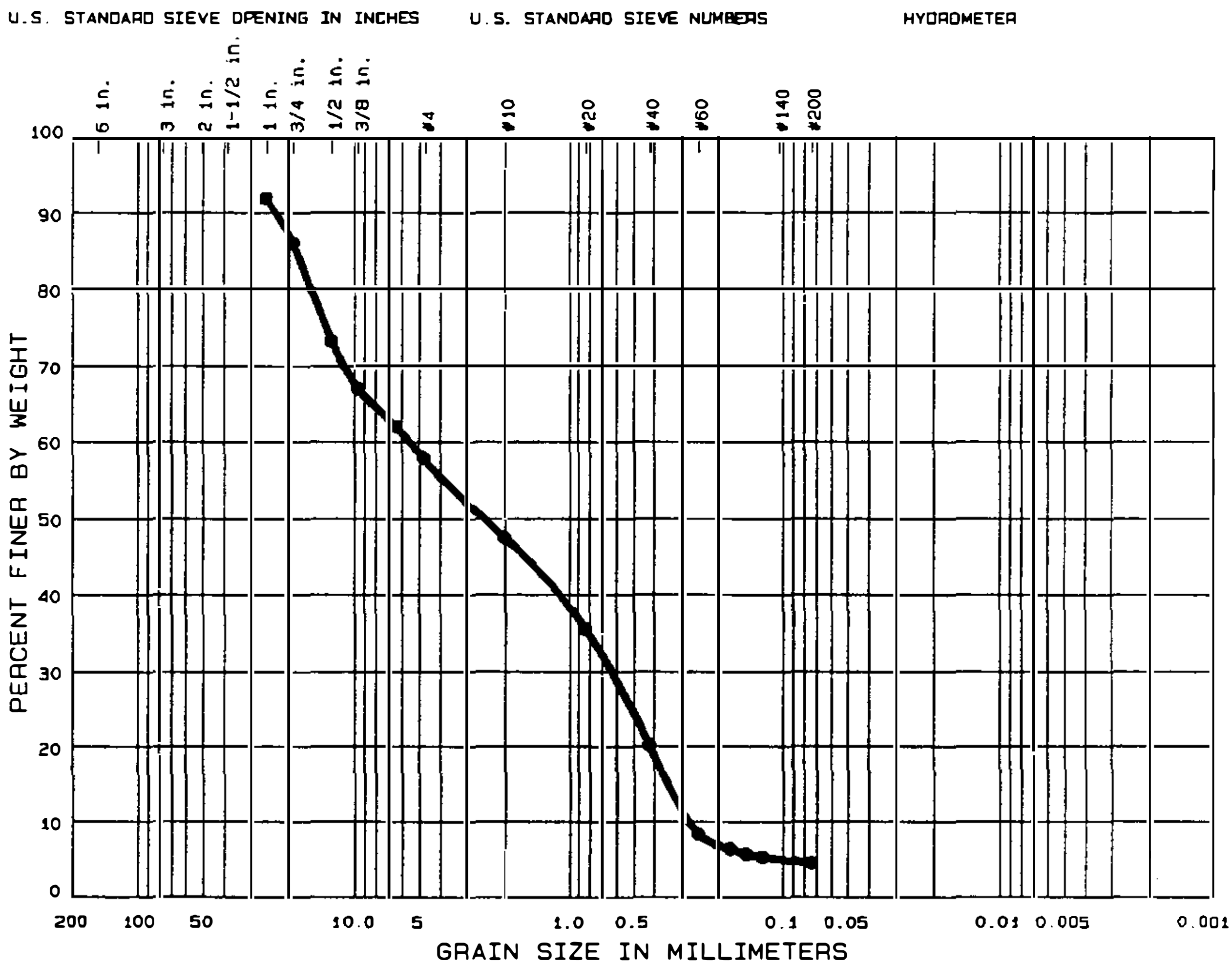
Area

Boring No. KAV-41 Date 12 Dec [illegible]

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. Broadkill Beach
Req. No. KAV-41
Contract No. KAV-41



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	42.1	53.4	4.5

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-3						0.26	19.7

CLASSIFICATION

●

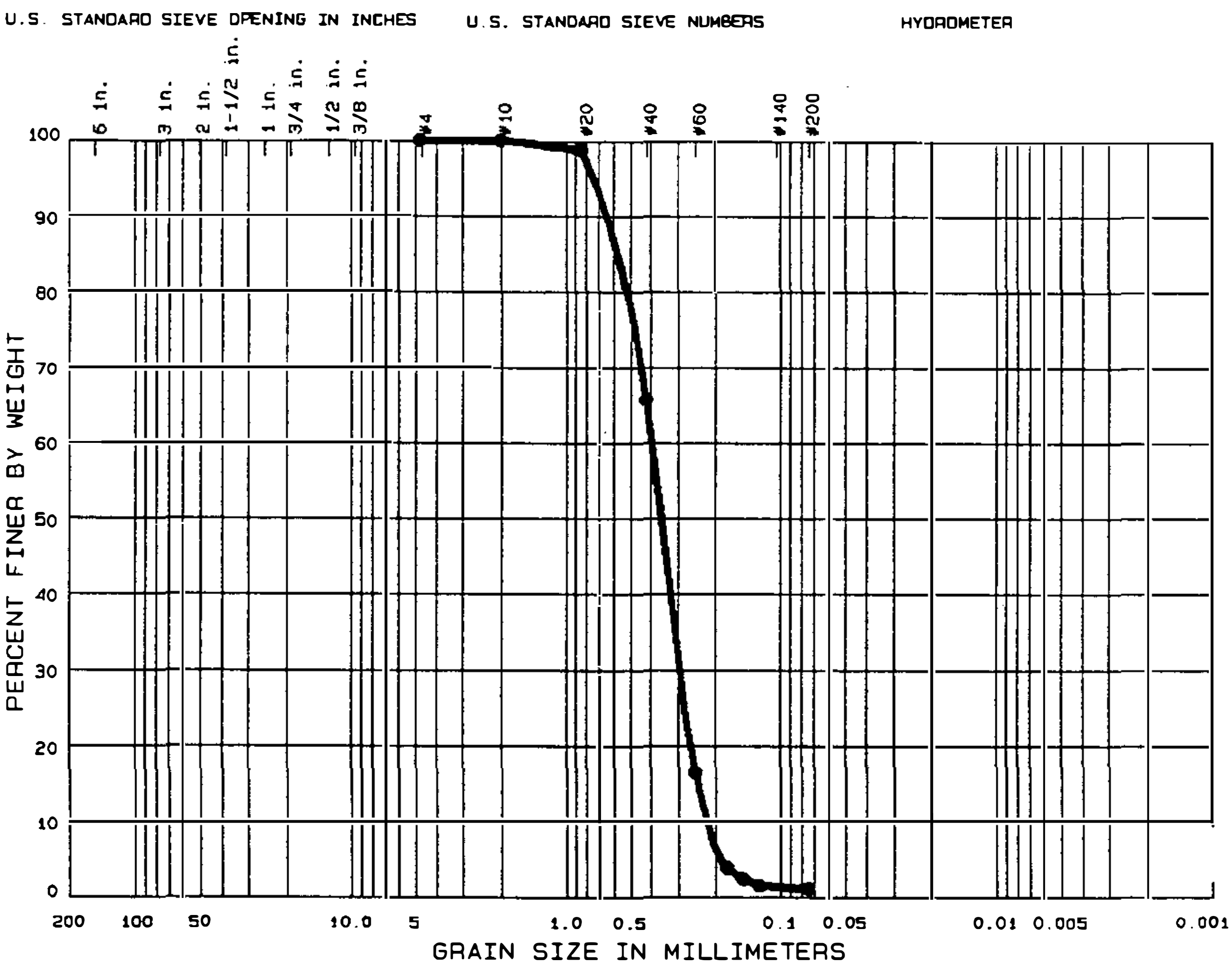
Remarks:

Project Broadkill Beach
Feasibility Study
Lab No.
Area
Boring No. KAV-41 Date 12 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. Broadkill Beach
Req. No. KAV-41
Contract No. KAV-41



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	0.0	98.9	1.1

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-4						0.99	1.8

CLASSIFICATION

●

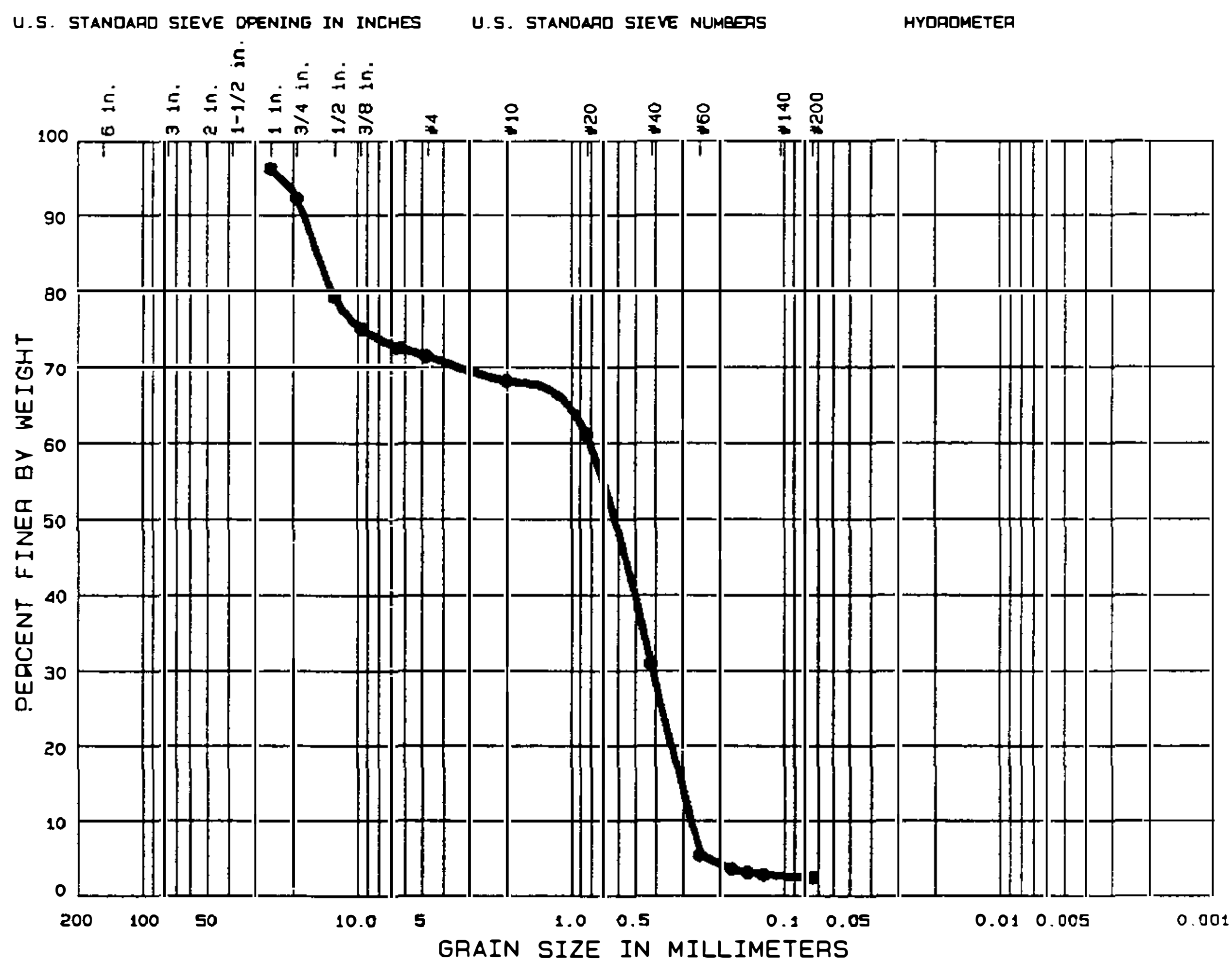
Remarks:

Project Broadkill Beach
Feasibility Study
Lab No.
Area
124
Boring No. KAV-41 Date 12 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. Broadkill Beach
Req. No. KAV-41
Contract No. KAV-41



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	28.6	69.0	2.4

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-5	11.5'-15'					0.77	3.0

CLASSIFICATION

●

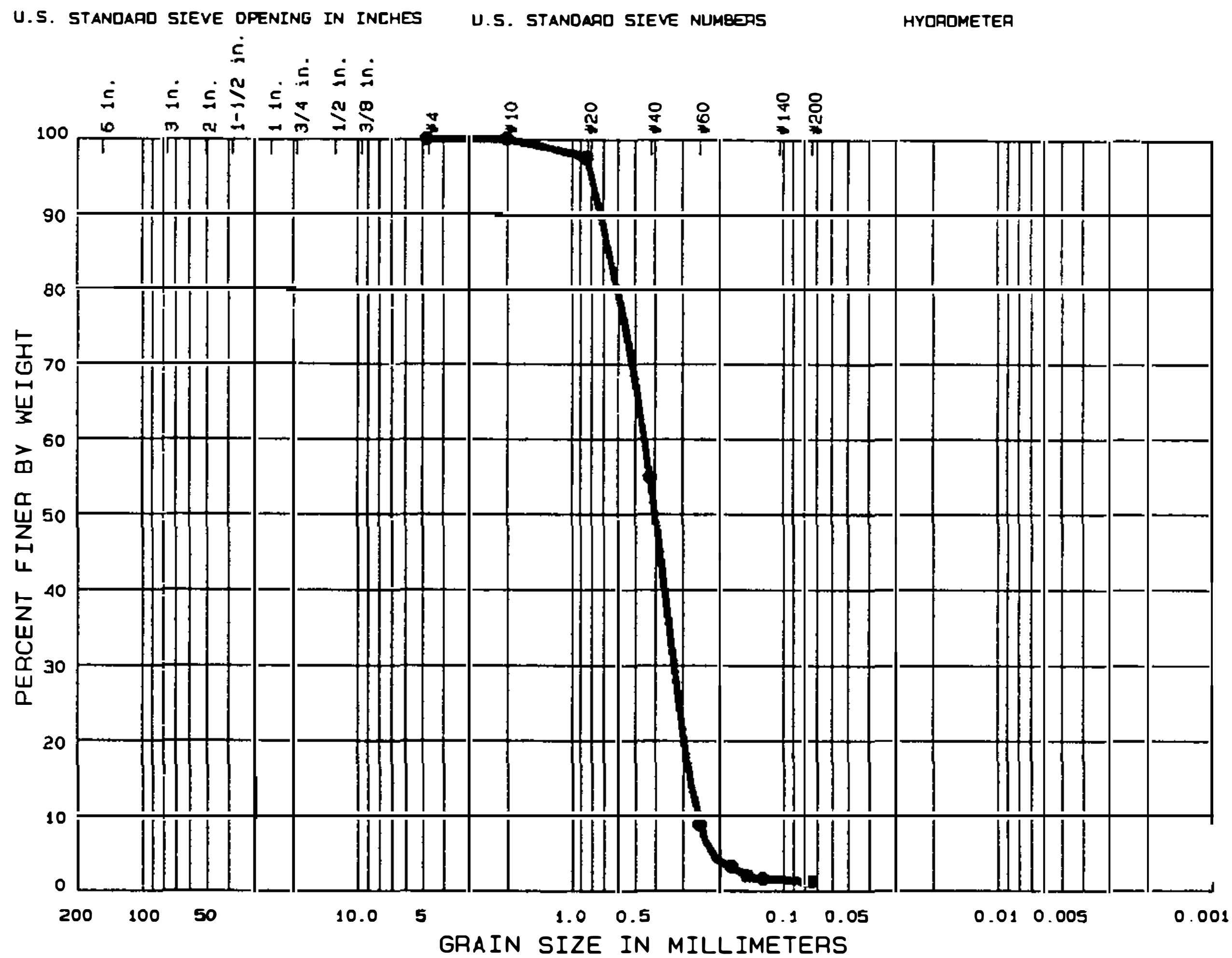
Remarks:

Project BROADKILL BEACH
Feasibility Study
Lab No.
Area 125
Boring No. KAV-41 Date 12 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. Broadkill Beach
Req. No. KAV-41
Contract No. KAV-41



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	0.0	98.8	1.2

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-6	15'-18.5'					0.94	1.7

CLASSIFICATION

●

Remarks:

Project BROADKILL BEACH
Feasibility Study
Lab No.
Area
126
Boring No. KAV-41
Date 12 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY. PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

Hole No.KAV-43

DRILLING LOG DIVISION North Atlantic	INSTALLATION Philadelphia District SHEET 1 OF 1
1. PROJECT Broadkill Beach	10. SIZE AND TYPE OF BIT
2. LOCATION (EASTING AND NORTHING) *(or sta.)* Easting=N 308,178 Northing=E 725,463	11. DATUM FOR ELEVATION SHOWN *(TBM or MSL)*
3. DRILLING AGENCY TES Oceanographic Services	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. *(As shown on drawing title and file number)* KAV-43	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN disturbed: undisturbed:
5. NAME OF DRILLER	14. TOTAL NUMBER OF CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED	15. ELEVATION GROUND WATER
	16. DATE HOLE STARTED 10-95 COMPLETED 10-95
7. THICKNESS OF BURDEN 16.0 Ft.	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK 0 Ft.	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 16.0 Ft.	19. SIGNATURE OF

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC ft	SAMPLE NUMBER	REMARKS
0.0	.0		(SP-SM) Dark Gray fine-medium SAND, trace Fines			*Note: Coordinates are NAD83 Delaware State Plane
	6.5		(SP) Dark Gray Sandy GRAVEL			
	9.5		(SP) Light Rust Brown & Light Brown fine-to-medium SAND			
	12.0		(SP) Light Gray & Rust Brown fine-to-medium SAND, trace Gravel			
	15.0		(SP) Brown medium-to-coarse Gravelly SAND			
	16.0		BOH @ 16.0 Soils are field visually classified and laboratory corrected in accordance with the Unified Soils Classification System.			

Depth scale: 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5

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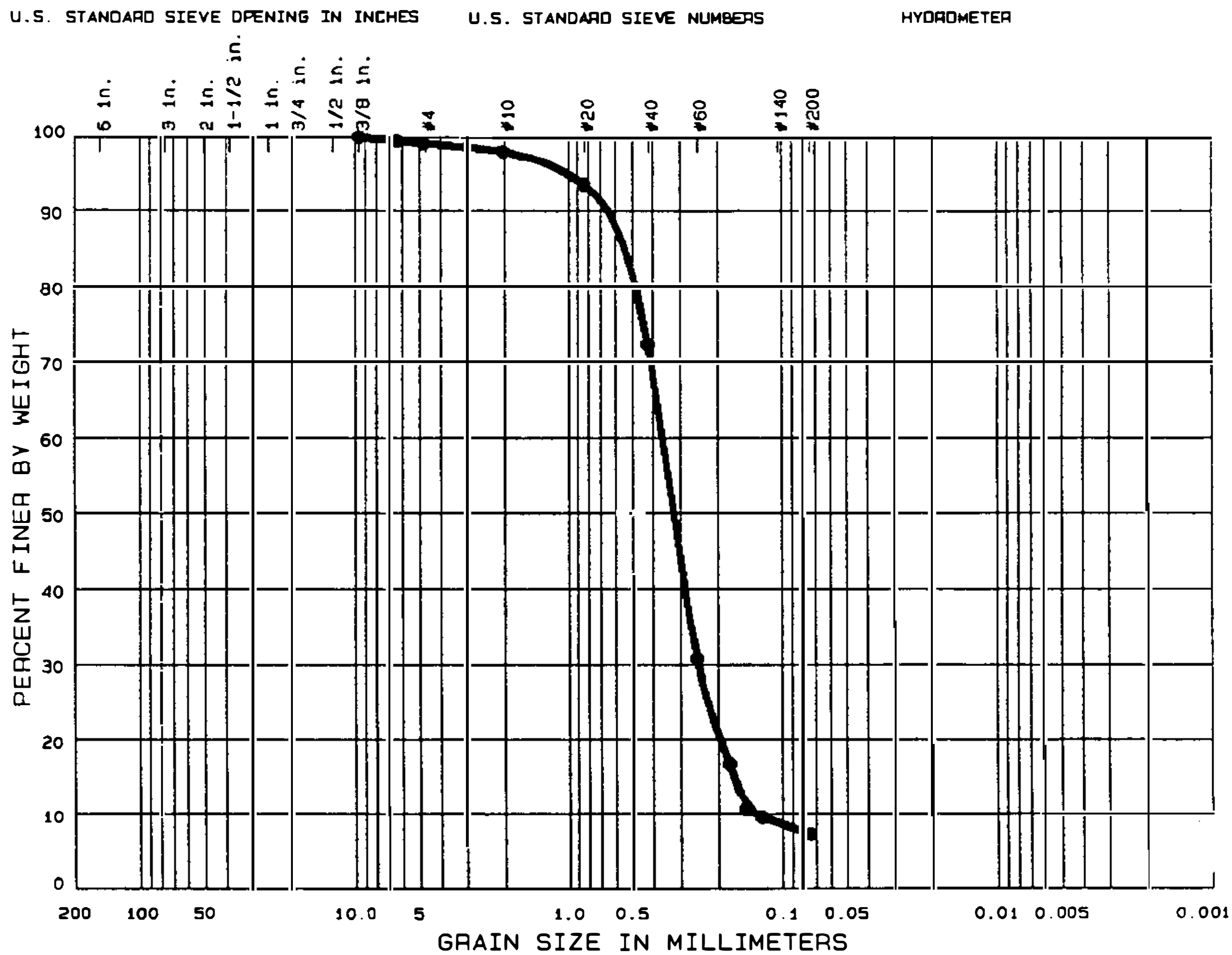
DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. KAV-43
Req. No. KAV-43
Contract No. KAV-43



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	1.0	91.8	7.2

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-1	0'-6.5'					1.29	2.7

CLASSIFICATION

●

Remarks:

Project BROADKILL BEACH
BROADKILL BEACH
Lab No.

Area

Boring No. KAV-43

Date 11 Dec. 1995

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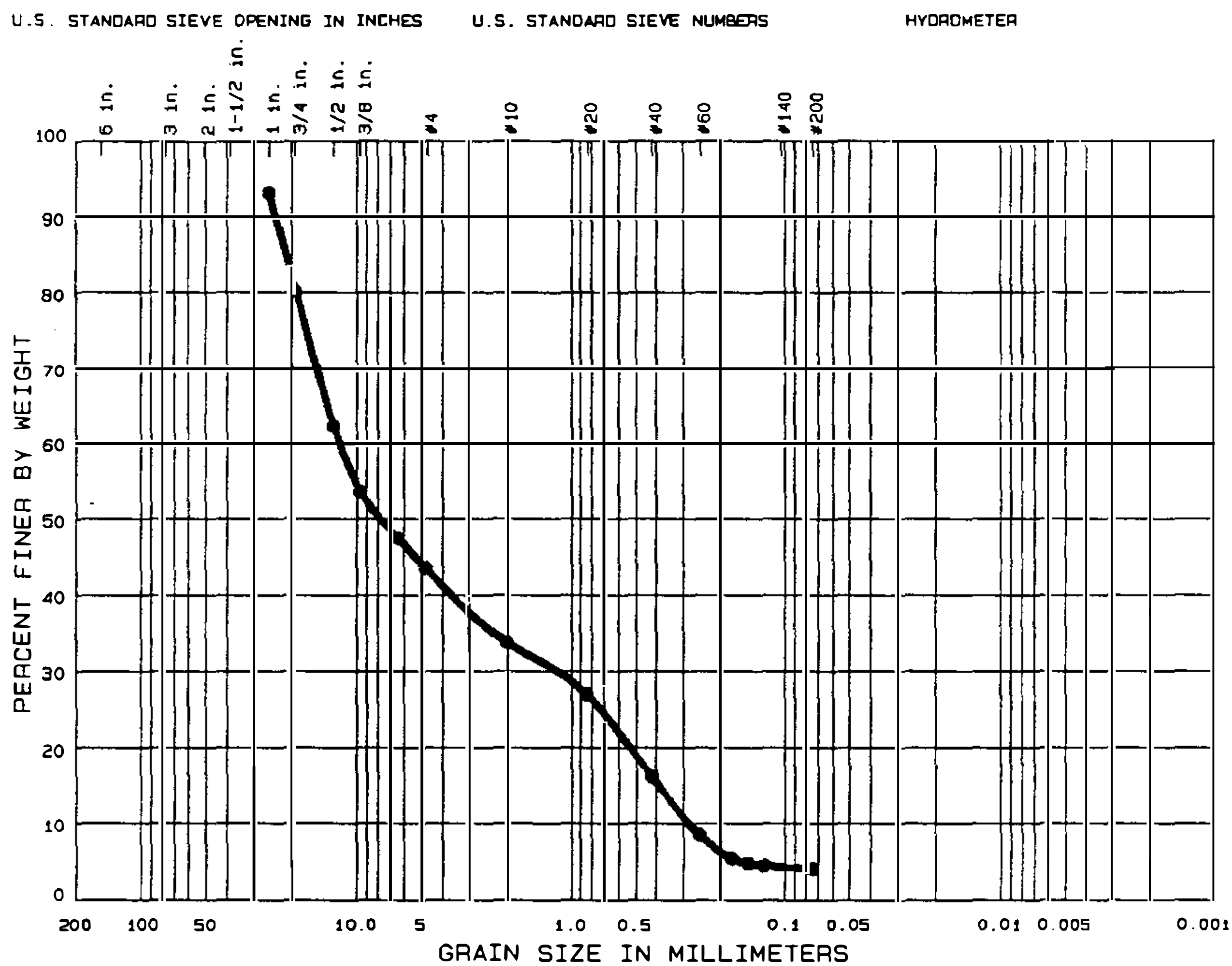
GRADATION CURVES

W.O. No. KAV-43
Req. No. KAV-43
Contract No. KAV-43



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	56.5	39.4	4.1

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-2	6.5'-9.5'					0.41	42.7

CLASSIFICATION

●

Remarks:

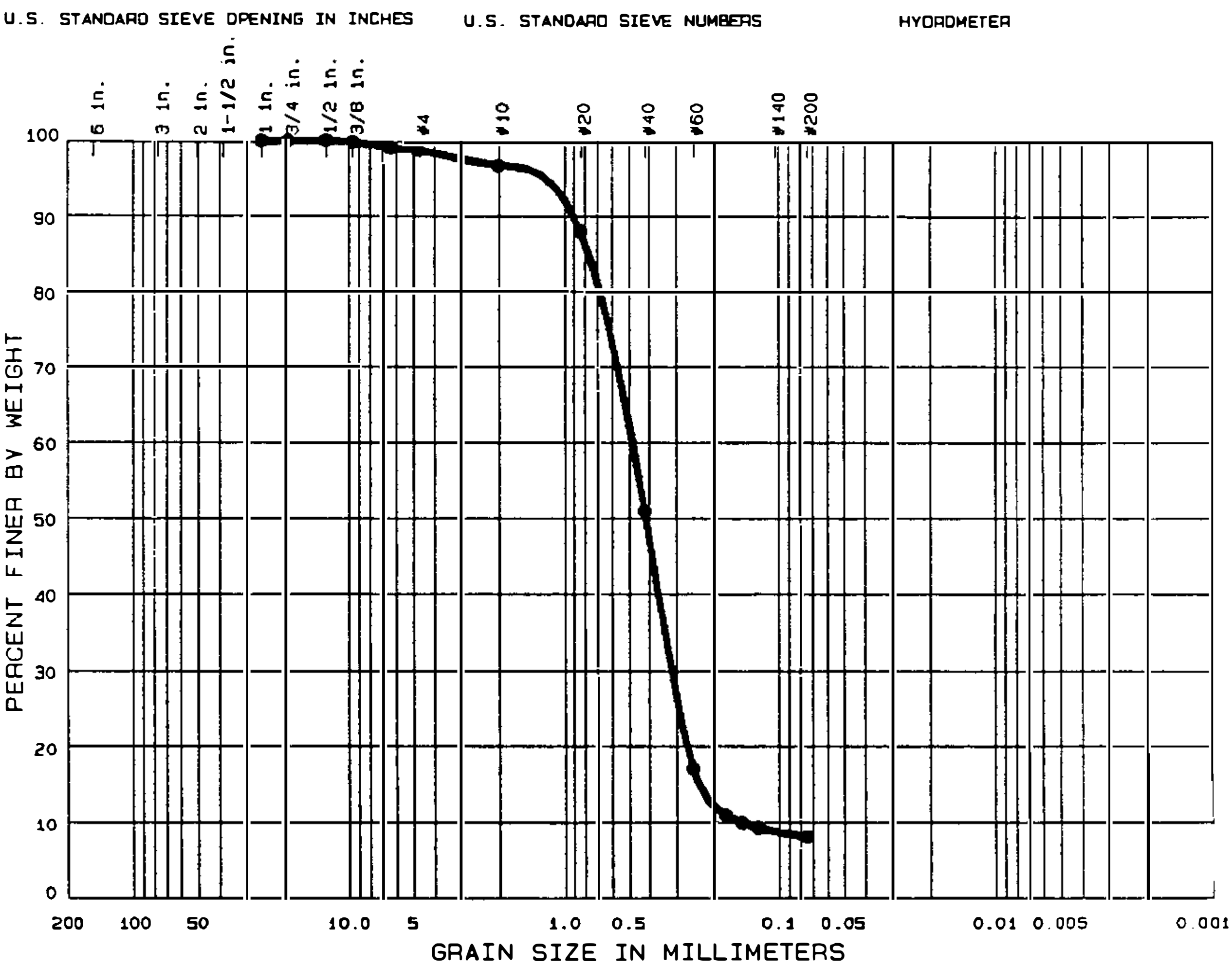
Project BROADKILL BEACH
BROADKILL BEACH
Lab No.
Area 129
Boring No. KAV-43
Date 11 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. KAV-43
Req. No. KAV-43
Contract No. KAV-43

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	1.2	90.7	8.1

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-3	9.5'-11.5'					1.41	3 2

CLASSIFICATION

●

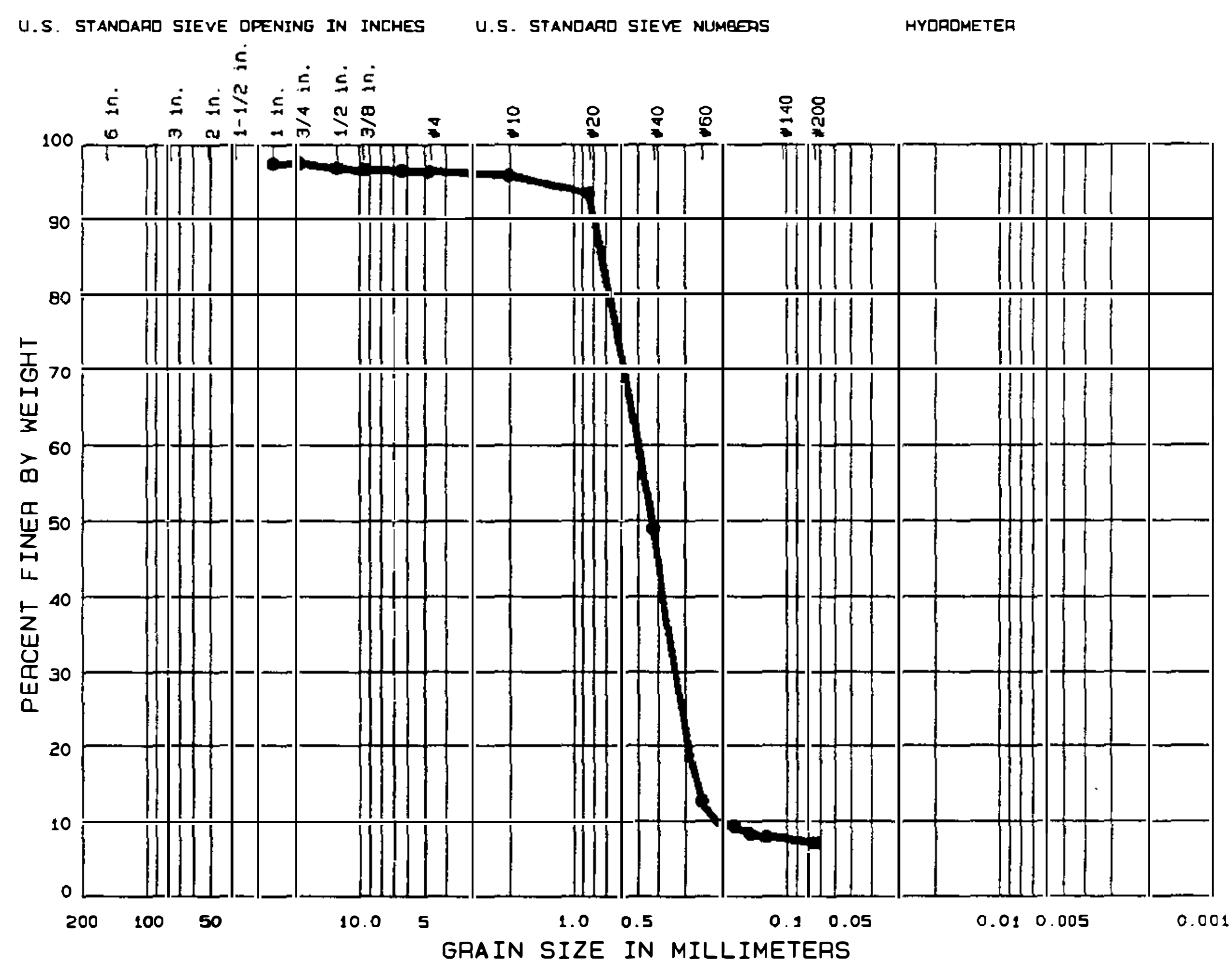
Remarks:

Project BROADKILL BEACH
BROADKILL BEACH
Lab No.
Area
130

Boring No. KAV-43 Date 11 Dec. 1995

GRADATION CURVES

W.O. No. KAV-43
Req. No. KAV-43
Contract No. KAV-43



% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
● 0.0	3.7	89.2	7.1

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-4	11.5'-15'					1.04	2.3

CLASSIFICATION

●

Remarks:

Project BROADKILL BEACH
BROADKILL BEACH
Lab No.
Area
131

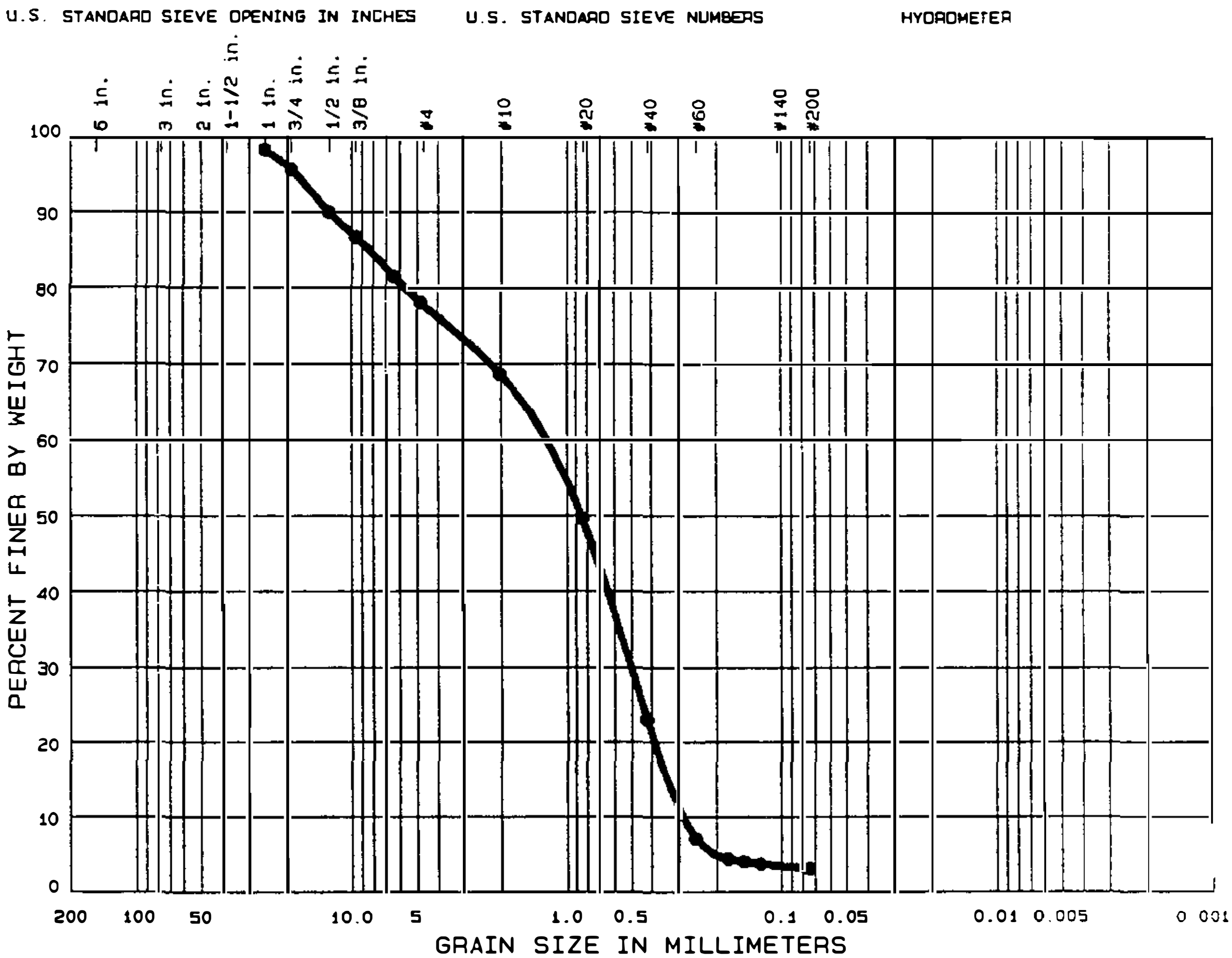
Boring No. KAV-43 Date 11 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. Broadkill Beach
Req. No. KAV-43
Contract No. KAV-43



% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
● 0.0	22.0	74.9	3.1

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-5	15'-16'					0.72	4 3

CLASSIFICATION

●

Remarks:

Project Delaware Bay
Broadkill Beach
Lab No.
Area 132

Boring No. KAV-43 Date 12 Dec [illegible]

GRADATION CURVES

Hole No.KAV-45

DRILLING LOG	DIVISION North Atlantic	INSTALLATION Philadelphia District	SHEET 1 OF 1

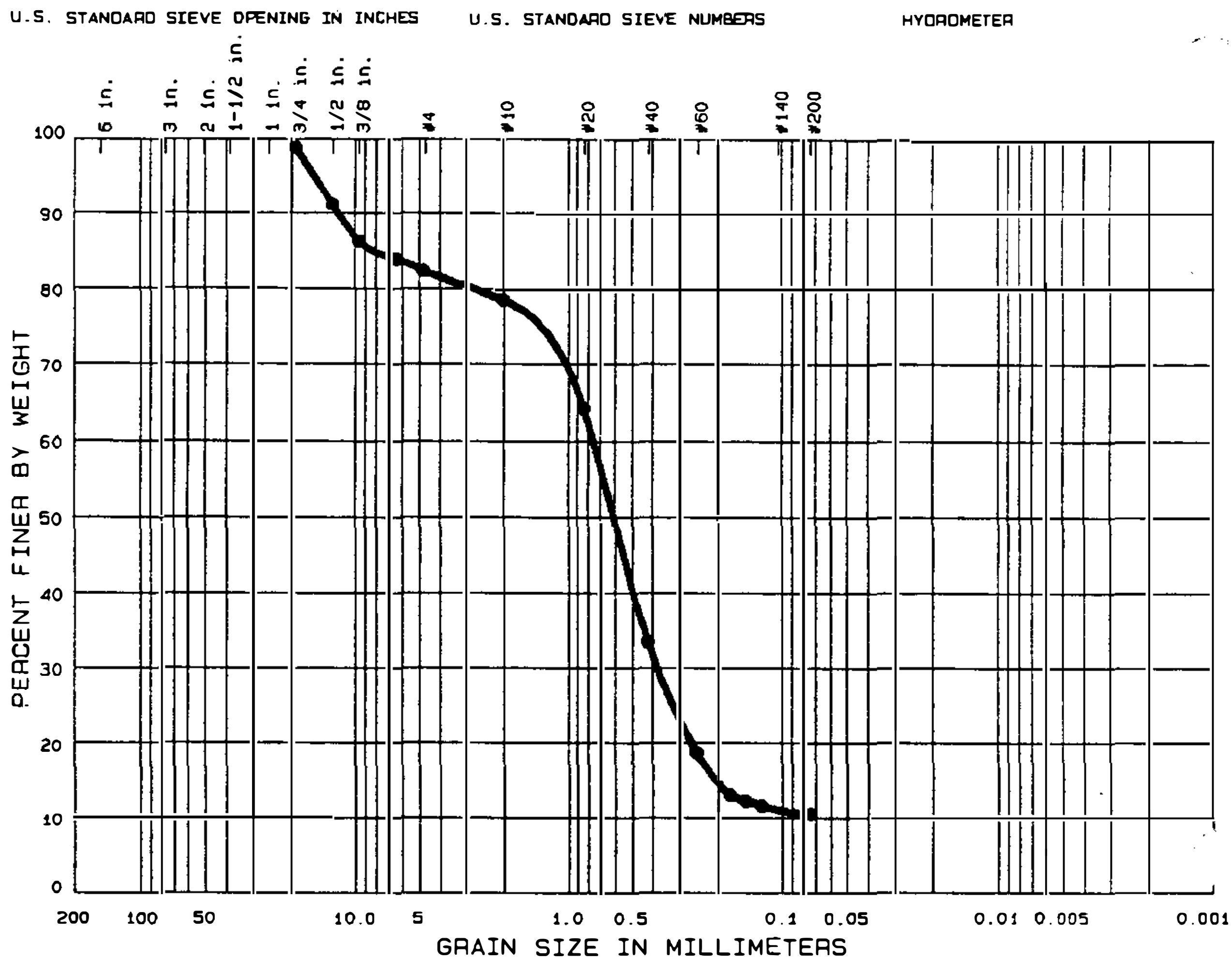
1. PROJECT Broadkill Beach	10. SIZE AND TYPE OF BIT
2. LOCATION (EASTING AND NORTHING) (or sta.) Easting=N 300,564 Northing=E 720,478	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY TEG Oceanographic Services	12. MANUFACTURER'S DESIGNATION OF DRILL Vibracore
4. HOLE NO. (As shown on drawing title and file numb r) KAV-45	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN disturbed: undisturbed:
5. NAME OF DRILLER	14. TOTAL NUMBER OF CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED	15. ELEVATION GROUND WATER
	16. DATE HOLE STARTED 10-95 COMPLETED 10-95
7. THICKNESS OF BURDEN 15.5 Ft.	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK 0 Ft.	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 15.5 Ft.	19. SIGNATURE OF

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC ft	SAMPLE NUMBER	REMARKS
n/a	0					
	1.5		(OH) Dark Gray/Black Silty, Peaty SILT, some Sand			
	5.5		(SP) Light Gray medium SAND, some Gravel, trace Fines			Note: Coordinates are NAD83 Delaware State Plane
	7.5		(SP) Dark Gray medium SAND, trace Fines			
	11.0		(SP) Light Gray medium SAND, trace Fines			
	15.5		(SP) Light Gray fine-to-medium SAND			
			BOH @ 15.5 Soils are field visually classified and laboratory corrected in accordance with the Unified Soils Classification System.			

Scale: 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5

133

W.O. No. Broadkill Beach
Req. No. KAV-45
Contract No. KAV-45



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	17.6	71.9	10.5

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-1	1.5'-5.4'						

CLASSIFICATION

●

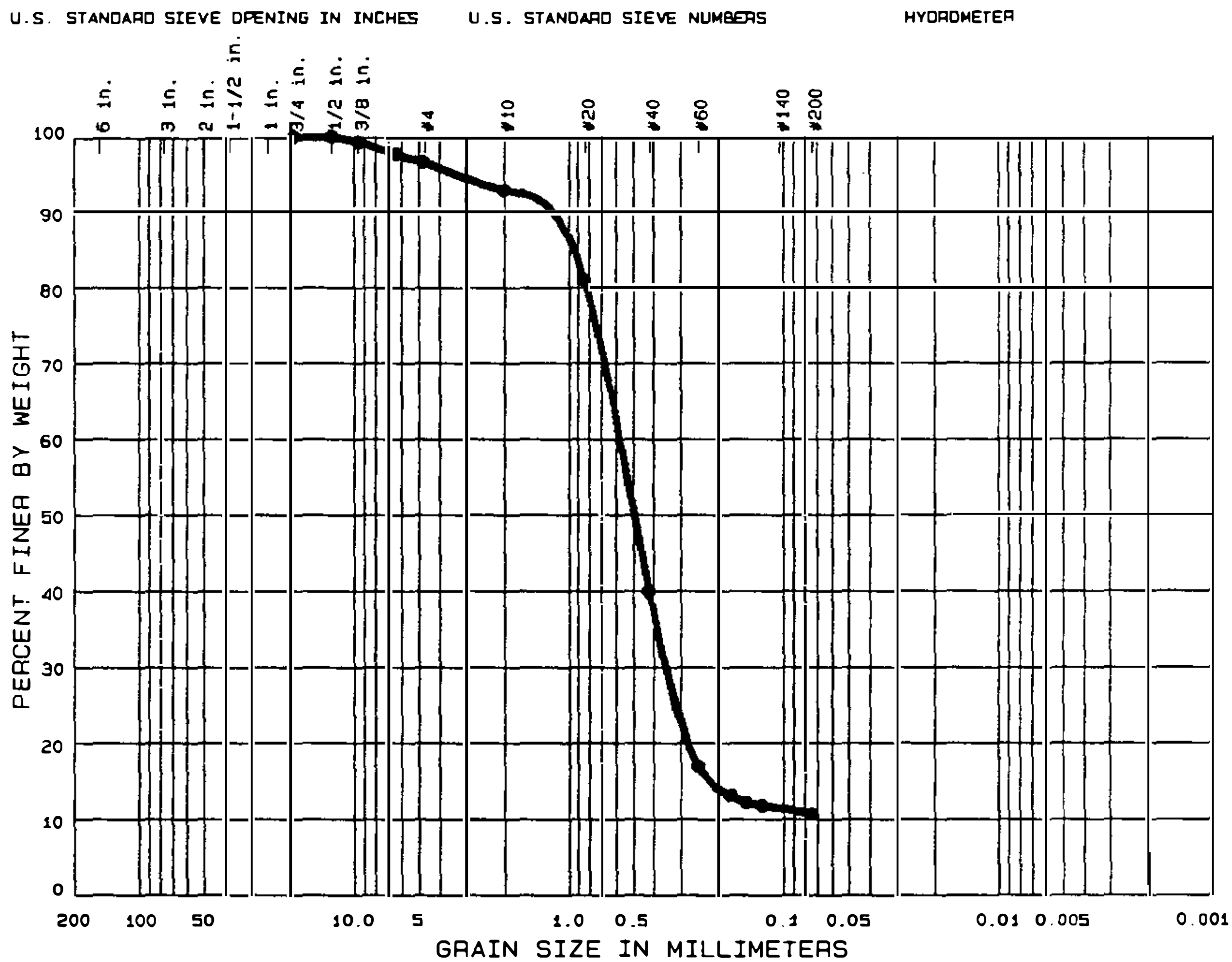
Remarks:

Project BROADKILL BEACH
Feasibility Study
Lab No.
Area 134
Boring No. KAV-45 Date 12 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. Broadkill Beach
Req. No. KAV-45
Contract No. KAV-45



% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
● 0.0	3.3	86.0	10.7

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-2	5.4'-7.5'						

CLASSIFICATION

● SP-SM

Remarks:

Project BROADKILL BEACH
Feasibility Study
Lab No. 135

Area

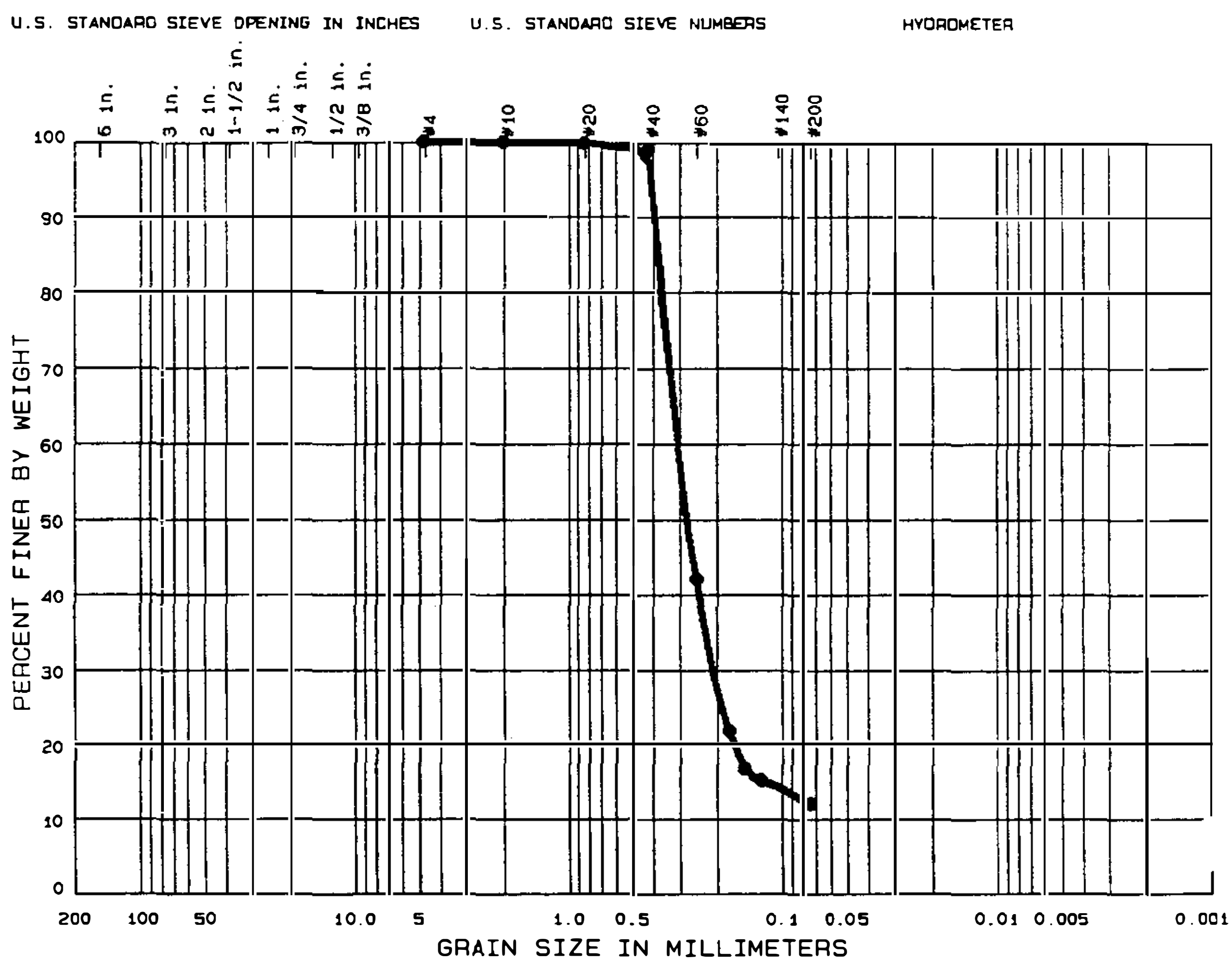
Boring No. KAV-45 Date 12 Dec [illegible]

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

552

W.O. No. Broadkill Beach
Req. No. KAV-45
Contract No. KAV-45



	% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
●	0.0	0.0	87.9	12.1

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-3	7.5'-12'						

CLASSIFICATION

●

Remarks:

Project BROADKILL BEACH
Feasibility Study
Lab No.
Area

136

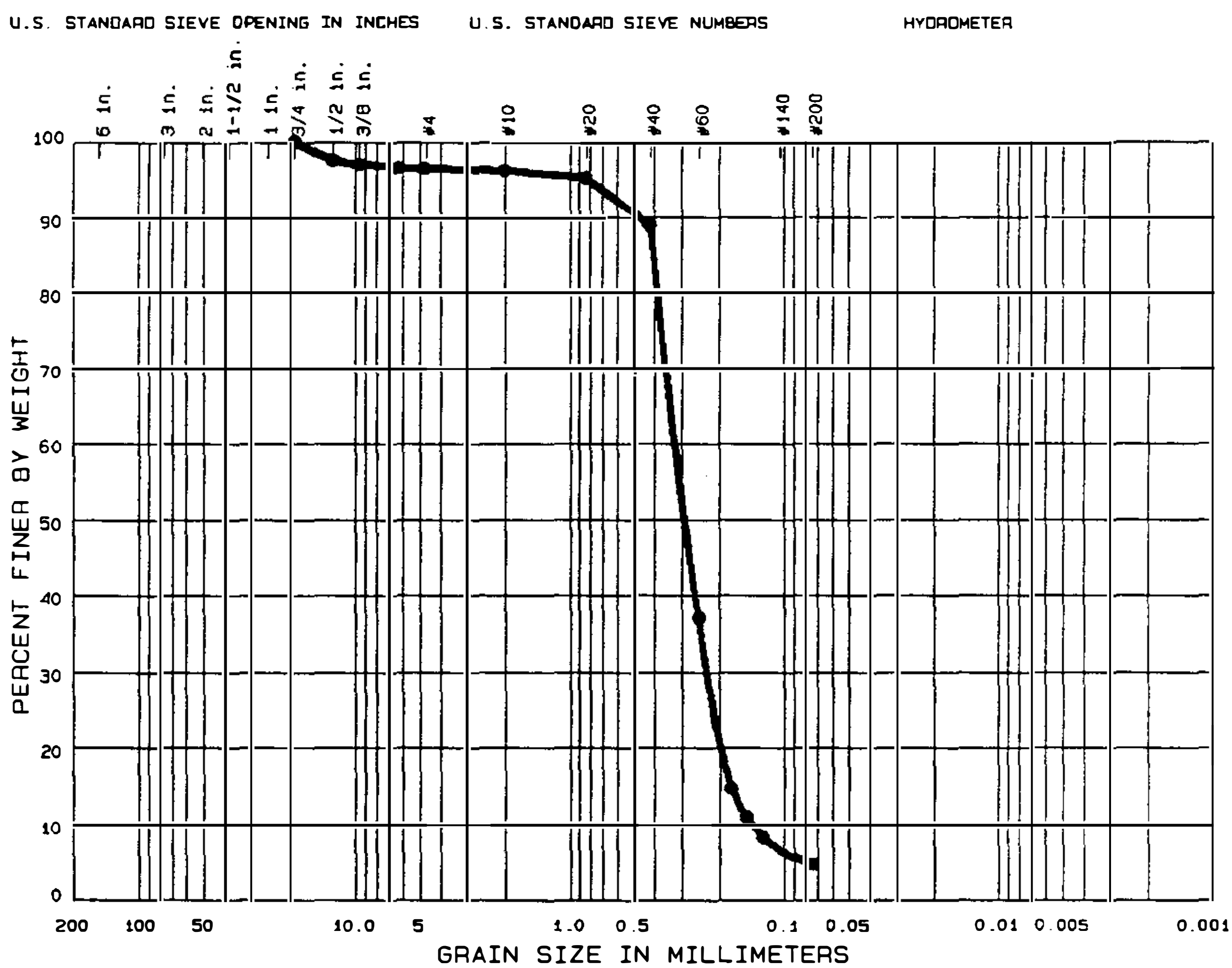
Boring No. KAV-45

Date 12 Dec. 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

W.O. No. Broadkill Beach
Req. No. KAV-45
Contract No. KAV-45



% COBBLES	% GRAVEL	% SAND	% SILT OR CLAY
● 0.0	3.5	91.7	4.8

	Sample No.	Elev or Depth	Nat W%	LL	PL	PI	C_c	C_u
●	S-4	12'-15.5'					1.18	2 3

CLASSIFICATION

● SP

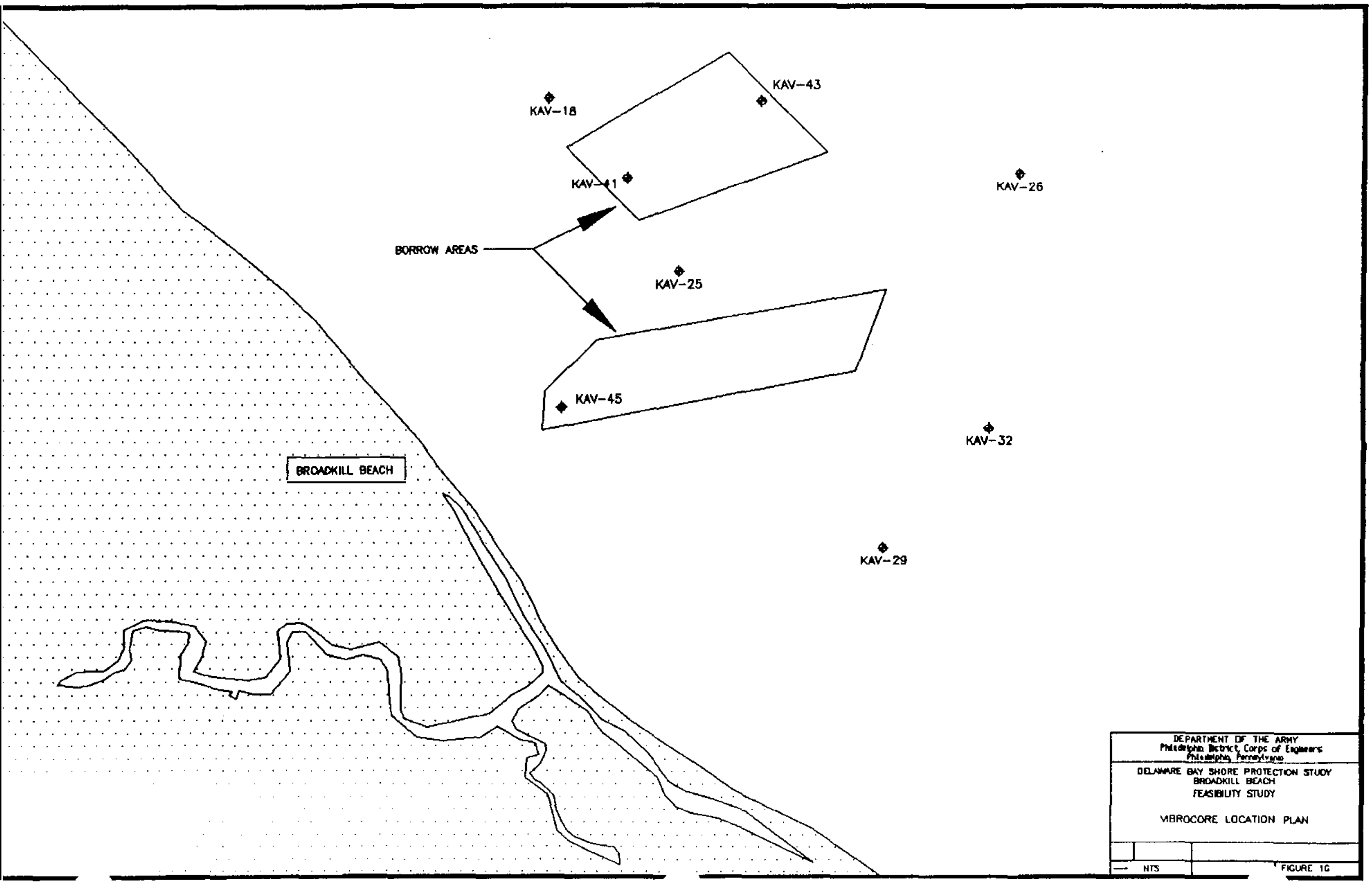
Remarks:

Project BROADKILL BEACH
Feasibility Study
Lab No.
Area
137
Boring No. KAV-45
Date 12 Dec 1995

GRADATION CURVES

DEPARTMENT OF THE ARMY, PHILADELPHIA DISTRICT
CORPS OF ENGINEERS, CUSTOM HOUSE, 2ND & CHESTNUT STREET

554



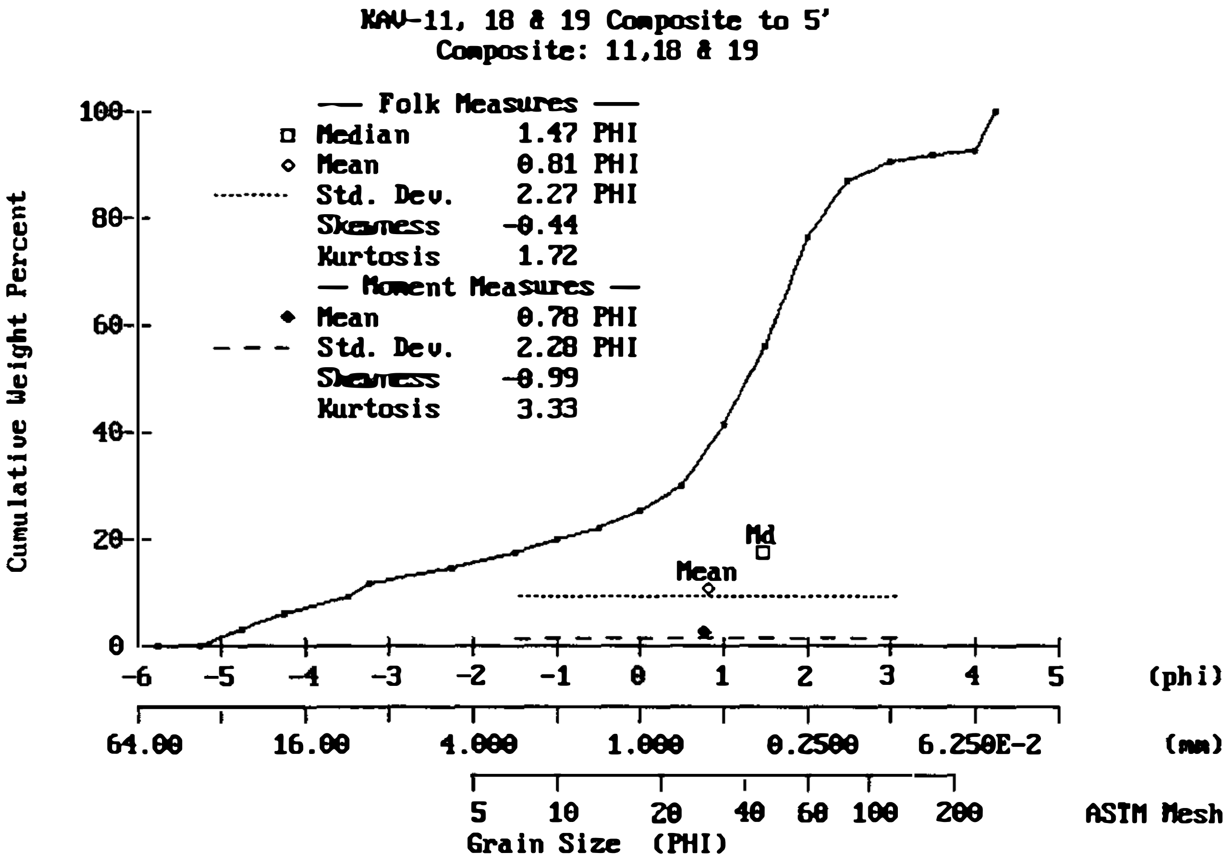
DEPARTMENT OF THE ARMY
Philadelphia District, Corps of Engineers
Philadelphia, Pennsylvania

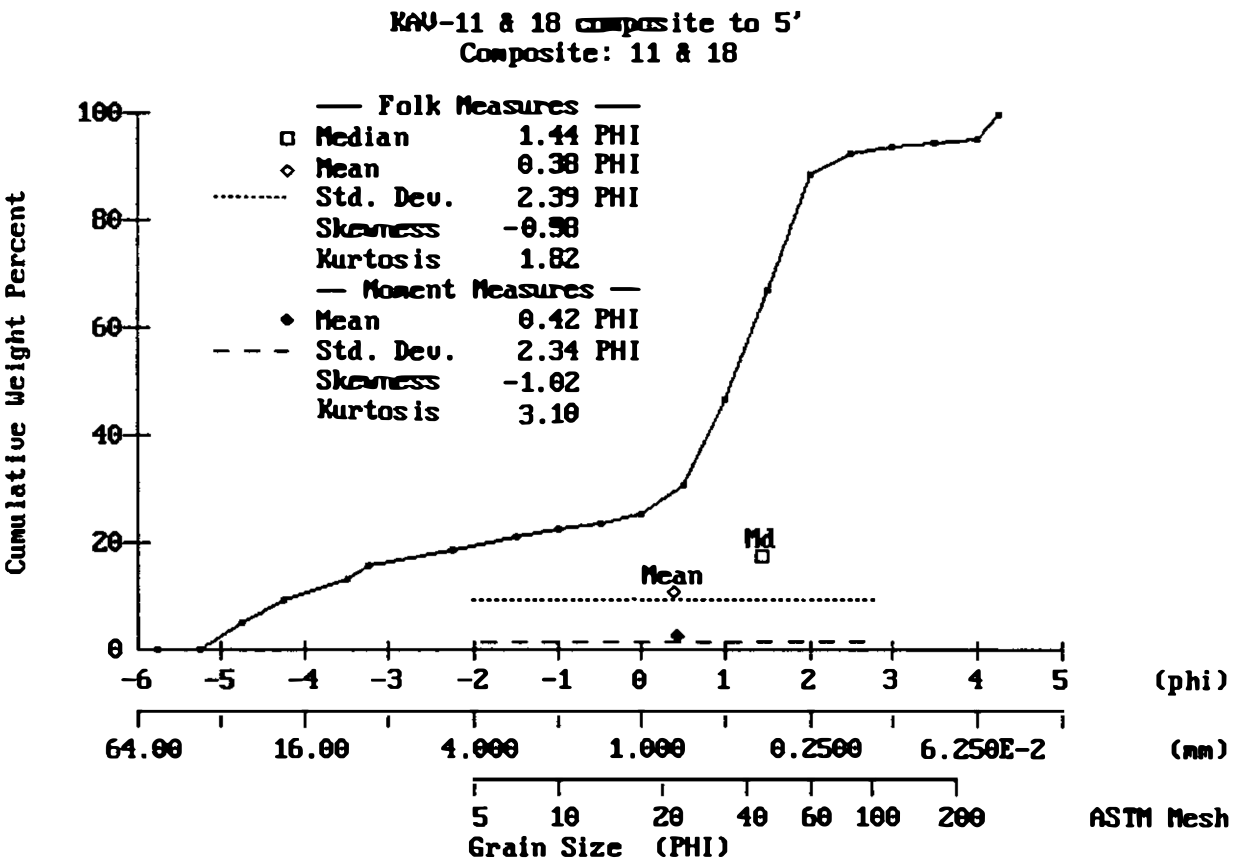
DELAWARE BAY SHORE PROTECTION STUDY
BROADKILL BEACH
FEASIBILITY STUDY

VIBROCORE LOCATION PLAN

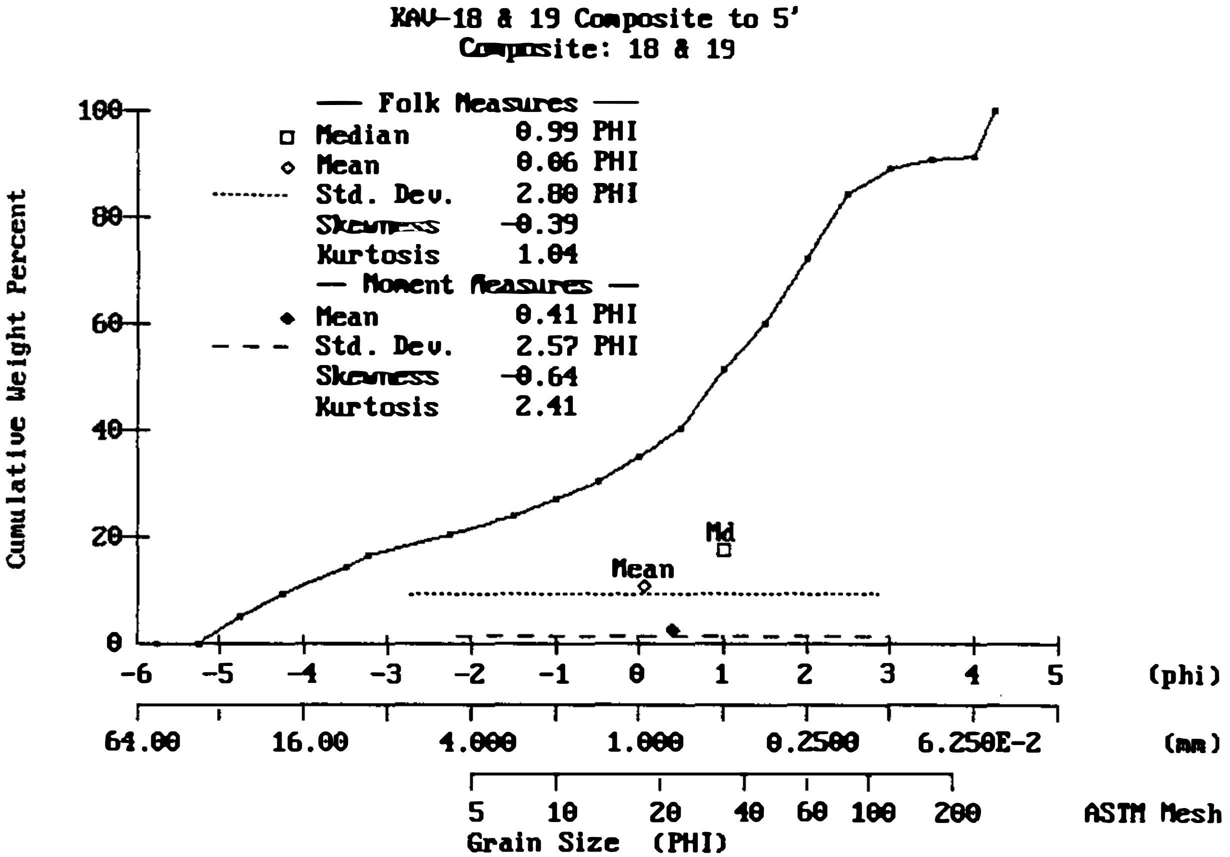
NTS

FIGURE 1G


KAV-11, 18 & 19 Composite to 5'
Composite: 11,18 & 19
— Folk Measures —
Median 1.47 PHI
Mean 0.81 PHI
Std. Dev. 2.27 PHI
Skewness -0.44
Kurtosis 1.72
— Moment Measures —
Mean 0.78 PHI
Std. Dev. 2.28 PHI
Skewness -0.99
Kurtosis 3.33
Cumulative Weight Percent
100
80
60
40
20
0
Md
Mean
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5
(phi)
64.00 16.00 4.000 1.000 0.2500 6.250E-2
(mm)
5 10 20 40 60 100 200
ASTM Mesh
Grain Size (PHI)

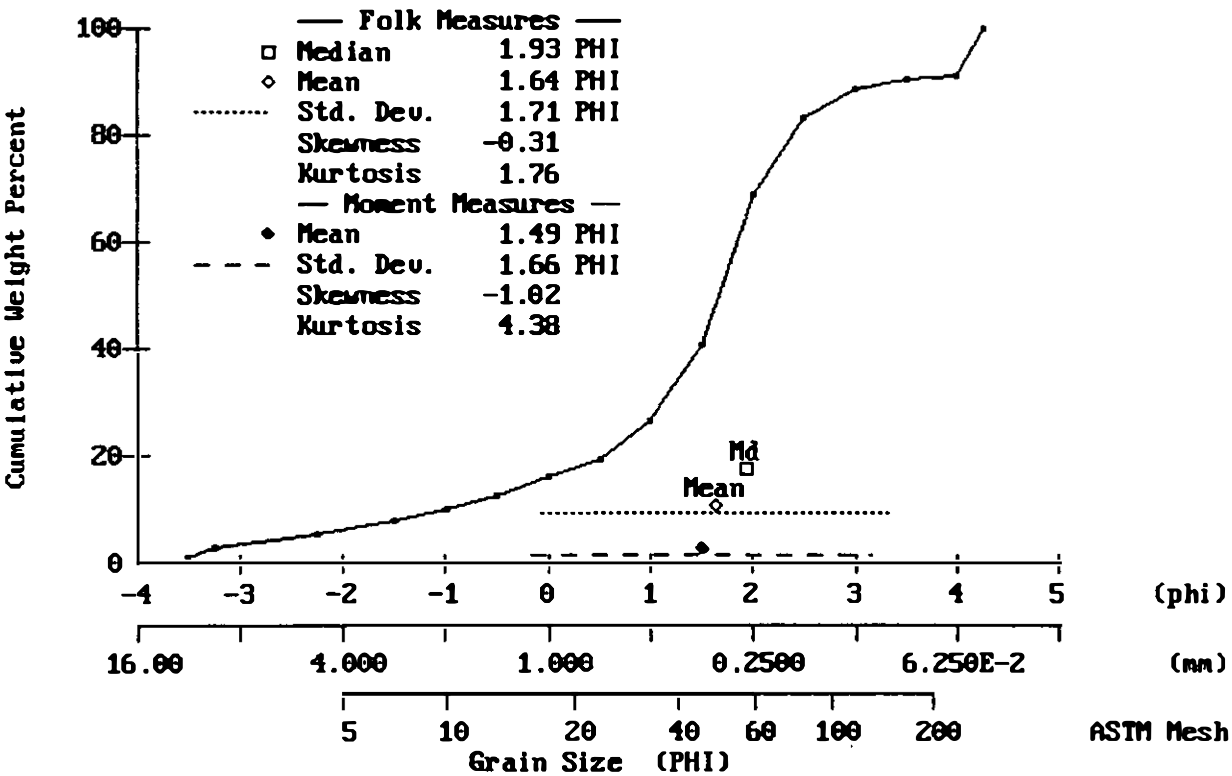

KAV-11 & 18 composite to 5'
Composite: 11 & 18
— Folk Measures —
Median 1.44 PHI
Mean 0.38 PHI
Std. Dev. 2.39 PHI
Skewness -0.58
Kurtosis 1.82
— Moment Measures —
Mean 0.42 PHI
Std. Dev. 2.34 PHI
Skewness -1.02
Kurtosis 3.10
Md
Mean
Cumulative Weight Percent
0
20
40
60
80
100
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
(phi)
64.00
16.00
4.000
1.000
0.2500
6.250E-2
(mm)
5
10
20
40
60
100
200
ASTM Mesh
Grain Size (PHI)

140

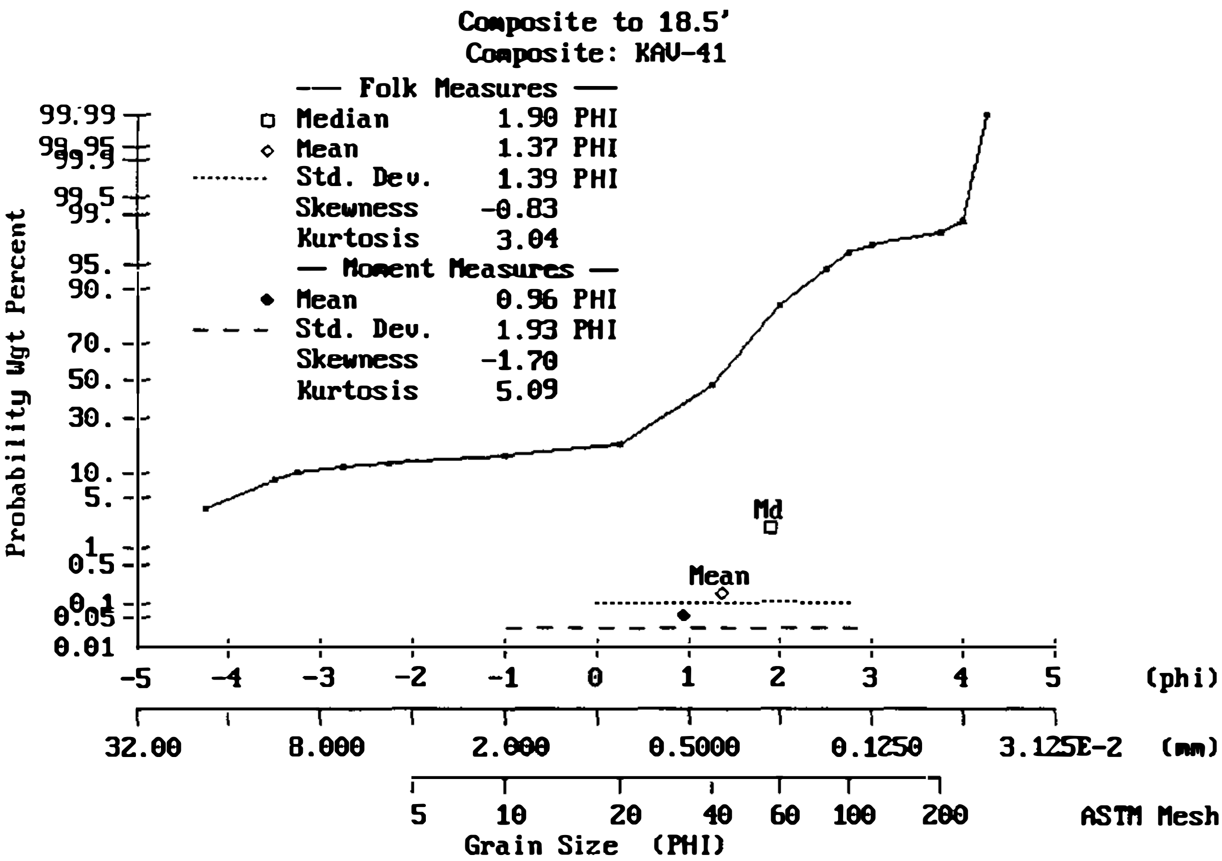

KAV-18 & 19 Composite to 5'
Composite: 18 & 19
— Folk Measures —
Median 0.99 PHI
Mean 0.06 PHI
Std. Dev. 2.80 PHI
Skewness -0.39
Kurtosis 1.04
— Moment Measures —
Mean 0.41 PHI
Std. Dev. 2.57 PHI
Skewness -0.64
Kurtosis 2.41
Md
Mean
Cumulative Weight Percent
100
80
60
40
20
0
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5
(phi)
64.00 16.00 4.000 1.000 0.2500 6.250E-2
(mm)
5 10 20 40 60 100 200
ASTM Mesh
Grain Size (PHI)

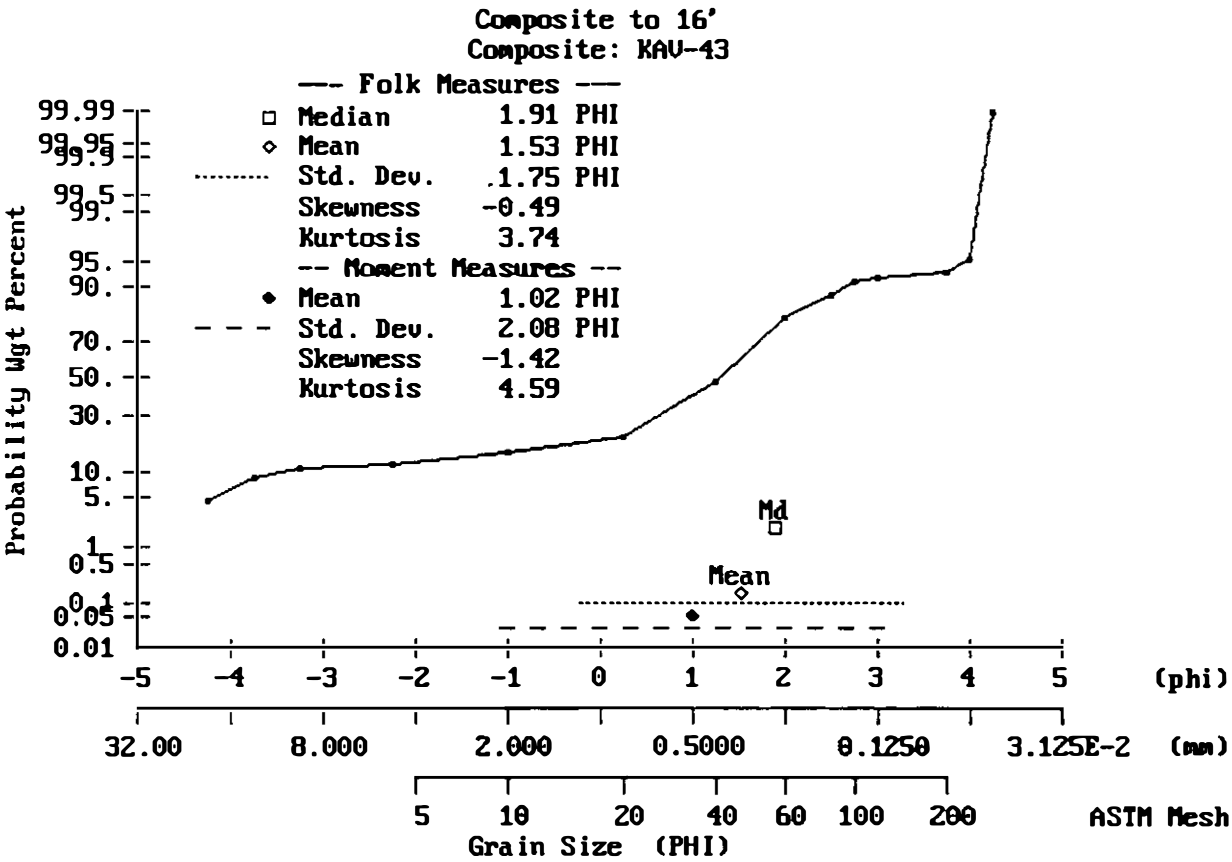
558

KAV-11 & 19 Composite to 5'
Composite: 11 & 19

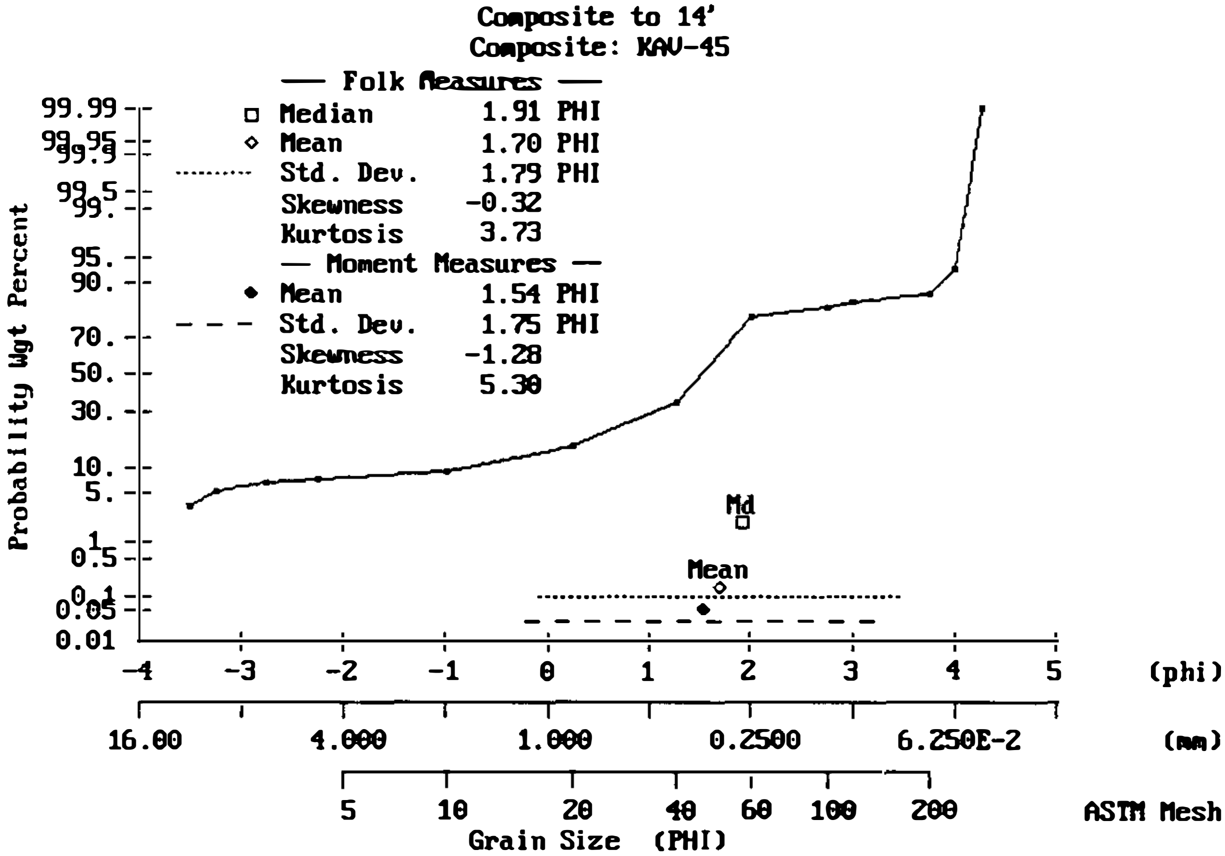


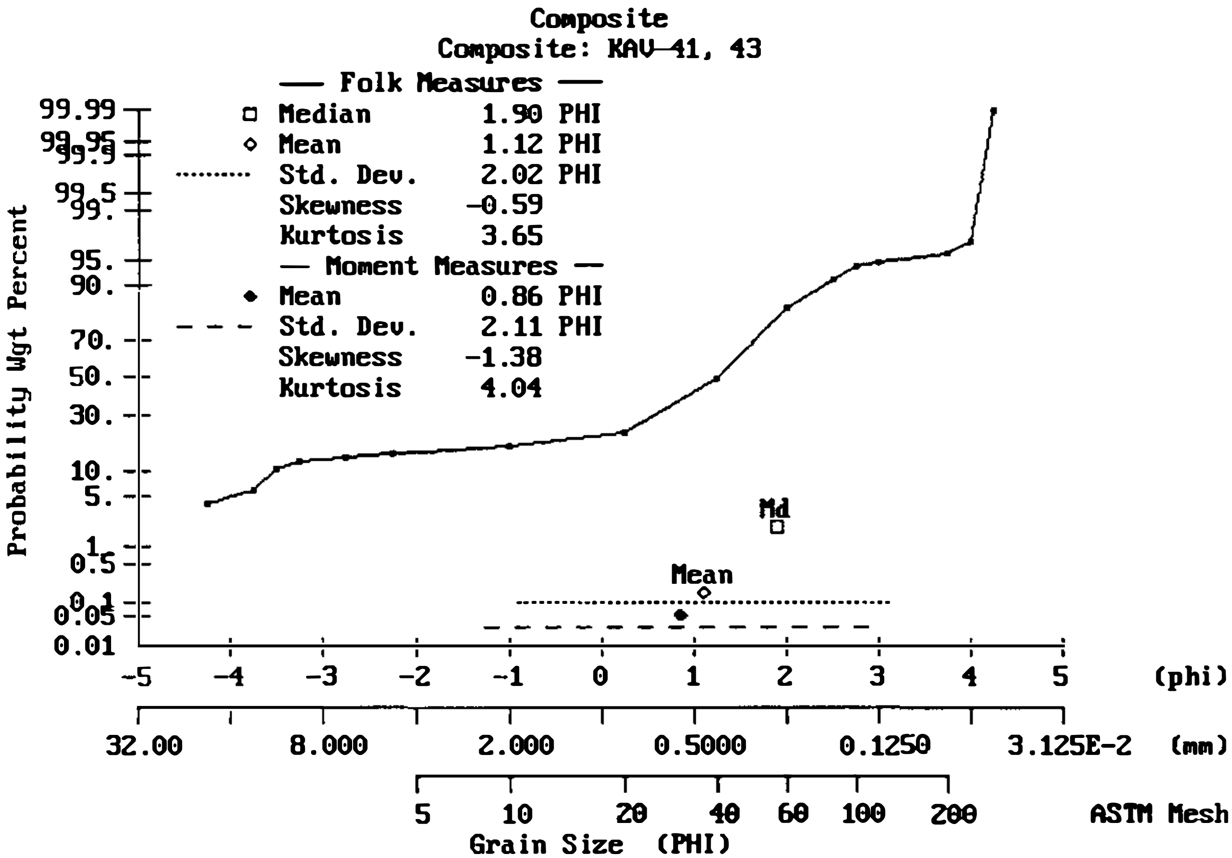
559

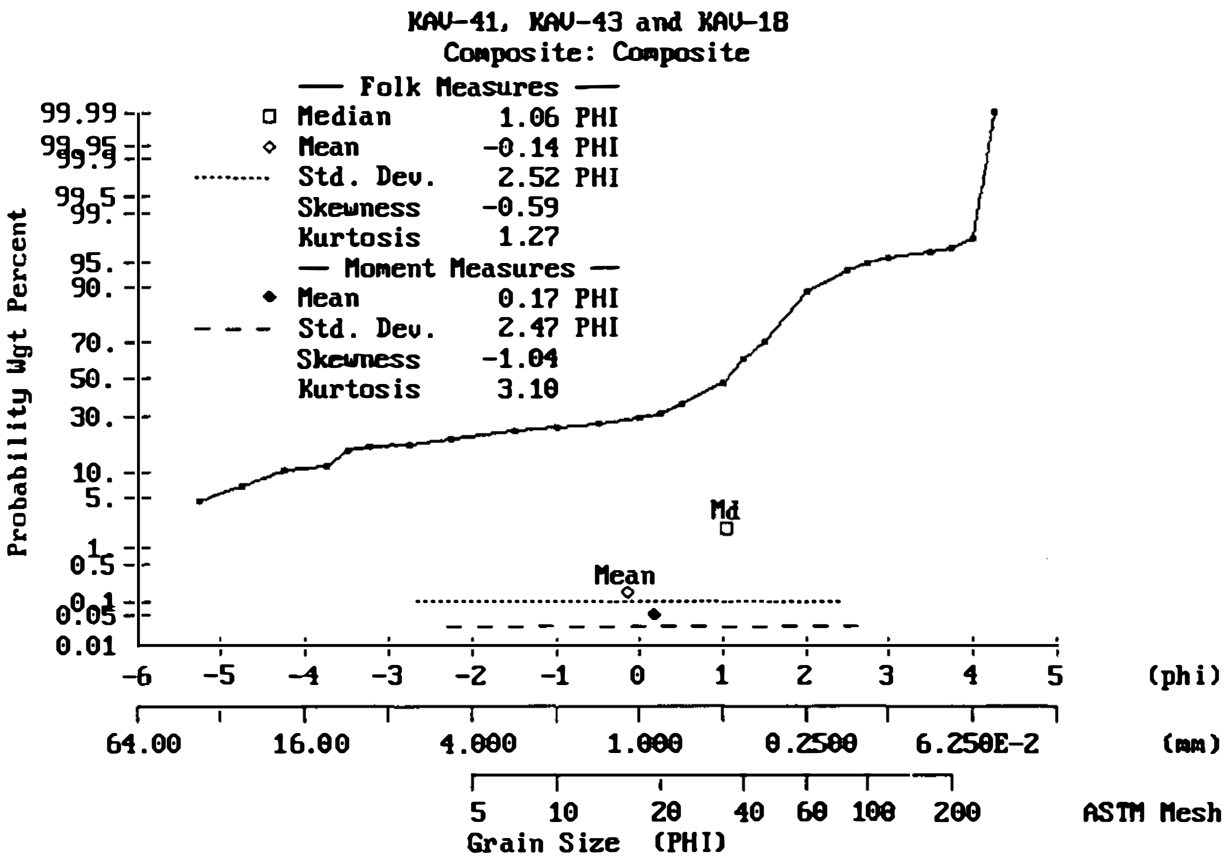

Composite to 18.5'
Composite: KAV-41
— Folk Measures —
Median 1.90 PHI
Mean 1.37 PHI
Std. Dev. 1.39 PHI
Skewness -0.83
Kurtosis 3.04
— Moment Measures —
Mean 0.96 PHI
Std. Dev. 1.93 PHI
Skewness -1.70
Kurtosis 5.09
Probability Wgt Percent
Md
Mean
(phi)
(mm)
ASTM Mesh
Grain Size (PHI)

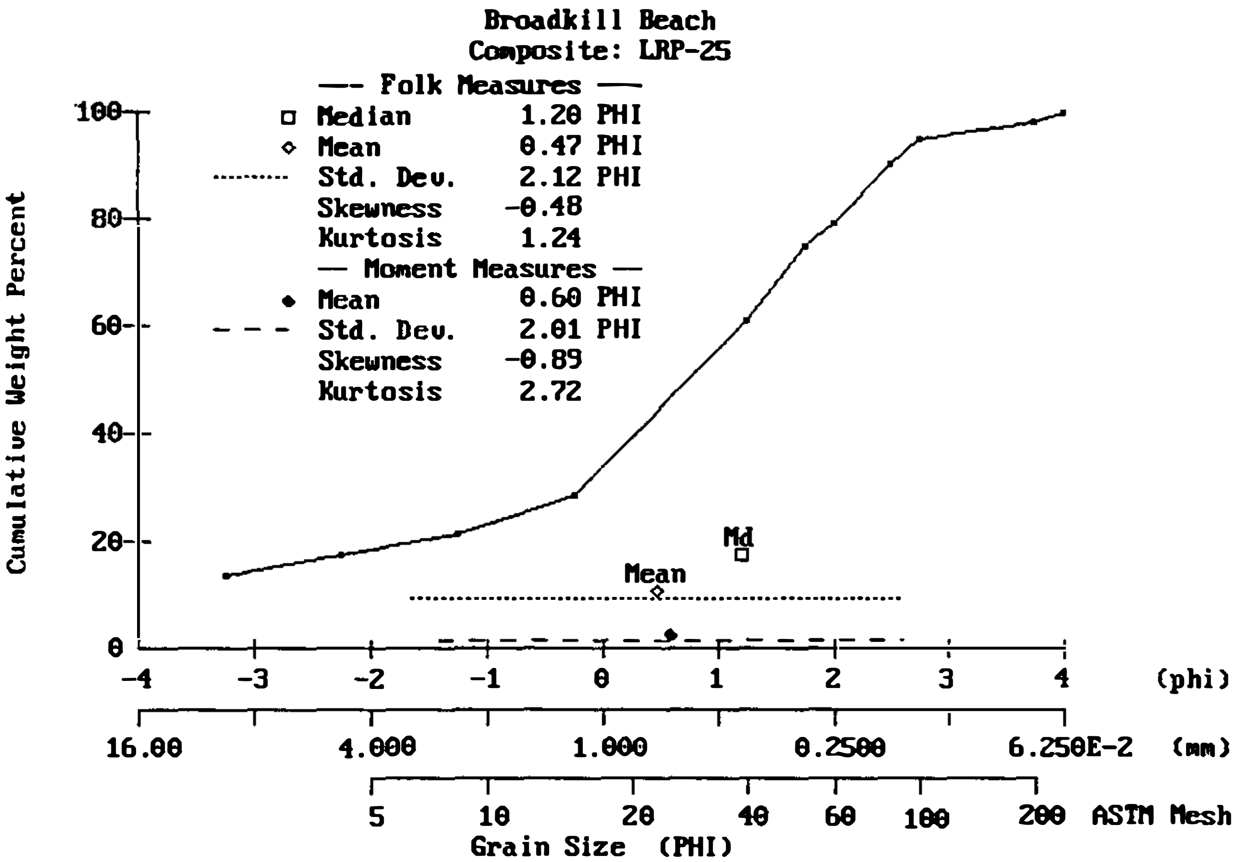


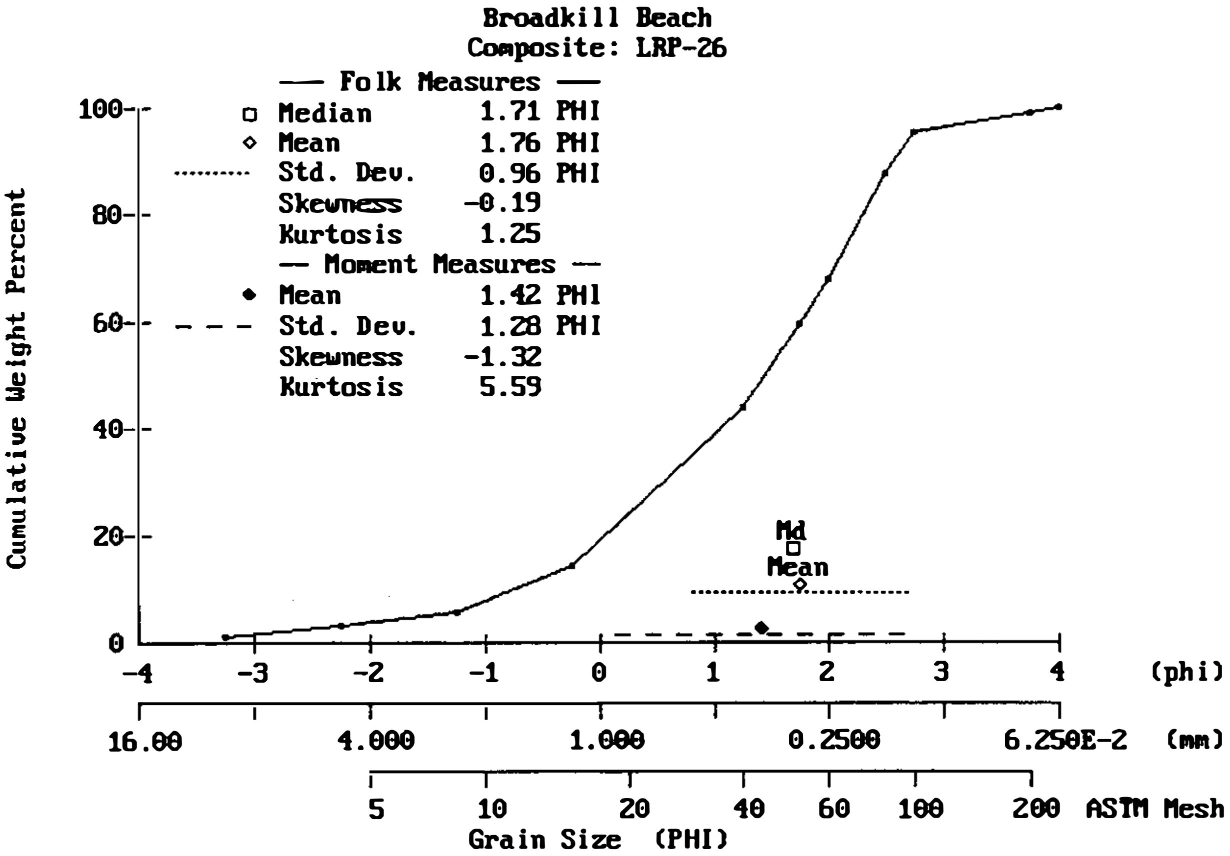
Composite to 16'
Composite: KAV-43
--- Folk Measures ---
Median 1.91 PHI
Mean 1.53 PHI
Std. Dev. 1.75 PHI
Skewness -0.49
Kurtosis 3.74
-- Moment Measures --
Mean 1.02 PHI
Std. Dev. 2.08 PHI
Skewness -1.42
Kurtosis 4.59
Probability Wgt Percent
99.99
99.95
99.9
99.5
99.
95.
90.
70.
50.
30.
10.
5.
1.
0.5
0.1
0.05
0.01
Md
Mean
-5 -4 -3 -2 -1 0 1 2 3 4 5 (phi)
32.00 8.000 2.000 0.5000 0.1250 3.125E-2 (mm)
5 10 20 40 60 100 200 ASTM Mesh
Grain Size (PHI)


Composite to 14'
Composite: KAV-45
— Folk Measures —
Median 1.91 PHI
Mean 1.70 PHI
Std. Dev. 1.79 PHI
Skewness -0.32
Kurtosis 3.73
— Moment Measures —
Mean 1.54 PHI
Std. Dev. 1.75 PHI
Skewness -1.28
Kurtosis 5.30
Probability Wgt Percent
Md
Mean
(phi)
(mm)
ASTM Mesh
Grain Size (PHI)

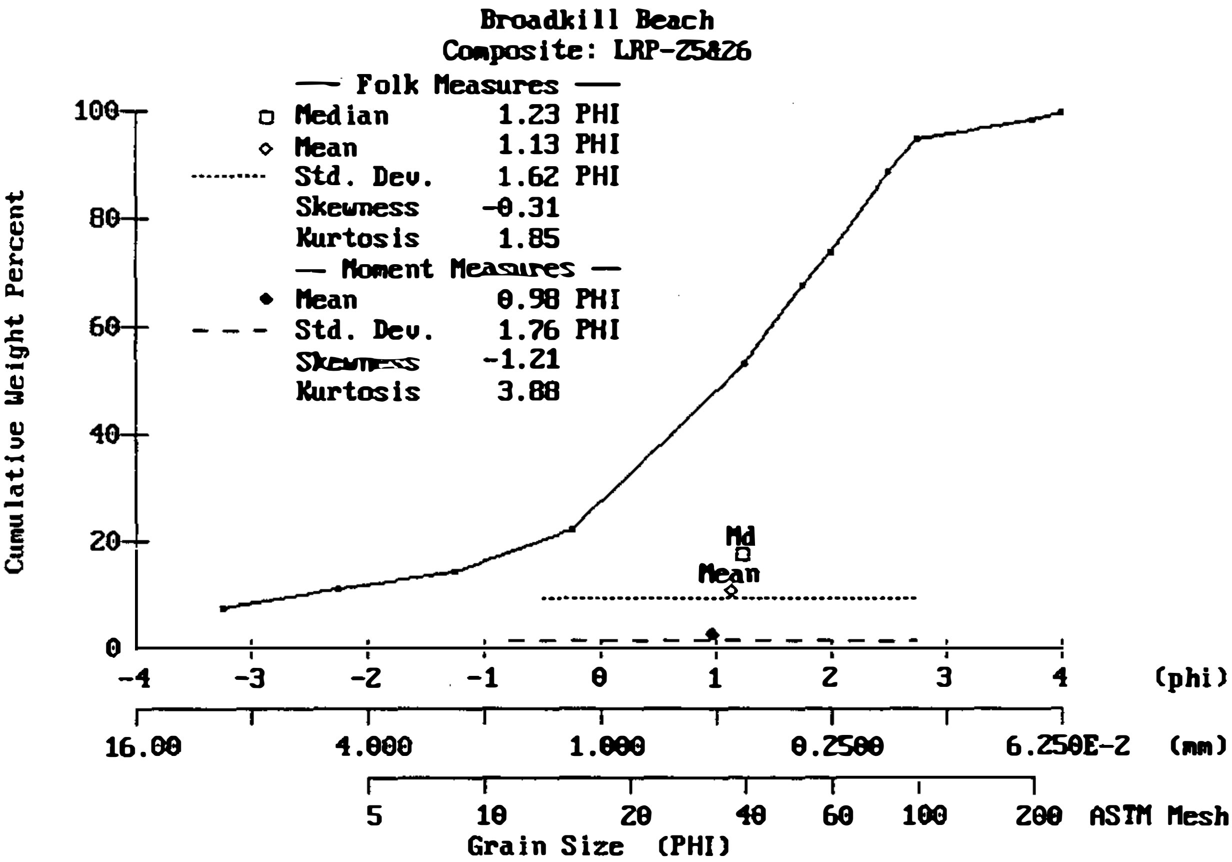

Composite
Composite: KAV-41, 43
— Folk Measures —
Median 1.90 PHI
Mean 1.12 PHI
Std. Dev. 2.02 PHI
Skewness -0.59
Kurtosis 3.65
— Moment Measures —
Mean 0.86 PHI
Std. Dev. 2.11 PHI
Skewness -1.38
Kurtosis 4.04
Probability Wgt Percent
99.99
99.95
99.9
99.5
99.
95.
90.
70.
50.
30.
10.
5.
1.
0.5
0.1
0.05
0.01
Md
Mean
-5 -4 -3 -2 -1 0 1 2 3 4 5 (phi)
32.00 8.000 2.000 0.5000 0.1250 3.125E-2 (mm)
5 10 20 40 60 100 200 ASTM Mesh
Grain Size (PHI)


KAV-41, KAV-43 and KAV-18
Composite: Composite
— Folk Measures —
Median 1.06 PHI
Mean -0.14 PHI
Std. Dev. 2.52 PHI
Skewness -0.59
Kurtosis 1.27
— Moment Measures —
Mean 0.17 PHI
Std. Dev. 2.47 PHI
Skewness -1.04
Kurtosis 3.10
Probability Wgt Percent
99.99
99.95
99.9
99.5
99.
95.
90.
70.
50.
30.
10.
5.
1.
0.5
0.1
0.05
0.01
Md
Mean
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 (phi)
64.00 16.00 4.000 1.000 0.2500 6.250E-2 (mm)
5 10 20 40 60 100 200 ASTM Mesh
Grain Size (PHI)


Broadkill Beach
Composite: LRP-25
— Folk Measures —
Median 1.20 PHI
Mean 0.47 PHI
Std. Dev. 2.12 PHI
Skewness -0.48
Kurtosis 1.24
— Moment Measures —
Mean 0.60 PHI
Std. Dev. 2.01 PHI
Skewness -0.89
Kurtosis 2.72
Cumulative Weight Percent
Md
Mean
(phi)
(mm)
ASTM Mesh
Grain Size (PHI)



Broadkill Beach
Composite: LRP-26
— Folk Measures —
Median 1.71 PHI
Mean 1.76 PHI
Std. Dev. 0.96 PHI
Skewness -0.19
Kurtosis 1.25
— Moment Measures —
Mean 1.42 PHI
Std. Dev. 1.28 PHI
Skewness -1.32
Kurtosis 5.59
Md
Mean
Cumulative Weight Percent
100
80
60
40
20
0
-4 -3 -2 -1 0 1 2 3 4 (phi)
16.00 4.000 1.000 0.2500 6.250E-2 (mm)
5 10 20 40 60 100 200 ASTM Mesh
Grain Size (PHI)


Broadkill Beach
Composite: LRP-25&26
— Folk Measures —
Median 1.23 PHI
Mean 1.13 PHI
Std. Dev. 1.62 PHI
Skewness -0.31
Kurtosis 1.85
— Moment Measures —
Mean 0.98 PHI
Std. Dev. 1.76 PHI
Skewness -1.21
Kurtosis 3.88
Cumulative Weight Percent
100
80
60
40
20
0
Md
Mean
-4 -3 -2 -1 0 1 2 3 4 (phi)
16.00 4.000 1.000 0.2500 6.250E-2 (mm)
5 10 20 40 60 100 200 ASTM Mesh
Grain Size (PHI)

BEACH FILL OVERFILL RATIO AND VOLUME

Initial Volume	VOLI:	1.000 YD3
Native Mean	Nmean:	0.980 PHI
Native Standard Deviation	Nstd:	1.760 PHI
Borrow Mean	Bmean:	0.960 PHI
Borrow Standard Deviation	Bstd:	1.930 PHI
Overfill Ratio	Ra:	1.042
Renourishment Ratio	Rj:	0.893
Design Volume	VOLD:	1.042 YD3

KAV-41

BEACH FILL OVERFILL RATIO AND VOLUME

Initial Volume	VOLI:	1.000	YD3
Native Mean	Nmean:	0.980	PHI
Native Standard Deviation	Nstd:	1.760	PHI
Borrow Mean	Bmean:	1.020	PHI
Borrow Standard Deviation	Bstd:	2.080	PHI
Overfill Ratio	Ra:	1.093	
Renourishment Ratio	Rj:	0.839	
Design Volume	VOLD:	1.093	YD3

KAV-43

BEACH FILL OVERFILL RATIO AND VOLUME

Initial Volume	VOLI:	1.000 YD3
Native Mean	Nmean:	0.980 PHI
Native Standard Deviation	Nstd:	1.760 PHI
Borrow Mean	Bmean:	1.540 PHI
Borrow Standard Deviation	Bstd:	1.750 PHI
Overfill Ratio	Ra:	1.496
Renourishment Ratio	Rj:	1.382
Design Volume	VOLD:	1.496 YD3

KAV-45

BEACH FILL OVERFILL RATIO AND VOLUME

Initial Volume	VOLI:	1.000	YD3
Native Mean	Nmean:	0.980	PHI
Native Standard Deviation	Nstd:	1.760	PHI
Borrow Mean	Bmean:	0.780	PHI
Borrow Standard Deviation	Bstd:	2.280	PHI
Overfill Ratio	Ra:	1.090	
Renourishment Ratio	Rj:	0.636	
Design Volume	VOLD:	1.090	YD3

KAV-11, KAV-18 & KAV-19 COMPOSITE

BEACH FILL OVERFILL RATIO AND VOLUME

Initial Volume	VOLI:	1.000 YD3
Native Mean	Nmean:	0.980 PHI
Native Standard Deviation	Nstd:	1.760 PHI
Borrow Mean	Bmean:	0.420 PHI
Borrow Standard Deviation	Bstd:	2.340 PHI
Overfill Ratio	Ra:	1.055
Renourishment Ratio	Rj:	0.496
Design Volume	VOLD:	1.055 YD3

KAV-11 & KAV-18 COMPOSITE

KAV-11 & 18
composite

BEACH FILL OVERFILL RATIO AND VOLUME

Initial Volume	VOLI:	1.000 YD3
Native Mean	Nmean:	0.980 PHI
Native Standard Deviation	Nstd:	1.760 PHI
Borrow Mean	Bmean:	0.410 PHI
Borrow Standard Deviation	Bstd:	2.570 PHI
Overfill Ratio	Ra:	1.093
Renourishment Ratio	Rj:	0.411
Design Volume	VOLD:	1.093 YD3

KAV-18 & KAV-19 COMPOSITE

BEACH FILL OVERFILL RATIO AND VOLUME

nitial Volume	VOLI:	1.000 YD3
.ative Mean	Nmean:	0.980 PHI
Native Standard Deviation	Nstd:	1.760 PHI
Borrow Mean	Bmean:	1.490 PHI
Borrow Standard Deviation	Bstd:	1.660 PHI
Overfill Ratio	Ra:	1.517
Renourishment Ratio	Rj:	1.412
Design Volume	VOLD:	1.517 YD3

KAV-11 & KAV-19 COMPOSITE

BEACH FILL OVERFILL RATIO AND VOLUME

Initial Volume	VOLI:	1.000 YD3
Native Mean	Nmean:	0.980 PHI
Native Standard Deviation	Nstd:	1.760 PHI
Borrow Mean	Bmean:	0.170 PHI
Borrow Standard Deviation	Bstd:	2.470 PHI
Overfill Ratio	Ra:	1.052
Renourishment Ratio	Rj:	0.389
Design Volume	VOLD:	1.052 YD3

KAV-41, KAV-43 & KAV-18 COMPOSITE

BEACH FILL OVERFILL RATIO AND VOLUME

~nitial Volume	VOLI:	1.000 YD3
,ative Mean	Nmean:	0.980 PHI
Native Standard Deviation	Nstd:	1.760 PHI
Borrow Mean	Bmean:	0.860 PHI
Borrow Standard Deviation	Bstd:	2.110 PHI
Overfill Ratio	Ra:	1.067
Renourishment Ratio	Rj:	0.751
Design Volume	VOLD:	1.067 YD3

KAV-41 & KAV-43 COMPOSITE

SECTION 5

ENVIRONMENTAL AND CULTURAL INVESTIGATIONS

ENVIRONMENTAL INVESTIGATION

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FINAL REPORT

Delaware Bay Coastline — Broadkill Beach Interim Feasibility Study, Sussex County Delaware: Benthic Animal Assessment of Potential Borrow Source

by

Roy K. Kropp
Battelle Ocean Sciences
397 Washington Street
Duxbury, MA 02332

for

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Research Triangle Park, NC 27709

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Forty benthic grab samples were collected from two potential borrow areas and two control sites near Broadkill Beach in Delaware Bay, DE. Samples were analyzed for benthic macrofauna, sediment grain size distribution and total organic carbon content. Potential Borrow Area "A" had a very high sand content and was characterized by high infaunal abundance and low species diversity. Characteristic organisms included the small clam *Gemma gemma*, which occurred at very high densities, and haustoriid amphipods. The high density of *Gemma gemma* in Potential Borrow Area "A" contributed to the low diversity values obtained for the area. Actually, Potential Borrow Area "A" had slightly more species per station than Potential Borrow Area "B". Potential Borrow Area "B" was less sandy than Area "A" and was characterized by low infaunal abundance and relatively high species diversity. Characteristic organisms included the small snail *Acteocina canaliculata* and ampeliscid amphipods.

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Purpose/Objective

Broadkill Beach, which is located on a 3-mile stretch of shoreline in lower Delaware Bay, is subject to hurricanes and shoreline erosion. As a predominately summer resort, the beach is used extensively by the Broadkill Beach community for summer recreation. Beach nourishment is necessary to repair hurricane damage and to protect the shore (i.e., increase the portion of beach that is exposed during high tide.) for continued recreational use. Possible sources of sediment for beach nourishment (i.e., borrow sources) are located offshore. The Broadkill Beach Interim Feasibility Study involves the investigation of these borrow sources for beach nourishment.

The primary focus of this investigation is to describe the benthic macroinvertebrate community within the proposed borrow areas and control sites for the the Broadkill Beach Interim Feasibility Study. The benthic macroinvertebrate community within the proposed borrow area is compared to the community in control sites. Data on the benthic macroinvertebrate assemblages provides a baseline within the borrow area, and may be used in the future to identify changes in species composition and abundance as a result of borrow activities. In addition, an evaluation of commercial/recreational macroinvertebrates and endangered or protected species is also necessary to minimize disruption to resident communities. Information on endangered or protected species residing in the area of the burrow site are identified and their residence times is summarized.

Materials and Methods

Sampling Sites

Benthic macroinvertebrates, sediment samples, and water-quality data were collected from two potential borrow areas (i.e., A and B) in Delaware Bay (Figures 1 and 2) that were selected by the Philadelphia District Army Corps of Engineers. Potential Borrow Area "A" covers about 312 acres and was defined by the following coordinates.

Delaware State Plane Coordinates	Longitude/Latitude
722395, 305225	75° 11' 03.0" W, 38° 50' 16.3"N
727078, 306921	75° 10' 03.8" W, 38° 50' 33.0"N
724619, 309377	75° 10' 34.8" W, 38° 50' 57.3"N
720580, 307037	75° 11' 25.9" W, 38° 50' 34.3"N

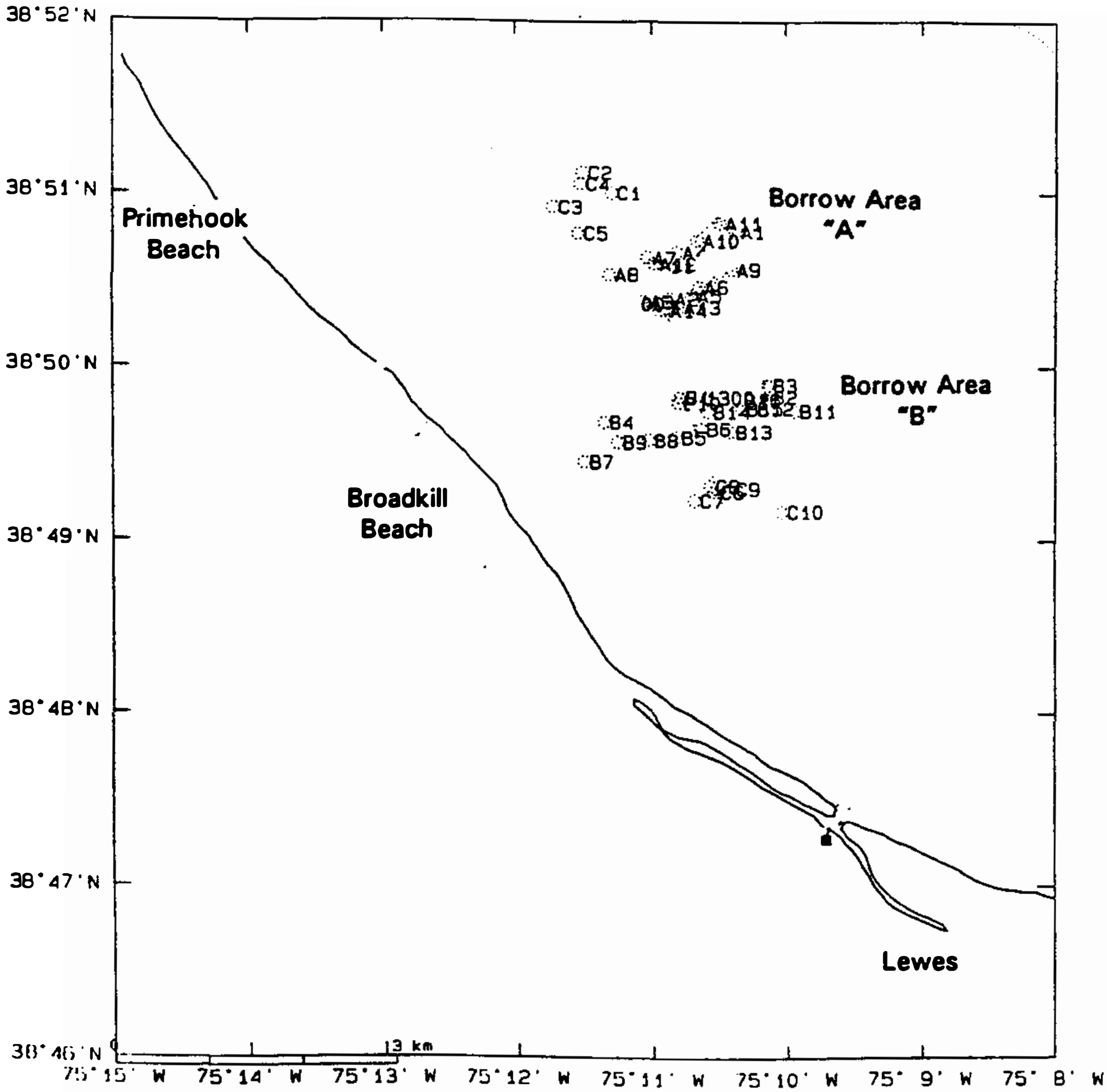

Figure 1. General location of the Broadkill Beach study area.

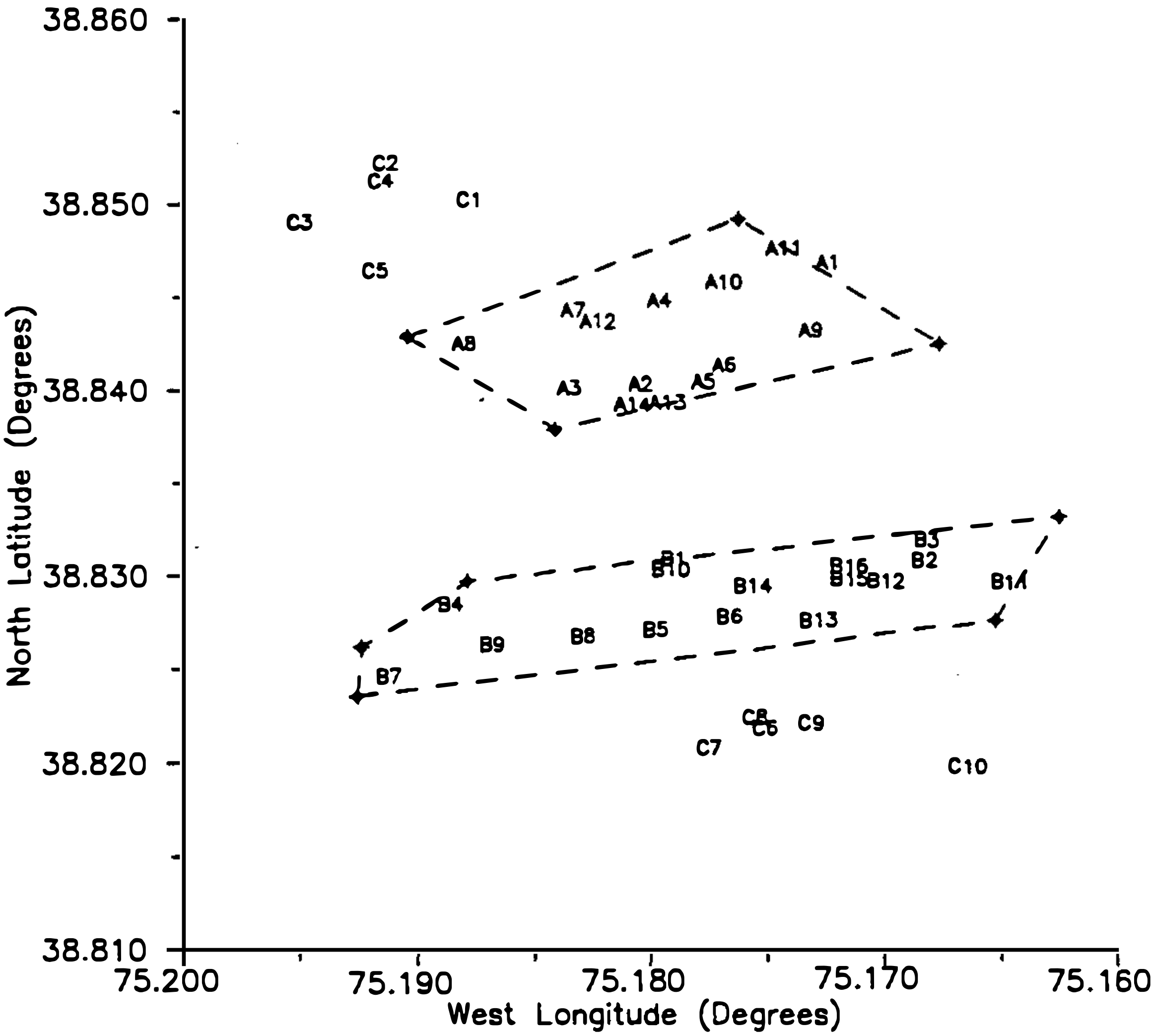

Figure 2. Locations of the sampling stations in the Broadkill Beach study area, 1994.

Within this area 14 stations were selected randomly by computer. The coordinates for each station in this area (designated A-1, etc.) are listed in Table 1.

Potential Borrow Area "B" covers about 349 acres and was defined by the following coordinates.

Delaware State Plane Coordinates	Longitude/Latitude
720000, 300000	75° 11' 33.4" W, 38° 49' 24.8"N
727780, 301481	75° 09' 55.1" W, 38° 49' 39.2"N
728541, 303528	75° 09' 45.4" W, 38° 49' 59.4"N
721336, 302245	75° 11' 16.5" W, 38° 49' 47.0"N
720072, 300982	75° 11' 32.5" W, 38° 49' 34.5"N

Within this area 16 stations were selected randomly. The coordinates for each station in this area (designated B-1, etc.) are listed in Table 1.

Ten "control" samples were taken from randomly-selected stations outside the borrow areas but within areas (i.e., control sites) that exhibit physical characteristics (i.e., depth and substrate) similar to those of the borrow areas. Five control stations were selected from an area just to the northwest of Potential Borrow Area "A". Five other control stations were selected from an area just to the south of Potential Borrow Area "B". The coordinates for each of these control stations (designated C-1, etc.) are given Table 1. Stations C-1 through C-5 were located to the northwest of Potential Borrow area "A"; stations C-6 through C-10 were located south of Potential Borrow Area "B".

Navigation

Northstar LORAN/GPS navigation system (15- 100 m accuracy) was used on board to accurately verify the sampling locations. The actual coordinates of each sampling station were recorded on station log forms.

The navigation system was calibrated at Battelle prior to departure for the survey. At Lewes, Delaware, the calibration was checked at the dock before the start and at the completion of each day's sampling activities.

The Battelle Ocean Sampling System (BOSS) acquired data for all on-board electronic sampling systems and navigation systems. The software displayed all of the information

Table 1. Station coordinates and depths for sites sampled during the Broadkill Beach replenishment study, 1994.

Station	West Longitude	North Latitude	Depth (m)	Station	West Longitude	North Latitude	Depth (m)	Station	West Longitude	North Latitude	Depth (m)
Potential Borrow Area A				Potential Borrow Area B				Control Sites			
A1	75.1730°	38.8465°	3.5	B1	75.1796°	38.8306°	4.2	C1	75.1884°	38.8499°	3.3
A2	75.1810°	38.8400°	4.1	B2	75.1689°	38.8305°	4.3	C2	75.1920°	38.8519°	3.4
A3	75.1841°	38.8398°	2.5	B3	75.1888°	38.8316°	4.2	C3	75.1956°	38.8487°	3.7
A4	75.1802°	38.8445°	4.8	B4	75.1892°	38.8281°	4.4	C4	75.1922°	38.8509°	3.5
A5	75.1783°	38.8402°	4.4	B5	75.1804°	38.8268°	5.0	C5	75.1924°	38.8461°	3.9
A6	75.1774°	38.8411°	4.3	B6	75.1772°	38.8275°	4.3	C6	75.1757°	38.8215°	4.8
A7	75.1839°	38.8440°	4.8	B7	75.1918°	38.8243°	4.5	C7	75.1781°	38.6205°	5.1
A8	75.1888°	38.8422°	2.7	B8	75.1835°	38.8264°	5.2	C8	75.1761°	38.8221°	4.9
A9	75.1737°	38.8429°	3.8	B9	75.1874°	38.8260°	4.9	C9	75.1737°	38.8218°	5.2
A10	75.1777°	38.8455°	4.1	B10	75.1800°	38.8300°	4.4	C10	75.1673°	38.8195°	4.9
A11	75.1751°	38.8473°	3.3	B11	75.1655°	38.8293°	4.6				
A12	75.1831°	38.8434°	4.4	B12	75.1708°	38.8294°	4.1				
A13	75.1801°	38.8390°	4.3	B13	75.1737°	38.8273°	4.2				
A14	75.1816°	38.8389°	3.7	B14	75.1765°	38.8291°	4.3				
				B15	75.1724°	38.8295°	4.4				
				B16	75.1724°	38.8302°	4.2				

once per second on a color monitor and automatically wrote the data to a data file. The navigation portion of the display showed digitized coastlines, navigation aids, sampling statistics and vessel track. During grab sampling, position fixes were recorded at 2-s intervals. Hard-copy printouts of position fixes were made during grab sampling events or at the start of a hydrocast.

Sample Collection

The survey was conducted July 1-2, 1994 onboard the R/V *Surveysa.* A tide chart for the dates of the survey is provided in Appendix A.

Water/Miscellaneous—Once the survey vessel was on station and coordinates were verified, the vessel was anchored, and water-quality data were collected. An Ocean Sensor OS-100 CTD was used to obtain temperature, salinity, and depth data. The CTD also was equipped with sensors to measure dissolved oxygen (DO; Beckman Module S/N DO sensor) and pH (Innovative Sensors). Data were recorded at a rate of 4 hz during downcast of the CTD package, which was lowered slowly until it contacted the bay bottom.

Sediment—At each station, one sediment sample was collected using a 0.1 m^2 Young-modified Van Veen grab sampler. After collection of the water-quality data, the sediment grab was deployed. Upon retrieval of the grab, the sample was inspected for acceptability. The sample was acceptable if (1) the jaws of the grab were closed properly, (2) the sampler was more than half full, but the sediment did not touch the upper surface, and (3) the surface of the sediment was not significantly disturbed and the sample was even from side-to-side. If the grab was unacceptable, it was emptied, rinsed with filtered seawater and redeployed. If the grab was acceptable, the penetration depth and sediment texture was estimated and recorded. A small subsample was removed for grain-size analysis (see below). The grab was placed over a bucket, the jaws were opened, and filtered seawater was used to gently wash the sample into the bucket.

To provide sediment for grain-size analysis, a standard chemistry scoop was used to extract a small (~150 ml) subsample from each grab. The sediment was transferred to a precleaned sample jar, the subsample properly labeled, and placed immediately in ice filled coolers for storage and transport to shore. On shore the samples were stored in a freezer (4 °C). After the survey, samples were returned (in ice filled coolers) to Battelle for shipment to the appropriate subcontractors.

Each sample was placed into a 0.5-mm-mesh sieve bucket. The sieve bucket was agitated in a large trash can one-half to three-quarters full of filtered seawater. After removal of most of the fine sediment, the remaining sample was poured through a funnel into the appropriate-size jar. Jars were not filled more than three-quarters full to avoid damage to animals. The sieve bucket was carefully examined to ensure that no organisms are remaining, and then backwashed before the next sample was processed. The water in the trash cans was changed between each station.

Each sample was transferred to a clean, labelled jar. A magnesium chloride solution (about 7%) was poured into the sample jar to a level that covered the sample material and allowed to sit for about 0.5 h. After that time, concentrated, buffered, Rose Bengal-stained formaldehyde was added to a final concentration of 10% by volume. After addition of the magnesium chloride and the formaldehyde, the sample jar was turned so that the chemicals mixed to the bottom of the jar. Samples were kept out of the sun during both "relaxation" and after preservation.

Laboratory Analyses

Water Quality—Water-quality data were recorded directly into computer files by the BOSS. Although no subsequent analysis was required, the data were summarized by clump averaging the recorded data.

Sediment Grain Size—Sediment grain-size analysis was performed by GeoPlan Associates according to methods presented in Folk (1974). Briefly, coarse and fine fractions were separated by wet-sieving. The fine fraction (silt and clay) was further separated by suspending the sediment in a deflocculant solution and taking aliquots of the settling sediment at timed intervals after the solution was thoroughly mixed. The coarse fraction (sand and gravel) was dried and then separated by sieving at whole phi intervals. For each station, graphical methods were used to calculate the phi (ϕ) size at the 16^{th}, 50^{th}, and 84^{th} percentiles of the cumulative distribution curve. These values were used to calculate the graphical mean (M_z) and standard deviation according to the formulae:

$$M_z = \frac{phi16 + phi50 + phi84}{3}$$

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and,

$$sd = \frac{phi84 - phi16}{2}$$

Grain size was reported as percentage (based on dry weight) of each fraction (gravel, sand, and mud) of the total sample weight.

Total Organic Carbon (TOC)—Global Geochemistry Corporation used a LECO model 761-100 carbon analyzer to determine the TOC content of solid samples. The principle of operation was the high-temperature conversion of all carbon in the treated sample to carbon dioxide in the presence of oxygen. The carbon dioxide was then quantified by thermal conductivity detection. TOC data were reported as percent dry-weight.

Macrofauna—Sample analyses were conducted by Cove Corporation, Lusby, MD. Prior to being sorted, samples were rinsed with fresh water and transferred to 70% ethanol for storage. All intact macrofaunal species and body fragments identifiable to species level were removed from each sample. Dead bivalves (hinged shells and intact single valves) of commercial value (e.g., *Ensis, Tagelus, Spisula, Mercenaria*) were removed from the sample debris and counted. Appropriate quality control procedures were followed.

Identification of all specimens was to the species level whenever possible. Juveniles or damaged specimens lacking the characters necessary for identification to species were identified to the next highest taxonomic level. Specimens that were counted had a critical part of its body present; for example, polychaetes and arthropods had the head, bivalves the umbo, and sea stars more than one-half the central disc present. Animals lacking these parts were considered fragments and not counted as part of the sample. Epifauna attached to shell fragments, pelagic contaminants, and pieces of colonial organisms were noted as present, but not counted. Each identified taxon was placed in its own labeled vial and stored.

The animals in each taxonomic unit were estimated for approximate length (greater than or equal to; or less than 2 cm in length). If individuals were fragmented, the length was approximated.

The wet-weight biomass of each major taxonomic category (Annelida, Arthropoda, Mollusca, Miscellaneous) was determined to 1-mg accuracy by using a calibrated electronic balance. Prior to weighing each taxon, the specimen was placed on absorbent paper toweling to blot dry. In an effort to obtain consistent weights, specimens were blot-dried for 2 min. However, the time required for blot-drying may have been less for small (e.g., amphipods), less numerous taxa. For larger taxa (e.g., hard clams), the shell was opened and water was drained before weighing. Weights of "megafauna," an individual specimen having a wet weight greater than 2 g (e.g., a larger specimen of *Cancer*), were recorded separately.

A reference collection of each taxonomic unit was provided to Battelle for presentation to the Philadelphia District Army Corps of Engineers. For this collection, a suitable representative (or representatives) of each taxonomic unit was placed in a properly labeled container containing 70% ethanol. Cove shall retain the sorted samples for a period of three (3) months after the issuance of the final report. After this period, sorted residues may be discarded. The reference collection and the identified infauna shall be returned to Battelle.

Macrofaunal Data Analysis

Calculations of numbers of species per sample, diversity, evenness, and dominance per sample, and similarity analyses included only taxa identified to species. Two taxa, Oligochaeta and *Polygordius* sp., although not identified to species were included in these analyses. The former was included because of its importance in early colonization, the latter because it is likely only one species. Other analyses, e.g., total and major taxon abundance, included all taxa collected.

Prior to starting faunal data analyses, the data set was scanned quickly to identify species or taxa that were predominant throughout the study area or in one of the potential borrow areas. These taxa were selected for individual analysis. Species selected were *Amastigos caperatus* (a capitellid polychaete), *Brania wellfleetensis* (a syllid polychaete), *Acteocina canaliculata* (a gastropod mollusc), *Gemma gemma* (a bivalve mollusc), *Nucula annulata* (a bivalve mollusc), and *Tellina agilis* (a bivalve mollusc). More inclusive taxa selected were, oligochaete worms, ampeliscid amphipods, and haustoriid amphipods.

Descriptive community ecological measures—the Shannon Diversity Index (H'), Pielou's evenness (J'), and Simpson's Dominance Index (λ)—were calculated using standard formulae (see Ludwig and Reynolds, 1988). The Shannon index, which is based on information theory, estimates the uncertainty of predicting the identity of an individual chosen at random from a sample. This uncertainty increases as the number of species in a sample increases and as the individuals in a sample become evenly allocated among the species. *H'* would have a value of 0 if there was only one species in a sample and would be at a maximum when all species in the sample have the same number of individuals. In practice, values of *H'* range from < 0 to just greater than 6. Evenness is an indication of the relative abundance of species. *J'* is calculated as the proportion between the measured Shannon diversity value for a sample and the maximum diversity value possible if the number of individuals in the sample were evenly distributed among the species. *J'* is at a maximum (1.0) when all species present are equally abundant. Simpson's Dominance Index, more properly known as Simpson's Diversity Index, estimates the likelihood that two individuals selected at random from the same sample belong to the same species. The index, which reaches a maximum of 1.0 when all individuals present in a sample belong to the same species, is calculated as the sum of the squared proportional abundance of each species in the sample. When community diversity is low, the Simpson Index is high.

The program PRARE1, written in 1972 by George Power for H. Sanders and F. Grassle at Woods Hole Oceanographic Institute and modified for the VAX in 1982 by T. Danforth), was used to calculate *H'* and *J'*. The spreadsheet program Quattro® Pro for Windows, version 5.0 (Borland, 1993) was used to produce graphs and to perform calculations of means, standard deviations, confidence intervals, and Pearson correlation coefficients (*r*). Similarity analyses were conducted on untransformed abundance data using the Bray-Curtis (Bray and Curtis, 1957) and Normalized Expected Species Shared (NESS: Grassle and Smith, 1976) algorithms. The two similarity measures were used because the Bray-Curtis measure is strongly influenced by very abundant taxa (Boesch, 1977), whereas NESS is more sensitive to the contribution made by rare taxa (Grassle and Smith, 1976). Clustering was accomplished with the unweighted pair-groups method using arithmetic averages (UPGMA; Sneath and Sokal, 1973; Gauch, 1982). The results are presented as dendrograms.

Results

Water Quality

Of the near-bottom water-quality parameters measured, temperature, salinity, and pH varied little throughout the Broadkill Beach study area. Near-bottom temperature ranged from 20.5-22.4 °C, salinity from 27.1-29.1 ‰, and pH from 8.2-8.4 (Table 2). Near-bottom dissolved oxygen ranged from 6.0-7.8 mg/L at stations in Potential Borrow Area "A" and from 6.9-8.0 mg/L (Table 2). Among the Control-Site stations, DO was relatively low at

Table 2. Near-bottom water-quality data collected during the Broadkill Beach replenishment study, 1994.

Station	Temp (° C)	Salinity (‰)	DO (mg/L)	pH	Station	Temp (° C)	Salinity (‰)	DO (mg/L)	pH	Station	Temp (° C)	Salinity (‰)	DO (mg/L)	pH
A1	21.2	28.3	6.8	8.4	B1	21.0	29.1	6.9	8.3	C1	21.1	28.1	6.5	8.3
A2	22.1	28.3	7.1	8.3	B2	22.3	28.6	7.0	8.3	C2	21.0	28.2	4.8	8.2
A3	22.4	28.5	6.5	8.3	B3	22.2	28.6	6.8	8.3	C3	21.2	28.5	5.6	8.2
A4	21.1	28.8	7.1	8.3	B4	21.4	29.1	8.0	8.4	C4	21.0	28.2	6.5	8.3
A5	22.1	28.1	6.7	8.4	B5	20.7	29.2	7.6	8.3	C5	21.2	28.6	6.1	8.2
A6	22.1	28.1	7.1	8.4	B6	21.1	29.1	7.1	8.3	C6	21.0	28.9	7.1	8.2
A7	20.9	28.6	6.3	8.2	B7	22.1	28.6	7.7	8.3	C7	21.2	29.0	7.1	8.3
A6	21.2	28.6	6.0	8.2	B6	20.9	29.1	7.3	8.3	C8	21.0	29.0	7.6	8.2
A9	21.8	28.2	7.2	8.4	B9	21.3	29.1	7.8	8.3	C9	20.8	28.6	7.5	8.3
A10	21.9	28.2	7.8	8.4	B10	20.8	29.1	7.4	8.3	C10	20.5	29.0	7.3	8.3
A11	21.3	28.3	7.3	8.4	B11	21.4	28.7	7.2	8.3					
A12	20.9	27.1	7.1	8.3	B12	21.9	28.8	7.5	8.3					
A13	22.1	28.2	7.0	8.3	B13	21.0	29.1	7.3	8.3					
A14	22.3	28.4	6.7	8.3	B14	20.9	29.1	—*	8.3					
					B15	21.3	29.0	7.2	8.3					
					B16	21.7	28.6	7.4	8.3					

* No Data.

Stations C-2 (4.8 mg/L) and C-3 (5.6 mg/L), but ranged from 6.1-7.6 mg/L at the remaining stations. Complete water-quality data are listed in Appendix B.

Sediments

At one control site, Station C-3, sediments in the grab sampler were strongly layered, with a layer of fine sediment over sand. A grain-size and TOC sample was taken from each layer. Although the data for each layer are reported in Table 3, they were excluded from subsequent analyses.

Grain Size— Cumulative distribution plots of sediment grain size at each station are presented in Appendix C. Sediments in Potential Borrow Area "A" were very coarse to medium sands, with graphic means (M_z) ranging from -0.10 (Station A-7) to 1.60 ϕ (Stations A-1 and A-11; Table 3). At most stations in Potential Borrow Area "A", sediments were moderately to well sorted, but were poorly sorted at Stations A-4, A-5, and A-7 (Table 3). The mud fraction (% silt + % clay) ranged from 0 to 3.6 %.

Sediments in Potential Borrow Area "B" were finer than those in Potential Borrow Area "A", ranging from coarse to fine sand. Graphic means in Potential Borrow Area "B" ranged from 0.40 (Station B-4) to 2.75 ϕ (Station B-5). At stations B-4 and B-9, sediments were poorly sorted, whereas at the remaining stations in Potential Borrow Area "B", sediments were moderately to very well sorted. The mud fraction in Potential Borrow Area "B" (% silt + % clay) ranged from about 2 to 51% (Table 3). At four stations (Stations B-5, B-7, B-8, and B-) the mud fraction exceeded 25%.

Sediments in the two Control Sites were generally similar to those in adjacent borrow areas. At the northern Control Site, sediments ranged from very coarse sand to medium sand with M_z ranging from -0.25 to 1.45 ϕ (Table 3). In this area, sediments were poorly (Station C-5) to moderately well sorted (Station C-4). The mud fraction ranged from 0 to 17.6% (excluding Station C-3 as discussed above). Sediments in the southern Control Site ranged from fine to very fine sand with M_z ranging from 2.70 (Stations C-7 and C-10) to 3.05 ϕ (Station C-6). The mud fraction in this area ranged from 14.5 to 43.3 %. Sediments here were moderately to very well sorted.

TOC—Sediment TOC levels in the study area were relatively low. In Potential Borrow Area "A", TOC ranged from below-detection-limit to 0.06% (Table 3). In Potential Borrow Area

Table 3. Sediment percent composition, sorting, graphic mean statistics, and TOC content in the Broadkill Beach study area, 1994.

Station	% Gravel	% Sand	% Mud	Graphic Mean	Standard Deviation	Sorting	Phi 16	Phi 50	Phi 84	TOC (%)
A1	0.0	100.0	0.0	1.60	0.60	MWS	1.2	2.0	2.4	BDL
A2	1.2	97.8	1.0	1.00	0.50	WS	0.7	1.3	1.7	BDL
A3	0.6	99.1	0.3	1.20	0.85	MS	0.6	1.8	2.3	BDL
A4	6.5	92.3	1.2	0.45	1.05	PS	-0.2	1.1	1.9	BDL
A5	9.2	90.1	0.7	0.35	1.10	PS	-0.3	1.0	1.9	0.02
A6	5.1	91.3	3.6	0.50	0.95	MS	-0.1	1.1	1.8	0.03
A7	20.2	76.5	3.3	-0.10	1.35	PS	-1.0	0.8	1.7	0.06
A8	0.1	97.9	2.0	1.10	0.40	WS	0.9	1.3	1.7	0.02
A9	0.2	99.8	0.0	1.25	0.65	MWS	0.9	1.6	2.2	BDL
A10	0.2	99.8	0.0	1.20	0.45	WS	1.0	1.4	1.9	BDL
A11	0.0	100.0	0.0	1.60	0.50	WS	1.3	1.9	2.3	BDL
A12	0.7	96.4	2.9	0.90	0.75	MS	0.5	1.3	2.0	0.01
A13	1.6	96.1	2.3	0.75	0.95	MS	0.2	1.3	2.1	BDL
A14	0.2	97.2	2.6	1.35	0.65	MWS	1.0	1.7	2.3	BDL
B1	0.3	82.1	17.6	1.90	0.60	MWS	1.6	2.2	2.8	0.36
B2	0.6	89.8	9.5	2.10	0.55	MWS	1.8	2.4	2.9	0.13
B3	0.2	98.0	1.8	2.10	0.35	VWS	1.9	2.3	2.6	0.01
B4	3.5	89.3	7.2	0.40	1.10	PS	-0.1	0.9	2.1	0.04
B5	0.8	73.3	25.9	2.75	0.50	WS	2.4	3.1	3.4	0.54
B6	0.1	92.0	7.9	2.40	0.35	VWS	2.2	2.6	2.9	0.13
B7	1.0	63.8	35.2	0.55	0.90	MS	0.1	1.0	1.9	1.27
B8	0.4	48.9	50.7	2.65	0.55	MWS	2.2	3.1	3.3	1.07
B9	3.0	91.0	6.0	1.30	1.15	PS	0.5	2.1	2.8	0.68
B10	0.2	90.2	9.6	2.25	0.45	WS	2.0	2.5	2.9	0.21
B11	0.4	81.4	18.2	2.55	0.45	WS	2.3	2.8	3.2	0.33
B12	0.6	84.4	15.0	2.30	0.40	WS	2.1	2.5	2.9	0.26
B13	0.6	87.7	11.7	2.40	0.35	VWS	2.2	2.6	2.9	0.24
B14	0.5	89.0	10.5	2.30	0.40	WS	2.1	2.5	2.9	0.16
B15	0.3	89.3	10.4	2.15	0.55	MWS	1.9	2.4	3.0	0.17
B16	0.2	61.4	38.5	2.05	0.55	MWS	1.8	2.3	2.9	0.89
C1	0.1	99.9	0.0	1.25	0.75	MS	0.8	1.7	2.3	BDL
C2	0.0	99.1	0.9	1.45	0.45	WS	1.2	1.7	2.1	BDL
C3	18.3	79.5	2.2	-0.15	1.60	PS	-1.1	0.8	2.1	2.89
C3	0.4	13.7	85.9	1.10	1.35	PS	0.4	1.8	3.1	0.01
C4	0.0	100.0	0.0	1.10	0.55	MWS	0.8	1.4	1.9	BDL
C5	16.9	65.4	17.6	-0.25	1.70	PS	-1.1	0.6	2.3	0.49
C6	0.0	66.0	34.0	3.05	0.25	VWS	2.9	3.2	3.4	0.64
C7	1.4	55.3	43.3	2.70	0.55	MWS	2.3	3.1	3.4	0.85
C8	0.2	63.2	36.6	3.00	0.30	VWS	2.8	3.2	3.4	0.76
C9	0.6	73.9	25.5	2.95	0.35	VWS	2.7	3.2	3.4	0.66
C10	0.1	85.5	14.5	2.70	0.45	WS	2.4	3.0	3.3	0.31

BDL: Below detection limit
VWS: Very well sorted
WS: Well sorted
MWS: Moderately well sorted
MS: Moderately sorted
PS: Poorly sorted

"B", TOC was a bit higher, ranging from 0.01 to 1.27%. At the control stations, (excluding Station C-3) TOC ranged from below-detection-limit to 0.85%.

Macrofaunal Communities

In this section, for all instances where a mean value is presented, the 95% confidence intervals are provided parenthetically.

Abundance—Total macrofaunal abundance per station in Potential Borrow Area "A" ranged from 350 individuals/0.1 m^2 at Station A-14 to 6836 individuals/0.1 m^2 at Station A-3 (Figure 3, Table 4). Mean total abundance within Potential Borrow Area "A" was 2126 (± 1114) individuals/0.1 m^2. The relative contribution of the major taxonomic groups varied considerably within this area. Annelid worms were the predominant component of the total macrofaunal abundance at seven other stations, contributing about 36% (Station A-14) to 88% (Station A-7) of the individuals present at those stations (Table 4). Molluscs were the most numerous major taxon at seven stations, contributing about 47% (Station A-2) to 93% (Station A-3) of the individuals present at those stations (Table 4). The contribution made by arthropods to total infaunal abundance in Potential Borrow Area "A" was relatively small, ranging from < 1% (Stations A-3 and A-12) to about 19% (Station A-1).

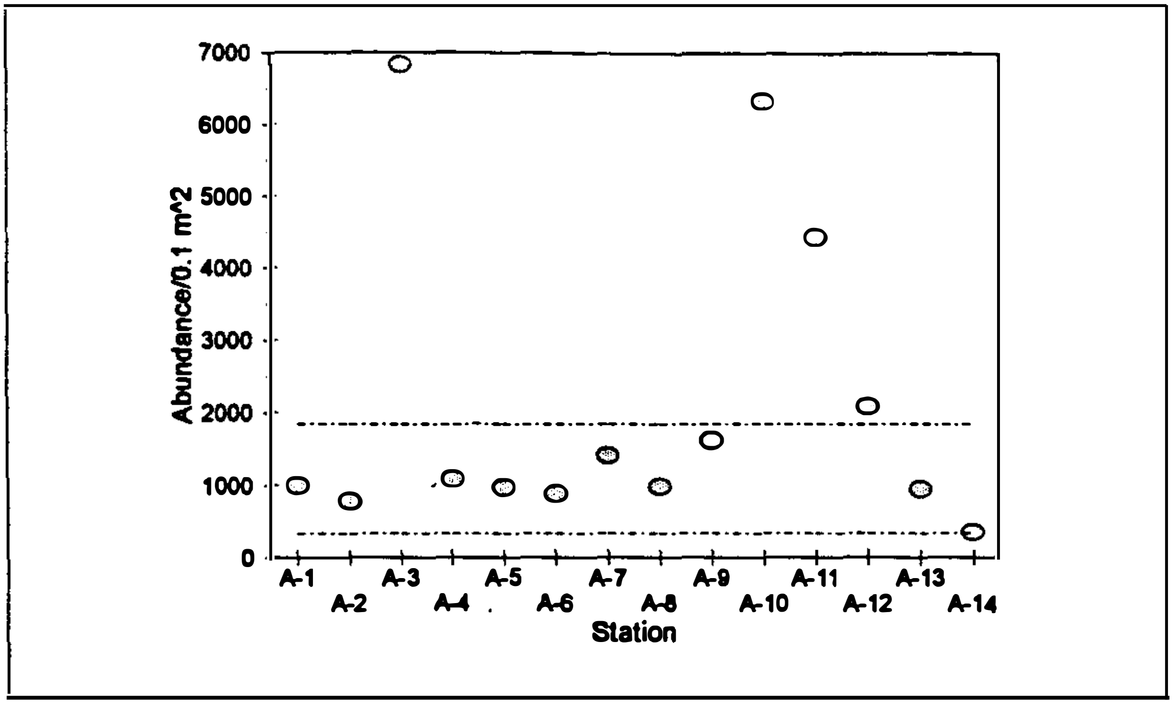
In Potential Borrow Area "B", total macrofaunal abundance ranged from 184 individuals/0.1 m^2 at Station B-1 to 648 individuals/0.1 m^2 at Station B-5 (Figure 3, Table 4). Mean total abundance within Potential Borrow Area "B" was 374 (± 68) individuals/0.1 m^2. Molluscs were the most numerous major taxon at 12 stations, contributing about 49% (Station B-1) to 83% (Station B-5) of the individuals present at those stations (Table 4). Annelid worms were the predominant component of the total macrofaunal abundance at four stations, contributing about 43% (Station B-6) to 81% (Station B-4) of the individuals present at those stations (Table 4). Although still not the predominant taxon at any station, the contribution made by arthropods was greater in Potential Borrow Area "B" than in Potential Borrow Area "A", ranging from about 2% (Station B-4) to 29% (Station B-15).

Infaunal abundance in the Control Sites ranged from 120 individuals/0.1 m^2 at Station C-5 to 3637 individuals/0.1 m^2 at Station C-2 (Table 4). Mean total abundance in the two Control Sites was 1085 (± 754) individuals/0.1 m^2. Molluscs were the predominant major taxon at all 10 Control-Site stations, contributing about 53% (Station C-10) to 88% (Station C-2) of the individuals present. Annelids contributed from 2% (Station C-2) to 21%

Table 4. Abundance (#/0.1 m²) and percent contribution of major taxonomic groups in the Broadkill Beach study area, 1994. Mean, standard deviation (STDS), and 95% confidence intervals (CI) are provided.

	Abundance					Percent contribution		
Station	Total	Annelide	Arthropods	Molluscs	Misc.	Annelide	Arthropods	Molluscs
A-1	1000	42	185	688	85	4.20%	18.50%	68.80%
A-2	795	288	20	370	109	36.43%	2.55%	47.13%
A-3	6836	226	23	6387	200	3.31%	0.34%	93.43%
A-4	1100	931	70	72	27	84.64%	6.36%	6.55%
A-5	980	742	28	206	4	75.71%	2.86%	21.02%
A-6	687	744	54	63	6	83.88%	6.09%	9.36%
A-7	1408	1246	60	110	2	88.49%	3.65%	7.81%
A-8	990	551	24	381	54	55.66%	2.42%	38.48%
A-9	1610	118	54	1200	238	7.33%	3.35%	74.53%
A-10	6339	63	126	5623	527	0.99%	1.99%	88.70%
A-11	4429	40	230	4097	62	0.90%	5.19%	92.50%
A-12	2096	1687	12	303	84	80.95%	0.57%	14.46%
A-13	949	791	42	100	16	83.35%	4.43%	10.54%
A-14	350	127	18	173	32	36.29%	5.14%	49.43%
Mean	2128	543	67	1412	103			
STDS	2127	509	67	2213	141			
95% CI	1114	267	35	1159	74			
B-1	184	71	21	90	2	38.59%	11.41%	48.91%
B-2	389	39	85	259	6	10.03%	21.85%	66.58%
B-3	482	346	21	113	2	71.78%	4.36%	23.44%
B-4	444	361	7	76	0	81.31%	1.58%	17.12%
B-5	648	84	15	542	7	12.96%	2.31%	83.64%
B-6	231	99	33	90	9	42.86%	14.29%	38.96%
B-7	405	283	56	66	0	69.88%	13.83%	16.30%
B-8	545	207	11	324	3	37.98%	2.02%	59.45%
B-9	334	74	24	231	5	22.16%	7.19%	69.16%
B-10	520	143	70	292	15	27.50%	13.46%	56.15%
B-11	493	112	92	271	18	22.72%	18.66%	54.97%
B-12	281	30	41	189	21	10.68%	14.59%	67.26%
B-13	293	80	22	186	5	27.30%	7.51%	63.48%
B-14	222	58	18	140	6	26.13%	8.11%	63.06%
B-15	313	34	91	173	15	10.86%	29.07%	55.27%
B-16	197	35	36	117	9	17.77%	18.27%	59.39%
Mean	374	129	40	197	8			
STDS	139	111	29	123	8			
95% CI	68	54	14	60	3			
C-1	3041	190	166	2073	612	6.25%	5.46%	68.17%
C-2	3637	90	253	3211	83	2.47%	6.96%	88.29%
C-3	121	25	18	69	9	20.66%	14.88%	57.02%
C-4	665	70	67	454	74	10.53%	10.08%	68.27%
C-5	120	23	26	65	6	19.17%	21.67%	54.17%
C-6	713	123	88	486	16	17.25%	12.34%	68.16%
C-7	639	134	15	476	12	20.97%	2.35%	74.90%
C-8	564	98	22	433	11	17.38%	3.90%	76.77%
C-9	719	110	8	590	11	15.30%	1.11%	82.06%
C-10	633	41	247	337	8	6.48%	39.02%	53.24%
Mean	1085	90	91	920	84			
STDS	1217	53	86	1012	188			
95% CI	754	33	60	627	116			

599



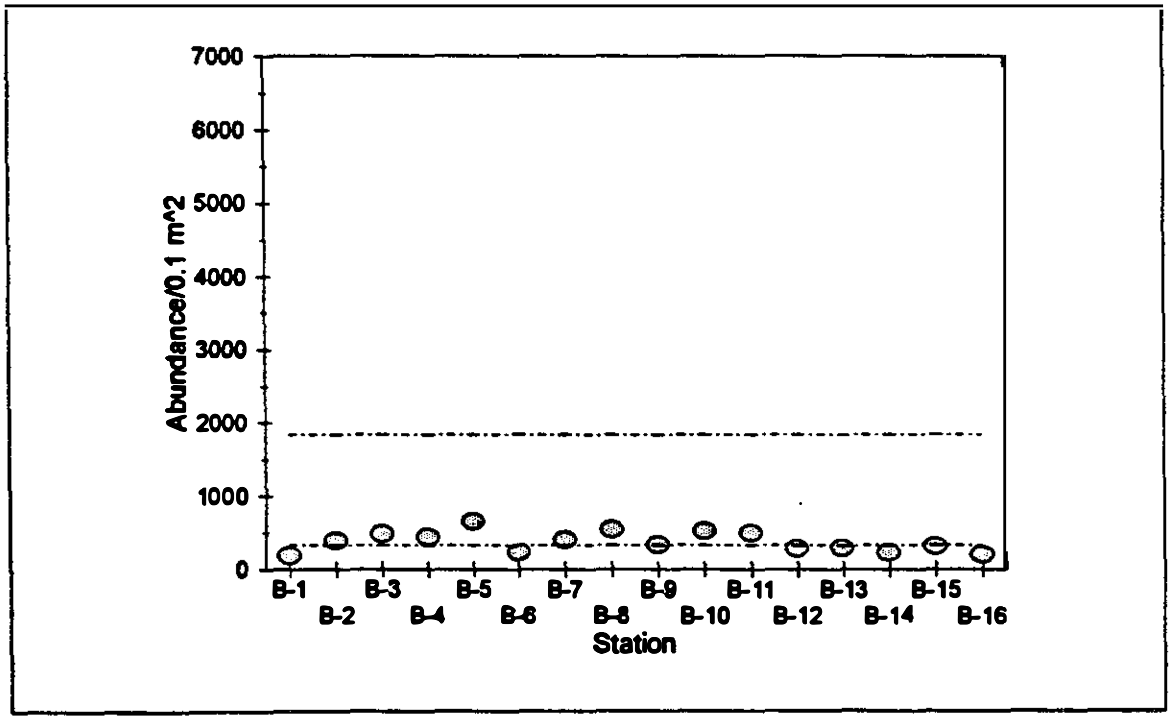


Figure 3. Macrofaunal abundance (#/0.1 m^2) at Potential Borrow Area "A" (top) and "B" (bottom) stations in relation to the range of values found at Control Sites (dashed lines) in the Broadkill Beach study area, 1994.

(Stations C-3 and C-7) and arthropods from 1% (Station C-9) to 39% (Station C-10) of the total macrofaunal abundance at the Control Sites.

Numbers of Species—The total number of species per sample in Potential Borrow Area "A" ranged from 21 at Station A-11 to 41 at Station A-7 (Figure 4, Table 5). The mean number of species in Potential Borrow Area "A" was 29 (± 3) species per station. At all stations the number of annelid species, which ranged from 43% (Station A-11) to 61% (Station A-7) of the total species identified, was greater than that of any other major taxon. The number of arthropod species ranked second to the number of annelid species at all stations except Station A-12.

The total number of species per sample in Potential Borrow Area "B" ranged from 15 at Station B-6 to 29 at Stations B-11 and B-15 (Figure 4, Table 5). The mean number of species in Potential Borrow Area "B" was 20 (± 2) species per station. The number of mollusc species was greater than that of any other major taxon at 10 stations, ranging from 38% (Station B-7) to 50% (Station B-9) of the total species identified at those stations. The number of annelid species identified was greater than the other major taxa at five stations (Table 5).

The total number of species per sample at the Control Sites ranged from 17 at Station C-9 to 33 at Station C-1 (Table 5). The mean number of species at the Control Sites was 23 (± 3) species per station. More mollusc species were found at five of the Control-Site stations than those of other major taxa. Annelid species were more numerous at four stations, ranging from 41% (Station B-7) to 50% (Station B-9) of the total species identified at those stations.

Community Indices—Species diversity (*H'*) at stations in Potential Borrow Area "A" was relatively low, ranging from 0.33 at Station A-10 to 3.04 at Station A-4 (Figure 5, Table 6). The mean species diversity in Potential Borrow Area "A" was 1.86 (± 0.53). Evenness (*J'*) at stations in Potential Borrow Area "A" ranged from 0.07 at Station A-10 to 0.62 at Station A-14 (Figure 5, Table 6). Simpson' Index (λ) in Potential Borrow Area "A" varied considrably, ranging from 0.20 to 0.91 (Table 6). The mean for the area was 0.50 (± 0.14).

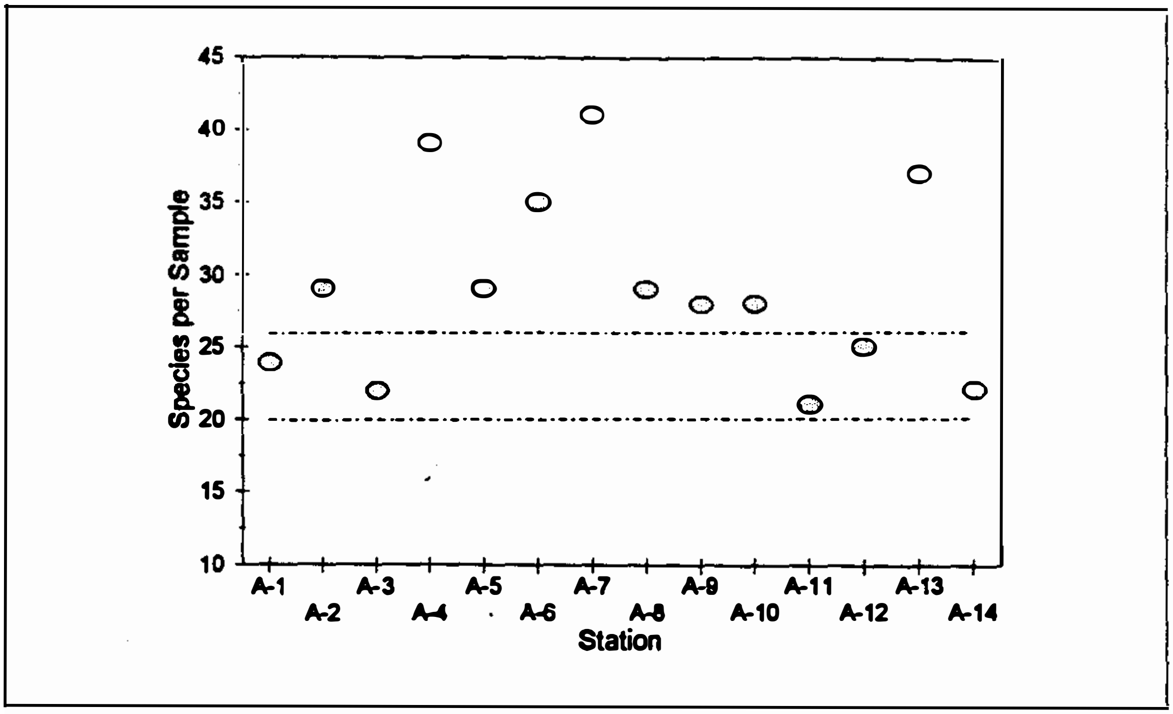
Species diversity (*H'*) at stations in Potential Borrow Area "B" was higher than at stations in Potential Borrow Area "A", ranging from 1.72 at Station B-7 to 3.30 at Station B-15 (Figure 5, Table 6). The mean species diversity in Potential Borrow Area "B" was 2.50 (± 0.18). Evenness (*J'*) at stations in Potential Borrow Area "B" ranged from 0.43 at

Table 5. Number of species and percent contribution of major taxonomic groups in the Broadkill Beach study area, 1994. Mean, standard deviation (STDS), and 95% confidence intervals (CI) are provided.

		Number of Species				Percent contribution		
Station	Total	Annelids	Arthropods	Molluscs	Misc.	Annelids	Arthropods	Molluscs
A-1	24	11	6	5	2	45.83%	25.00%	20.83%
A-2	29	13	11	4	1	44.83%	37.93%	13.79%
A-3	22	13	5	4	0	59.09%	22.73%	18.18%
A-4	39	20	13	6	0	51.28%	33.33%	15.38%
A-5	29	15	8	6	0	51.72%	27.59%	20.69%
A-6	35	21	9	5	0	60.00%	25.71%	14.29%
A-7	41	25	11	5	0	60.98%	26.83%	12.20%
A-8	29	16	8	4	1	55.17%	27.59%	13.79%
A-9	28	12	8	5	3	42.86%	28.57%	17.86%
A-10	28	15	8	4	1	53.57%	28.57%	14.29%
A-11	21	9	7	4	1	42.86%	33.33%	19.05%
A-12	25	15	4	6	0	60.00%	16.00%	24.00%
A-13	37	22	8	7	0	59.46%	21.62%	18.92%
A-14	22	12	6	4	0	54.55%	27.27%	18.18%
Mean	28	16	8	5	1			
STDS	6	5	2	1	1			
95% CI	3	2	1	1	0			
B-1	17	5	5	7	0	29.41%	29.41%	41.18%
B-2	17	4	6	7	0	23.53%	35.29%	41.18%
B-3	20	11	4	5	0	55.00%	20.00%	25.00%
B-4	19	12	2	5	0	63.16%	10.53%	26.32%
B-5	16	4	5	7	0	25.00%	31.25%	43.75%
B-6	15	5	4	6	0	33.33%	26.67%	40.00%
B-7	16	5	5	6	0	31.25%	31.25%	37.50%
B-8	17	5	4	8	0	29.41%	23.53%	47.06%
B-9	18	4	5	9	0	22.22%	27.78%	50.00%
B-10	25	10	4	11	0	40.00%	16.00%	44.00%
B-11	29	13	6	9	1	44.83%	20.69%	31.03%
B-12	23	8	6	9	0	34.78%	26.09%	39.13%
B-13	17	6	3	8	0	35.29%	17.65%	47.06%
B-14	18	8	3	7	0	44.44%	16.67%	38.89%
B-15	29	11	9	9	0	37.93%	31.03%	31.03%
B-16	21	8	5	8	0	38.10%	23.81%	38.10%
Mean	20	7	5	8	0			
STDS	4	3	2	2	0			
95% CI	2	2	1	1	0			
C-1	33	15	10	6	2	45.45%	30.30%	18.18%
C-2	29	13	10	5	1	44.83%	34.48%	17.24%
C-3	22	9	7	6	0	40.91%	31.82%	27.27%
C-4	21	12	5	3	1	57.14%	23.81%	14.29%
C-5	23	8	7	8	0	34.78%	30.43%	34.78%
C-6	22	7	5	10	0	31.82%	22.73%	45.45%
C-7	19	4	6	8	1	21.05%	31.58%	42.11%
C-8	20	4	6	9	1	20.00%	30.00%	45.00%
C-9	17	6	3	8	0	35.29%	17.65%	47.06%
C-10	22	7	7	8	0	31.82%	31.82%	36.36%
Mean	23	8	7	7	1			
STDS	5	4	2	2	1			
95% CI	3	2	1	1	0			

Table 6. Species diversity (*H'*), evenness (*J'*), and Simpson's Index (λ) at stations in the Broadkill Beach study area, 1994. Mean, standard deviation (STDS), and 95% confidence intervals (CI) are provided.

Station	*H'*	*J'*	λ	Station	*H'*	*J'*	λ	Station	*H'*	*J'*	λ
A-1	1.54	0.34	0.59	B-1	2.40	0.59	0.26	C-1	1.08	0.21	0.74
A-2	2.01	0.41	0.38	B-2	2.29	0.56	0.36	C-2	0.71	0.15	0.84
A-3	0.39	0.09	0.91	B-3	2.67	0.62	0.21	C-3	3.32	0.74	0.16
A-4	3.04	0.57	0.26	B-4	2.21	0.52	0.33	C-4	1.90	0.43	0.48
A-5	2.74	0.56	0.27	B-5	2.19	0.55	0.31	C-5	3.56	0.79	0.14
A-6	2.96	0.58	0.23	B-6	2.35	0.60	0.29	C-6	2.91	0.65	0.18
A-7	2.65	0.49	0.28	B-7	1.72	0.43	0.49	C-7	2.44	0.58	0.24
A-8	2.00	0.41	0.37	B-8	2.35	0.58	0.26	C-8	2.87	0.66	0.19
A-9	0.99	0.21	0.76	B-9	2.56	0.61	0.24	C-9	2.44	0.60	0.27
A-10	0.33	0.07	0.93	B-10	2.49	0.54	0.31	C-10	3.19	0.71	0.15
A-11	0.47	0.11	0.89	B-11	3.06	0.63	0.17				
A-12	1.40	0.30	0.59	B-12	2.73	0.60	0.26				
A-13	2.74	0.53	0.31	B-13	2.41	0.59	0.27				
A-14	2.78	0.62	0.20	B-14	2.56	0.61	0.25				
				B-15	3.30	0.68	0.16				
				B-16	2.79	0.63	0.26				
Mean	1.86	0.38	0.50		2.50	0.58	0.28		2.44	0.55	0.34
STDS	1.00	0.20	0.28		0.37	0.06	0.08		0.95	0.22	0.26
95% CI	0.53	0.10	0.14		0.18	0.03	0.04		0.59	0.14	0.16



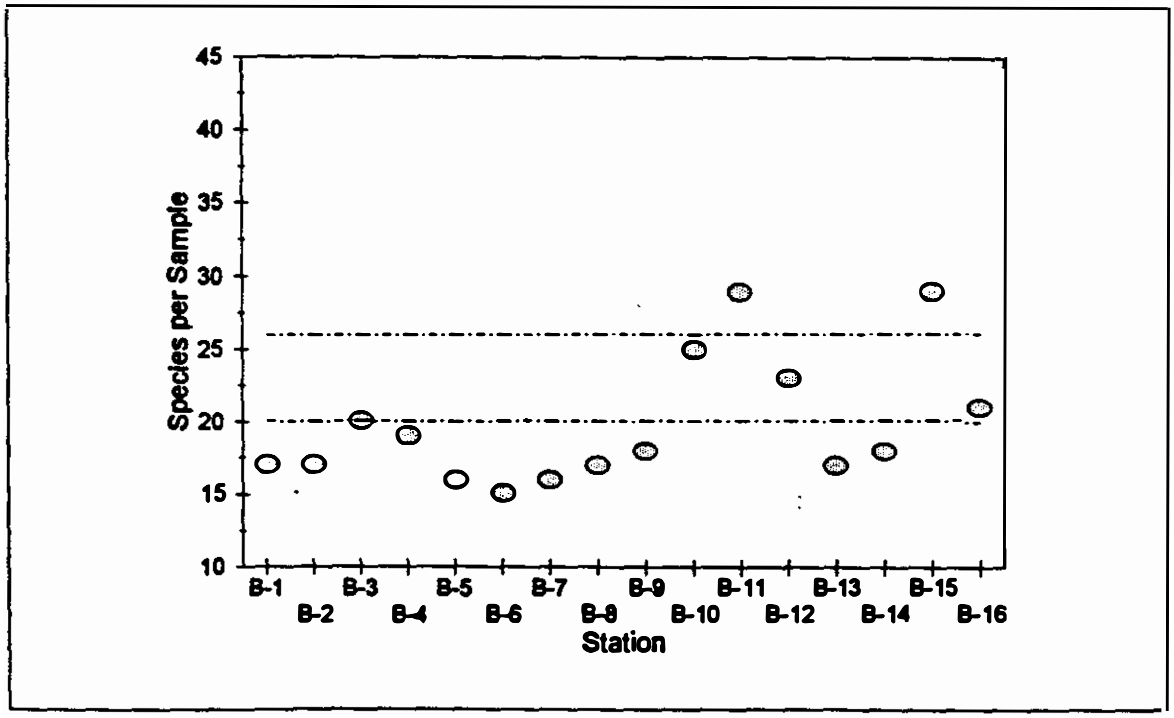


Figure 4. Macrofaunal species numbers at Potential Borrow Area "A" (top) and "B" (bottom) stations in relation to the range of values found at Control Sites (dashed lines) in the Broadkill Beach study area, 1994.

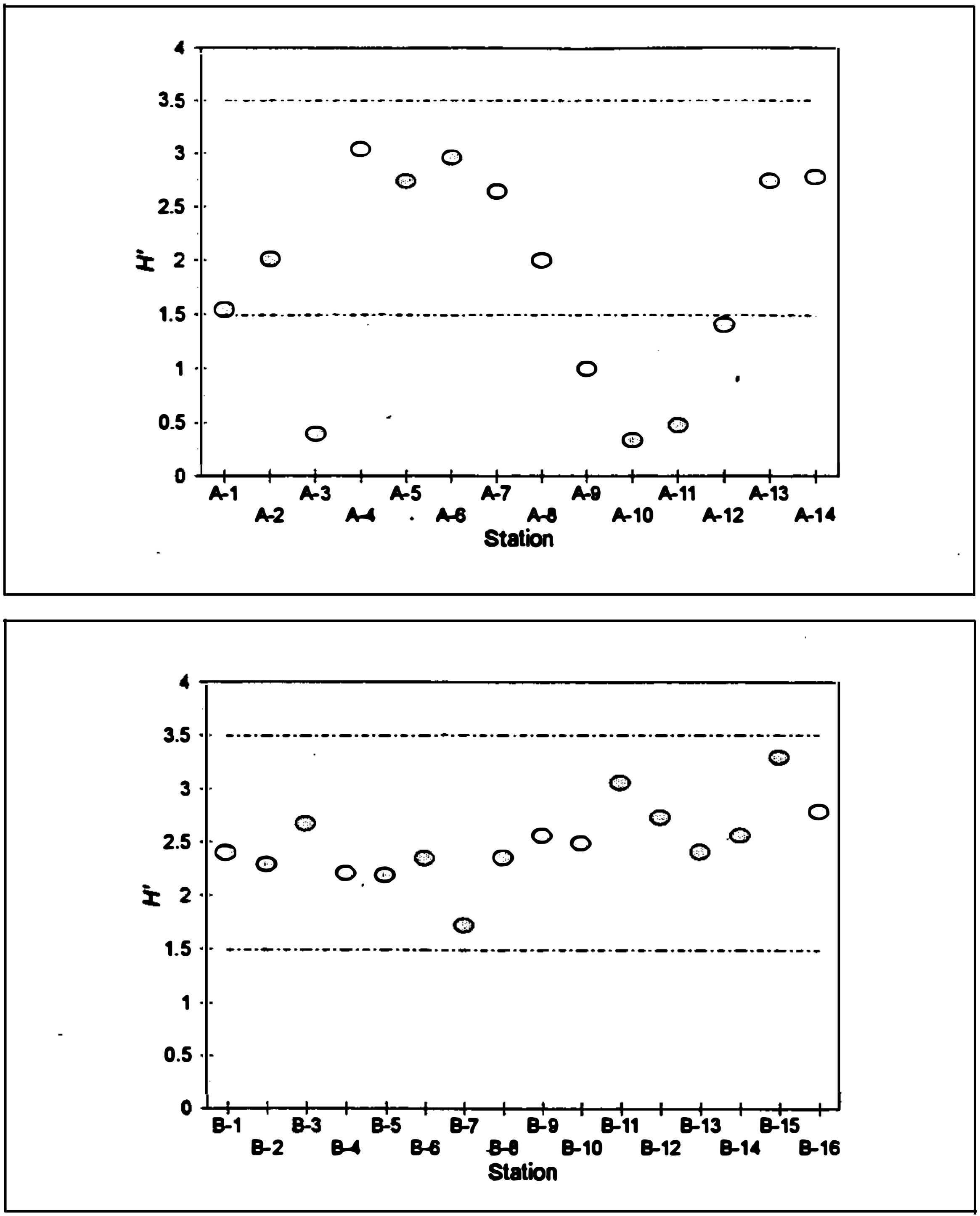


Figure 5. Macrofaunal species diversity at Potential Borrow Area "A" (top) and "B" (bottom) stations in relation to the range of values found at Control Sites (dashed lines) in the Broadkill Beach study area, 1994.

Station B-7 to 0.68 at Station B-15 (Figure 5, Table 6). Simpson' Index (λ) in Potential Borrow Area "B" varied relatively little, ranging from 0.16 to 0.49 (Table 6). The mean for the area was 0.28 ($\pm$ 0.04).

Species diversity (H') at stations in the Control Sites varied considerably, ranging from 0.71 at Station C-2 to 3.56 at Station C-5 (Table 6). The mean species diversity in the Control Sites was 2.44 ($\pm$ 0.59). Evenness (J') at stations in the Control Sites also varied considerably, ranging from 0.15 at Station C-2 to 0.79 at Station C-5 (Table 6). Simpson' Index (λ) in the Control Sites varied considrably, ranging from 0.14 to 0.84 (Table 6). The mean for the area was 0.34 ($\pm$ 0.16).

Selected Taxa—During preliminary examination of the data, taxa were selected to roughly characterize the two potential borrow areas. These taxa were also useful in characterizing the various cluster groups resulting from the classification analyses (see *Numerical Classification*). The most striking feature of Potential Borrow Area "A" was the very high abundance of the small venerid clam *Gemma gemma* (Table 7), which averaged about 1362 ($\pm$ 1164) individuals/0.1 m^2 in this area. Haustoriid amphipods, oligochaete worms, and the capitellid polychaete *Amastigos caperatus* were also relatively more abundant in Potential Borrow Area "A" than elsewhere. Potential Borrow Area "B" was characterized by relatively high abundances of the gastropod *Acteocina canaliculata*, the clam *Tellina agilis*, and ampeliscid amphipods (Table 7).

Numerical Classification—Both sets of similarity analysis yielded groups of stations that were linked by sets of common biological and sedimentological features. A summary of these features , based on the data provided in the following text, is provided in Table 8. The Bray-Curtis similarity analysis separated the 40 stations into 3 relatively dissimilar groups (Figure 6). Group A, which was linked to the remaining stations at a Bray-Curtis similarity value of 0.07, consisted of six stations in Potential Borrow Area "A" or the northern Control Site. Stations in this cluster were characterized by very sandy sediment (range = 99.1-100% sand) with TOC content below detection limits. The macrofaunal community characteristics of this station group were very low species diversity [mean H' = 0.66 ($\pm$ 0.25)], very high infaunal abundance [mean = 4315 ($\pm$ 1595) individuals/0.1 m^2], and very low evenness [mean J' = 0.14 ($\pm$ 0.05)]. Characteristic faunal elements were very high numbers of the bivalve *Gemma gemma* [mean = 3735 ($\pm$ 1599) individuals/0.1 m^2], relatively high numbers of haustoriid amphipods [mean = 108 ($\pm$ 58) individuals/0.1 m^2], and low numbers of the polychaete *Amastigos caperatus* and the snail *Acteocina canaliculata* that had only 4 and 1 individuals, respectively, found among the stations. Group B consisted of 22 stations that were linked to stations in Group C at a

Table 7. Abundance (#/0.1 m^2) of selected taxa in the Broadkill Beach study area, 1994. Mean, standard deviation (STDS), and 95% confidence intervals (CI) are provided.

	Abundance								
Station	Oligo	*A. cap*	*B. well*	*A. canal*	*G. gemma*	*N. ann*	*T. agil*	Ampel	Haust
A-1	10	0	3	0	676	0	5	0	128
A-2	197	2	34	0	356	0	1	1	0
A-3	122	0	22	0	6328	0	2	2	20
A-4	511	10	49	0	46	0	9	4	0
A-5	96	442	42	0	7	23	158	14	0
A-6	315	243	63	0	33	1	35	27	0
A-7	409	582	45	0	7	13	67	3	0
A-8	440	3	31	0	354	0	2	0	7
A-9	74	0	2	0	1179	0	13	2	38
A-10	34	1	2	0	5592	0	15	0	101
A-11	11	0	11	0	4085	0	3	1	173
A-12	1514	38	46	1	267	0	25	3	0
A-13	479	127	37	1	48	0	34	27	0
A-14	67	24	13	0	97	0	93	4	0
Mean	305.64	105.14	28.57	0.14	1361.93	2.64	32.29	6.29	33.36
STDS	393.14	187.42	19.85	0.36	2222.56	6.60	44.09	9.45	57.40
95% CI	205.64	98.17	10.40	0.19	1164.24	3.56	23.10	4.95	30.07
B-1	2	86	0	20	1	0	53	3	0
B-2	21	10	0	16	3	5	210	52	0
B-3	114	144	43	0	2	0	103	2	0
B-4	224	19	99	0	7	6	52	4	0
B-5	63	0	0	290	0	174	24	10	0
B-6	0	93	0	12	0	0	64	11	0
B-7	274	0	0	3	2	43	12	0	0
B-8	192	7	0	138	0	129	6	2	0
B-9	52	0	0	4	3	105	106	5	0
B-10	4	74	0	13	0	1	245	56	0
B-11	61	7	0	36	1	57	131	79	0
B-12	14	0	0	49	0	9	114	19	0
B-13	1	95	0	43	1	4	118	15	0
B-14	2	38	0	37	1	2	64	7	0
B-15	9	3	0	49	4	13	80	88	0
B-16	1	16	0	13	6	2	81	19	0
Mean	64.53	33.81	6.88	45.19	1.64	34.38	92.69	21.44	0.00
STDS	89.23	42.95	26.32	73.46	2.17	54.45	64.80	25.14	0.00
95% CI	43.72	20.90	12.90	36.00	1.07	26.68	31.75	12.32	
C-1	121	2	25	1	2051	0	9	2	112
C-2	32	1	1	0	3173	0	31	0	204
C-3	8	4	0	6	4	37	19	5	3
C-4	31	2	15	0	404	0	44	0	55
C-5	11	2	0	1	5	10	37	8	1
C-6	95	0	0	213	0	129	95	7	0
C-7	127	0	0	136	0	224	11	7	0
C-8	79	0	0	164	0	120	52	4	0
C-9	77	0	1	314	0	126	68	2	0
C-10	16	0	0	132	0	45	115	132	0
Mean	58.90	1.10	4.20	96.70	583.70	69.30	44.80	16.70	37.50
STDS	45.90	1.37	8.66	112.21	1116.54	76.79	32.47	40.61	69.23
95% CI	28.26	0.85	5.37	66.54	893.27	47.59	20.13	25.17	42.81

Olig: Oligochaeta
A. cap: Amastigos caperatus
B. well: Brania wellfleetensis
A. canal: Acteocina canaliculata
G. gemma: Gemma gemma
N. ann: Nucula annulata
T. agil: Tellina agilis
Ampel: Ampeliscid amphipods
Haust: Haustoriid amphipods

Table 8. Summary of sedimentary and biological features of cluster groups in the Broadkill Beach study area as defined by Bray-Curtis and NESS similarity analyses, 1994.

Cluster Group	Stations/General Location	Sedimentary Features	Biological Features	Characteristic Taxa
Bray-Curtis				
A	6; Potential Borrow Area "A"; northern Control Site	Very sandy, M_z 1.2-1.6; TOC below detection limit (BDL)	Low species diversity and evenness; high abundance	*Gemma gemma*; haustoriids
B	22; Potential Borrow Area "B"; southern Control Site	Sandy, M_z usually > 2; TOC BDL-1.07%	High species diversity and evenness; low abundance	*A. canaliculata*; *N. annulata*; ampeliscids
C	12; Potential Borrow Area "A"	Sandy; M_z usually < 1; very low TOC, BDL-0.06%	Intermediate species diversity, evenness, and abundance	Oligochaetes; *A. caperatus*; *B. wellfleetensis*
NESS				
A	21; Potential Borrow Area "B"; southern Control Site	Sandy, M_z usually > 2; low TOC	High species diversity and evenness; low abundance	*A. canaliculata*; *N. annulata*; ampeliscids
B	19; Potential Borrow Area "A"; northern Control Site	Very sandy, M_z usually < 2; very low TOC	Low species diversity and evenness; high abundance	*Gemma gemma*; haustoriids

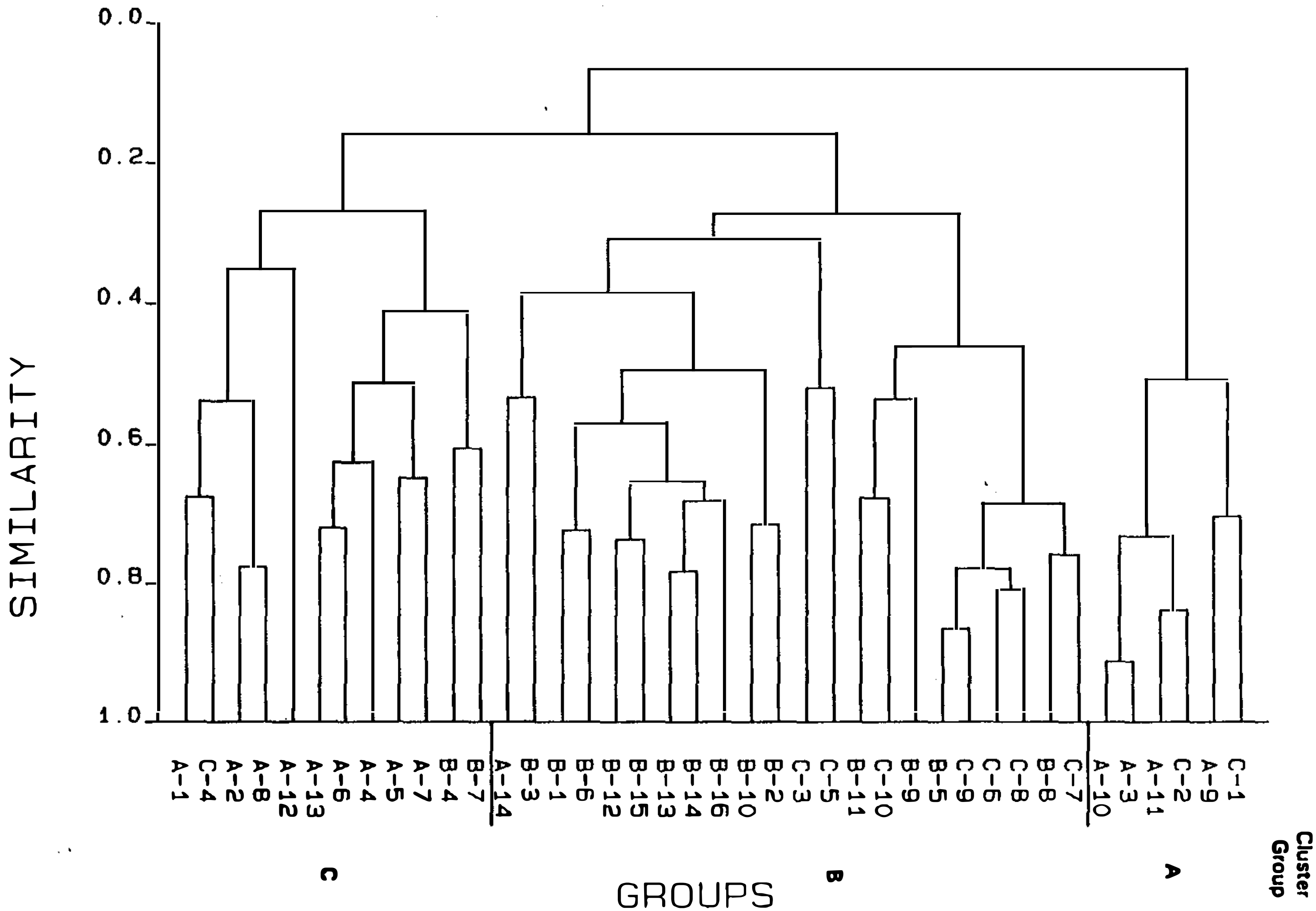


Figure 6. Dendrogram resulting from numerical classification analysis based on Bray-Curtis similarity of stations in the Broadkill Beach study area, 1994.

Bray-Curtis similarity value of 0.16. Most of these 22 stations were located in Potential Borrow Area "B" and the southern Control Site. Group B stations generally were less sandy than those of the other groups (range = 48.9-98% sand) with TOC content ranging from below detection limit to 1.07%. Group B was characterized by relatively high species diversity [mean H' = 2.71 (± 0.16)], low abundance ([mean = 409 (± 81) individuals/0.1 m^2], and relatively high evenness [mean J' = 0.62 (± 0.03)]. Characteristic taxa included *Acteocina canaliculata* [mean = 77 (± 40) individuals/0.1 m^2], the bivalve molluscs *Nucula annulata* [mean = 54 (± 29) individuals/0.1 m^2] and *Tellina agilis* [mean = 85 (± 25) individuals/0.1 m^2], and ampeliscid amphipods [mean = 23 (± 14) individuals/0.1 m^2]. Strikingly low in abundance were *G. gemma* [mean = 5 (± 8) individuals/0.1 m^2] and haustoriid amphipods (only 4 individuals collected). Group C consisted of 12 stations located primarily in Potential Borrow Area "A". These stations were sandy (range = 63-100% sand) with low sedimentary TOC (range = below-detection-limit to 0.06%). Species diversity [mean H' = 2.24 (± 0.32)], abundance [mean = 976 (± 253) individuals/0.1 m^2], and evenness [mean J' = 0.46 (± 0.05)] were intermediate to those of Groups A and B. High numbers of annelid worms characterized this group. Oligochaetes [mean = 375 (± 224) individuals/0.1 m^2] and the polychaetes *A. caperatus* [mean = 122 (± 112) individuals/0.1 m^2] and *Brania wellfleetensis* [mean = 39 (± 15) individuals/0.1 m^2] were found at higher abundances at Group C stations than elsewhere. Among Group C stations, the abundances of *G. gemma* [mean = 184 (± 126) individuals/0.1 m^2] and *T. agilis* [mean = 37 (± 25) individuals/0.1 m^2] were intermediate to those found for the other two groups. The snail *Acteocina canaliculata* was rare (5 individuals collected).

Classification of the 40 stations based on NESS similarity showed two major, relatively dissimilar groups (Figure 7) that were linked at a similarity value of 0.30. Group A, comprised of 21 stations primarily located in Potential Borrow Area "B" and the southern Control Site, and Group 8, consisting of 19 stations primarily located in Potential Borrow Area "A" and the northern Control Site, could be subdivided into three and two groups, respectively. Among Group A stations, species diversity [mean H' = 2.66 (± 0.19)] and evenness [mean J' = 0.62 (± 0.03)] were high, whereas infaunal abundance [mean = 408 (± 85) individuals/0.1 m^2] was low. Characteristic taxa included *Acteocina canaliculata* [mean = 80 (± 41) individuals/0.1 m^2], *Nucula annulata* [mean = 59 (± 29) individuals/0.1 m^2], *Tellina agilis* [mean = 81 (± 27) individuals/0.1 m^2], and ampeliscid amphipods [mean = 24 (± 14) individuals/0.1 m^2]. The three subgroups within Group A were relatively similar. Among Group B stations, species diversity [mean H' = 1.82 (± 0.42)] and evenness [mean J' = 0.38 (± 0.09)] were low, whereas infaunal abundance [mean = 2001 ± 882 individuals/0.1 m^2] was high. Characteristic taxa included *Gemma*

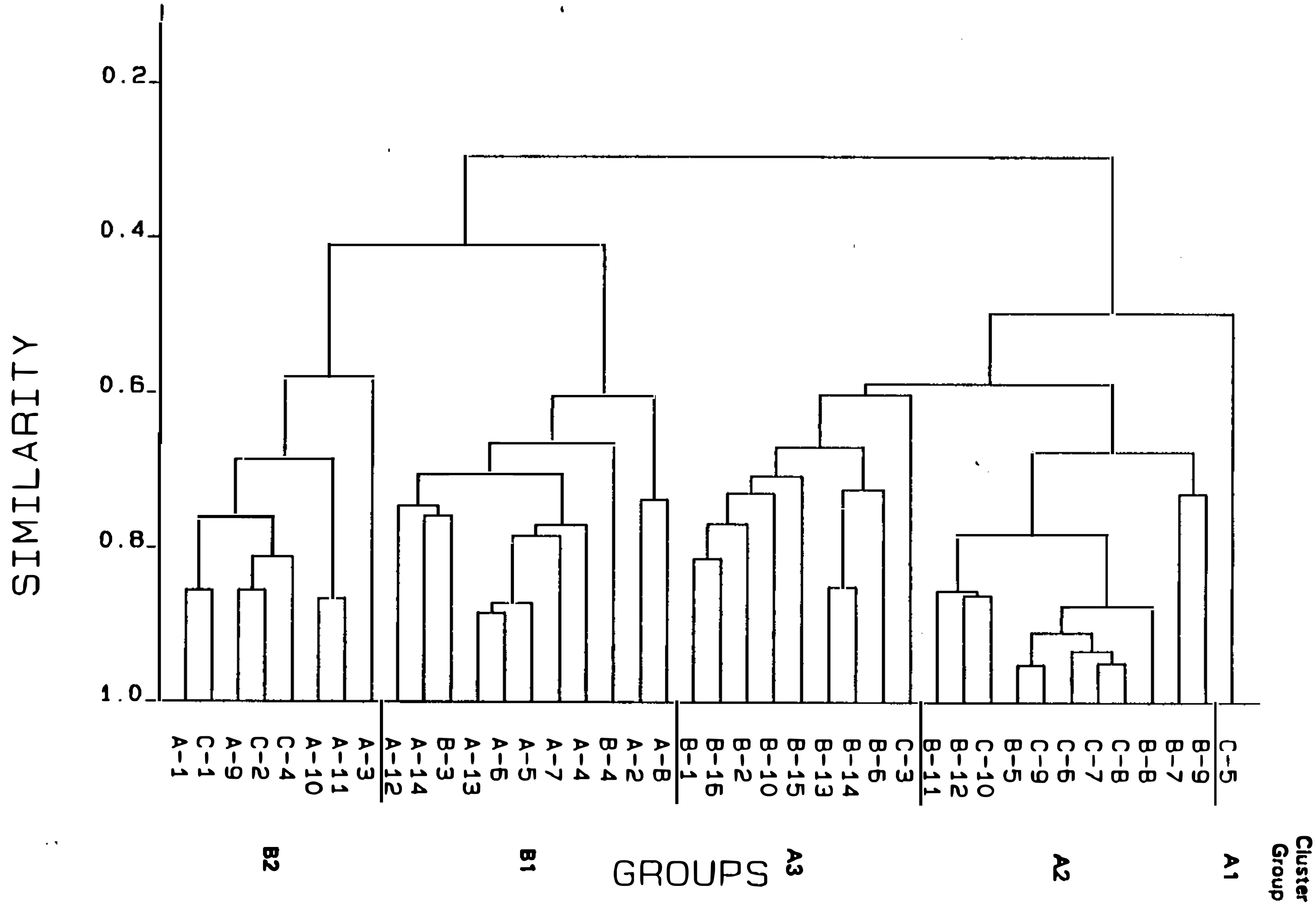


Figure 7. Dendrogram resulting from numerical classification analysis based on NESS similarity of stations in the Broadkill Beach study area, 1994.

gemma [mean = 1300 (± 902) individuals/0.1 m^2], haustoriid amphipods [mean = 44 (± 30) individuals/0.1 m^2], the polychaete *Amastigos caperatus* and [mean = 86 (± 74) individuals/0.1 m^2] and oligochaete worms [mean = 253 (± 157) individuals/0.1 m^2]. The two subgroups in Group B varied considerably with Group B2 characterized by low species diversity and high numbers of *Gemma gemma* and haustoriid amphipods. Group B1 had relatively high species diversity and high numbers of annelid worms (oligochaetes, *Amastigos caperatus*, and *Brania wellfleetensis*).

Wet-Weight Biomass—Total wet-weight biomass varied considerably among stations in Potential Borrow Area "A" (Figure 8, Table 9), ranging from 1.2 g/0.1 m^2 at Station A-12 to 28.3 g/0.1 m^2 at Station A-3. Mean total wet-weight biomass for Potential Borrow Area "A" stations was 6.568 (± 4.261) g/0.1 m^2. Molluscs were the predominant contributor to total biomass at 13 of the 14 stations in Potential Borrow Area "A". Molluscan biomass ranged from 0.9 to 26.9 g at these stations.

Total wet-weight biomass was generally lower and less variable among stations in Potential Borrow Area "B" than among those in Potential Borrow Area "A". Total biomass for samples collected in Potential Borrow Area "B" ranged from 0.9 g/0.1 m^2 at Station B-1 to 10.5 g/0.1 m^2 at Station B-5 (Figure 8, Table 9). Mean total wet-weight biomass for Potential Borrow Area "B" stations was 3.634 (± 1.228) g/0.1 m^2. Molluscs were the predominant contributor to total biomass at 15 of the 16 stations in Potential Borrow Area "B". Molluscan biomass ranged from 0.6 to 8.2 g at these stations. Several large molluscs, *Busycon carica* and *Ensis directus*, were collected in Potential Borrow Area "B", but were excluded from all calculations (Table 9).

Total wet-weight biomass was variable among stations in the Control Sites, ranging from 1.4 g/0.1 m^2 at Station C-5 to 18.8 g/0.1 m^2 at Station C-2 (Table 9). Mean total wet-weight biomass for the Control-Site stations was 7.468 (± 3.013) g/0.1 m^2. Molluscs were the predominant contributor to total biomass at 9 of the 10 stations in the Control Sites. Molluscan biomass ranged from 1.6 to 16.1 g at these nine stations. One *Limulus polyphemus* (horseshoe crab) and one *Ensis directus* were collected at Station C-2, but were excluded from all calculations (Table 9).

Correlations with Physical Factors—Pearson correlation analyses were run between the biological parameters measured and selected sedimentary parameters. Significant correlations between biological parameters and sediment percent sand (Table 10). Species diversity and evenness were negatively correlated, whereas total abundance and total species per station were positively correlated, with percent sand. Among the selected taxa,

Table 9. Wet-weight biomass (g/0.1 m^2) and percent contribution of major taxonomic groups in the Broadkill Beach study area, 1994. Mean, standard deviation (STDS), and 95% confidence intervals (CI) are provided.

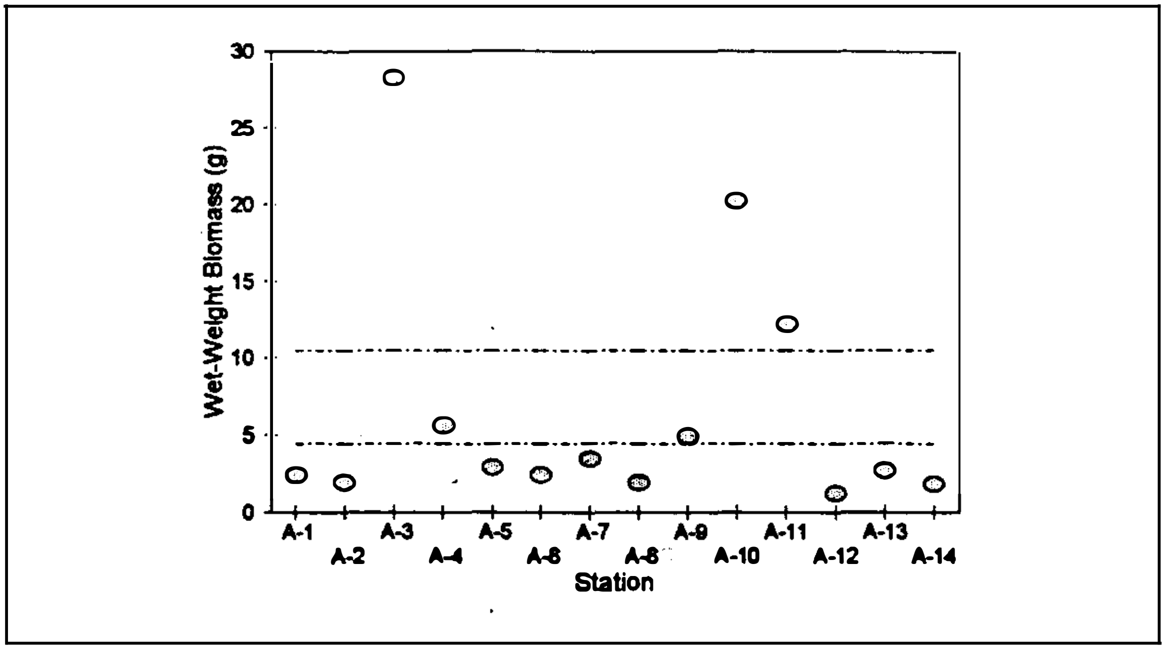
	Wet-Weight Biomass					Percent Contribution		
Station	Annelida	Arthropoda	Mollusca	Misc.	Total	Annelida	Arthropoda	Mollusca
A-1	0.245	0.370	1.072	0.642	2.329	10.52%	15.89%	46.03%
A-2	0.417	0.149	0.884	0.416	1.868	22.32%	7.98%	47.32%
A-3	0.358	0.163	26.875	0.882	28.278	1.26%	0.58%	95.05%
A-4	1.875	1.448	2.225	0.077	5.625	33.33%	25.74%	39.56%
A-5	0.713	0.167	2.011	0.009	2.9	24.59%	5.76%	69.34%
A-6	1.057	0.535	0.787	0.023	2.402	44.00%	22.27%	32.76%
A-7	1.192	0.134	2.134	0.022	3.482	34.23%	3.85%	61.29%
A-8	0.383	0.159	1.169	0.193	1.904	20.12%	8.35%	61.40%
A-9	0.157	0.198	2.882	1.667	4.904	3.20%	4.04%	58.68%
A-10	0.772	0.542	16.884	2.028	20.226	3.82%	2.68%	83.48%
A-11	0.250	0.744	10.797	0.395	12.186	2.05%	6.11%	88.60%
A-12	0.314	0.112	0.601	0.200	1.227	25.59%	9.13%	48.98%
A-13	1.126	0.108	1.495	0.060	2.791	40.36%	3.88%	53.76%
A-14	0.683	0.196	0.857	0.106	1.844	37.04%	10.63%	46.48%
Mean	0.682	0.359	5.034	0.494	6.568			
STDS	0.487	0.371	7.931	0.668	8.135			
95% CI	0.255	0.194	4.102	0.350	4.261			
B-1	0.300	0.043	0.550	0.033	0.926	32.40%	4.64%	59.40%
B-2	0.063	0.486	3.773	0.051	4.373	1.44%	11.11%	86.28%
B-3	0.480	0.110	1.567	0.025	2.182	22.00%	5.04%	71.81%
B-4	0.966	0.059	0.402	0.0	1.427	67.69%	4.13%	28.17%
B-5	2.193	0.119	8.170	0.008	10.49	20.88%	1.14%	78.11%
B-6	0.180	0.653	0.854	0.099	1.786	10.08%	36.56%	47.82%
B-7	0.172	0.090	1.534	0.0	1.796	9.58%	5.01%	85.41%
B-8	0.058	0.051	6.327	0.003	6.439	0.90%	0.79%	98.26%
B-9	0.422	0.025	4.691	0.006	5.144	8.20%	0.49%	91.19%
B-10	0.221	0.285	2.657	0.017	3.18	6.98%	8.99%	84.08%
B-11	0.459	0.725	3.968	0.055	5.207	8.82%	13.92%	76.21%
B-12	0.411	0.330	2.949	0.067	3.757	10.94%	8.78%	78.49%
B-13	0.353	0.243	1.008	0.005	1.609	21.94%	15.10%	62.65%
B-14	0.580	0.108	0.942	0.008	1.638	35.41%	6.59%	57.51%
B-15	0.661	0.318	1.602	0.035	2.617	25.26%	12.15%	61.22%
B-16	0.132	0.218	5.258	0.013	5.621	2.35%	3.88%	93.54%
Mean	0.476	0.240	2.881	0.027	3.634			
STDS	0.509	0.217	2.294	0.028	2.506			
95% CI	0.250	0.106	1.124	0.014	1.226			
C-1	0.238	0.514	6.964	1.654	9.57	2.49%	5.37%	72.77%
C-2	0.501	0.346	16.068	1.659	18.773	2.67%	1.84%	85.59%
C-3	0.207	0.094	1.783	0.215	2.299	9.00%	4.09%	77.56%
C-4	0.374	0.224	1.616	2.933	5.147	7.27%	4.35%	31.40%
C-5	0.278	0.099	1.055	0.002	1.434	19.39%	6.90%	73.57%
C-6	1.243	0.271	5.811	0.032	7.357	16.90%	3.68%	78.98%
C-7	0.017	0.071	8.048	0.144	8.28	0.21%	0.86%	97.20%
C-8	0.154	0.049	6.310	0.190	6.703	2.30%	0.73%	94.14%
C-9	1.451	0.032	6.882	1.499	9.873	14.70%	0.32%	69.81%
C-10	0.647	0.726	3.855	0.019	5.247	12.33%	13.84%	73.47%
Mean	0.511	0.2426	5.9402	0.9745	7.4083			
STDS	0.4772	0.2293	4.3671	1.0642	4.8615			
95% CI	0.2959	0.1421	2.7191	0.6596	3.0131			

Note: The following "megafauna" have been excluded from the above numbers: B-3, one 89.418 g *Busycon carica*; B-14, one 96.35 g *Busycon carica*; B-16, one 4.25 g *Ensis directus*; C-2, one 67.839 *Limulus polyphemus* and one 4.303 g *Ensis directus*.

Table 10. Pearson correlation coefficients (*r*) between selected biological and sedimentary parameters in the Broadkill Beach study area, 1994. Critical limits from Rohlf and Sokal (1969); significant correlations are shaded.

	Biological Parameter	% Sand	Graphic Mean	Phi 16	Phi 50	Phi 84	TOC (%)
				Sedimentary Parameter			
	H'	-0.457	0.082	0.030	0.152	0.338	0.262
	J'	-0.533	0.206	0.151	0.276	0.469	0.377
Abundance	Total	0.410	-0.167	-0.142	-0.199	-0.328	-0.343
	Annelids	0.154	-0.486	-0.483	-0.477	-0.514	-0.275
	Arthropods	0.327	0.079	0.104	0.043	-0.047	-0.242
	Molluscs	0.348	-0.048	-0.026	-0.077	-0.194	-0.259
Species	Total	0.350	-0.515	-0.502	-0.520	-0.573	-0.504
	Annelids	0.482	-0.627	-0.598	-0.650	-0.727	-0.630
	Arthropods	0.261	-0.459	-0.451	-0.458	-0.513	-0.373
	Molluscs	-0.572	0.548	0.492	0.613	0.759	0.567
Selected Taxa	Oligochaeta	0.115	-0.341	-0.326	-0.352	-0.392	-0.148
	Amastigos caperatus	0.030	-0.375	-0.396	-0.336	-0.336	-0.232
	Brania wellfleetensis	0.333	-0.557	-0.535	-0.573	-0.591	-0.454
	Acteocina cancaliculata	-0.565	0.668	0.620	0.718	0.727	0.535
	Gemma gemma	0.404	-0.123	-0.095	-0.159	-0.276	-0.314
	Nucula annulata	-0.700	0.507	0.432	0.598	0.648	0.692
	Tellina agilis	0.010	0.300	0.291	0.305	0.359	-0.003
	Ampeliscids	-0.018	0.313	0.297	0.326	0.378	0.003
	Haustoriids	0.421	-0.082	-0.043	-0.136	-0.262	-0.323
	% Sand	1.000	-0.308	-0.243	-0.390	-0.546	-0.878

Critical Limits (n = 40) =
0.3124 ($\alpha = 0.05$)   0.403 ($\alpha = 0.01$)



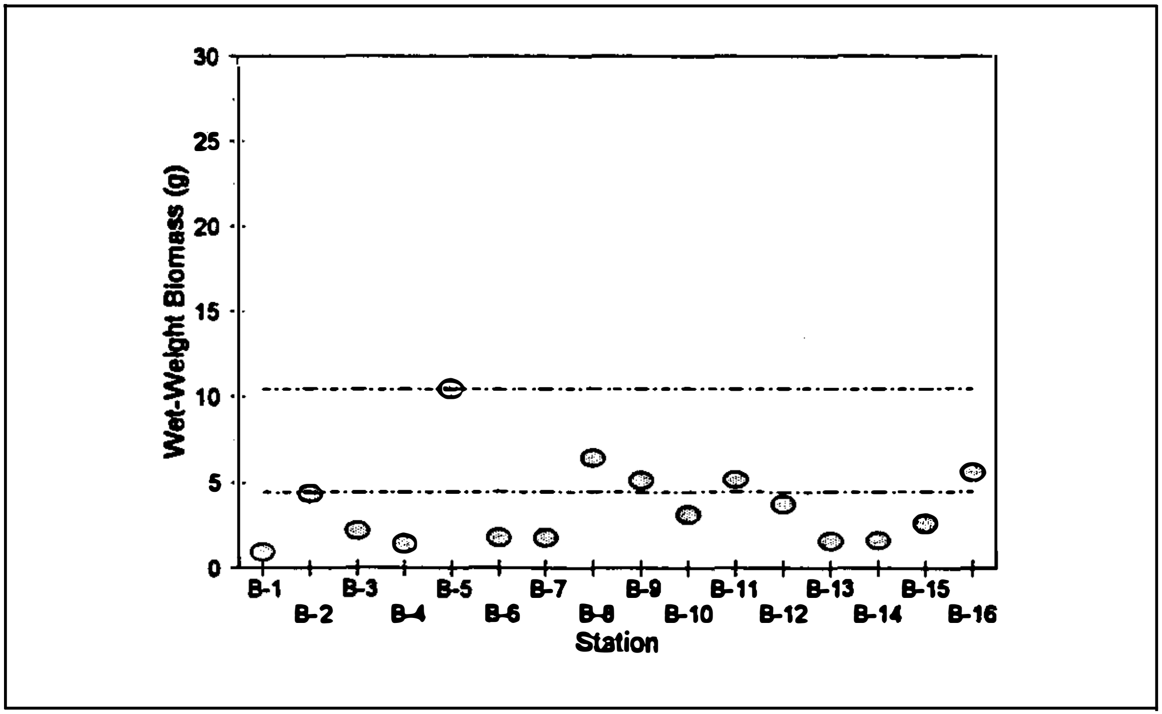


Figure 8. Wet-weight biomass (g/0.1 m^2) at Potential Borrow Area "A" (top) and "B" (bottom) stations in relation to the range of values found at Control Sites (dashed lines) in the Broadkill Beach study area, 1994.

the molluscs *Acteocina canaliculata* and *Nucula annulata* were negatively correlated with percent sand. *Gemma gemma, Brania wellfleetensis,* and haustoriid amphipods were positively correlated with percent sand. Among taxa that were not significantly correlated with percent sand, oligochaete worms and the capitellid polychaete *Amastigos caperatus* were negatively correlated, whereas ampeliscid amphipods were positively correlated, with M_z. Sediment TOC was very highly correlated with sediment percent sand, but was not correlated with M_z.

Infaunal Size Fractions and Empty Commercial Bivalves—Twenty-seven species were found to be ≥ 2 cm in length (Table 11). Of these, 20 species were polychaete annelids and 4 were molluscs. The most frequently occurring annelids ≥ 2 cm in length were *Glycera dibranchiata* (19 stations), *Leitoscoloplos robustus* (13 stations), and *G. americana* (12 stations). The Atlantic jackknife, *Ensis directus* (16 stations), was the most frequently occurring mollusc ≥ 2 cm in length. The mean abundance of infaunal organisms ≥ 2 cm in length was very low, with fewer than six individuals per station being found at either potential borrow area or the control sites.

Empty shells of four species of commercial bivalves were found in the study area (Table 12). Among stations in Potential Borrow Area "A", *Spisula solidissima* (Atlantic surfclam) was the most numerous species and occurred at more stations than the others. In Potential Borrow Area "B" and at the Control Sites, *M. edulis* was the most frequently occurring and the most numerous species.

Miscellaneous Information

Marine mammals occur in Delaware Bay. Harbor porpoise and bottlenose dolphins migrate up the Bay more frequently than in the past and several species of whales occur near the mouth of the Bay (L. Spence, personal communication). Harbor, harp, hooded, and gray seals also inhabit the Bay. None appear to be particularly common in the study area.

Migratory shorebirds inhabit coastal beach areas in very large numbers during the spring and fall migration seasons.

Although some recreational fishing likely occurs in the vicinity of the study area, little sport scuba diving or clamming occurs in the area (J. Tinsmen, personal communication). Oysters may be found in the vicinity, but are not commercially exploited.

Table 11. Macrofaunal species in the Broadkill Beach study area having lengths ≥ 2 cm, 1994. Occurrence, mean, and standard deviation (STDS) are provided.

Species	Area A # Stations	Area A Mean	Area A STDS	Area B # Stations	Area B Mean	Area B STDS	Control Sites # Stations	Control Sites Mean	Control Sites STDS
Annelida									
Asabellides oculata	0			1	0.1	0.25	1	0.1	0.32
Caulleriella sp. A	1	0.1	0.27	0			1	0.2	0.63
Diopatra cuprea	1	0.1	0.27	0			0		
Dispio uncinata	1	0.2	0.58	0			2	0.4	0.97
Drilonereis longa	1	0.1	0.27	1	0.1	0.25	0		
Glycera americana	0			6	0.5	0.82	6	2	2.06
Glycera dibranchiata	8	2.1	2.68	7	0.6	0.73	4	0.6	0.97
Heteromastus filiformis	0			1	0.1	0.25	0		
Leitoscoloplos cf. fragilis	1	0.1	0.27	0			0		
Leitoscoloplos robustus	5	0.4	0.50	4	0.4	1.03	4	0.7	1.06
Neanthes succinea	1	0.1	0.27	0			0		
Nephtys bucera	3	0.4	0.76	0			1	0.2	0.63
Nephtys incisa	0			0			1	0.2	0.63
Nephtys picta	5	0.7	1.38	5	1.0	2.00	1	0.2	0.63
Notocirrus spiniferus	1	0.2	0.80	0			0		
Owenia fusiformis	0			0			1	0.2	0.63
Pectinaria gouldii	0			1	0.1	0.25	0		
Scoloplos rubra	1	0.1	0.27	4	0.9	2.03	3	0.3	0.48
Spio setosa	1	0.1	0.53	0			0		
Spiochaetopterus costarum	0			2	0.1	0.34	1	0.2	0.63
Mollusca									
Ensis directus	4	0.8	1.53	8	1.4	2.16	4	0.6	0.97
Mytilus edulis	0			1	0.1	0.25	0		
Yoldia limatula	0			1	0.1	0.25	0		
Busycon carica	0			2	0.1	0.34	0		
Arthropoda									
Limulus polyphemus	0						1	0.1	0.32
Crangon septemspinosa	1	0.1	0.53	2	0.1	0.34	0		
Holothuroidea									
Leptosynapta tenuis	1	0.1	0.27	0			0		

Table 12. Occurrence, meen, standard deviation (STDS), and size range of empty commercial bivalves in the Broadkill Beach study area, 1994.

	Area A				Area B				Control Sites			
Species	# Stations	Mean	STDS	Size Range (mm)	# Stations	Mean	STDS	Size Ranga (mm)	# Stations	Mean	STDS	Size Range (mm)
Ensis directus	4	0.4	0.76	19-46	14	3.9	4.03	10-70	4	1	1.56	15-66
Mytilus edulis	3	0.8	2.39	10-14	16	17.6	17.52	2-27	7	13.6	17.16	2-21
Spisula solidissima	7	2.9	6.91	3-96	14	4.6	3.12	4-15	5	1.8	2.44	4-33
Mercenaria mercenaria	0				2	0.3	0.77	2-7	1	0.1	0.32	7

Discussion and Conclusions

The Broadkill Beach Replenishment study area is in the vicinity of stations sampled as part of two previous studies of Delaware Bay. In the 1970's a study was conducted to investigate benthic assemblages bay-wide (Watling and Maurer, 1975; Watling and Wethe, 1975; Maurer *et al.*, 1978). Their Station 2-1 was located about 1.5 km north of the Broadkill Beach study area (Figure V-1 in Watling and Wethe, 1975). A second study, conducted in the early 1980s, was conducted as part of the Northeast Monitoring Program (NEMP) of the National Marine Fisheries Service that studied secondary production of the benthos at one station in the Bay and a two or more offshore stations (Howe and Leathem, 1984; Howe *et al.*, 1988; Maurer *et al.*, 1992). Station 29 as discussed in the NEMP studies, was located about 2 km north of the Broadkill Beach study area (Figure 1 in Maurer *et al.*, 1992).

Water Quality—The limited near-bottom water-quality data reported by both sets of studies provide some comparison to the data collected during the present study. Water temperature was reported in the NEMP studies to range from 19.8 °C (August 1980) to 21.9 °C (September 1980) at Station 29. Watling and Maurer (1975) summarized hydrographic conditions bay-wide and reported that near-bottom temperature ranged up to about 24 °C in early August. Watling and Maurer (1975) classified regions of the Bay into three salinity zones, one of which was an upper polyhaline zone where salinities ranged from 25-30 ‰. The Broadkill Beach study area falls within this category as did Station 29 of the NEMP studies (30-31.2 ‰).

DO values encountered during the present study were generally higher than those reported by either set of previous studies. DO values reported by Watling and Maurer (1975) were low during the summer (3.9 ml/L), but high during the winter (8.4 ml/L). The NEMP studies also reported lower DO values at Station 29 (2.9-4.9 ml/L) than found in the Broadkill Beach study.

Sediments—In the Broadkill Beach study area, sediments, with M_z values ranging from -0.25 to 3.05 ϕ, generally fit within the descriptions made by Watling and Wethe (1975) and Howe and Leathem (1984). Watling and Wethe classified the area around their Station 2-1 as moderately to moderately well sorted coarse sand with M_z values coarser than 1.5 ϕ. These values were similar to those reported here for Potential Borrow Area "A". Howe and Leathem reported the mud fraction at their Station 29 to be about 15 % and the mean ϕ to be 2.89. These values were similar to those reported here for Potential Borrow Area "B".

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Macrofaunal Communities—Direct comparisons between the faunal communities found during the present study and those discussed by either of the previous sets of studies in Delaware Bay are not possible. Watling and Wethe (1975), although using a grab sampler of the same area as that used in the present study, rinsed their samples over a 1.0-mm mesh sieve. Therefore, abundances and numbers of species found in their study would be expected to be less than those reported here. The primary focus of the Howe and Leathem (1984) study was secondary production, therefore they were not concerned with abundance or numbers of species. However, some comparisons of the predominant features of the infaunal communities found in all studies may be made. The small venerid clam, *Gemma gemma,* was the predominant taxon at several stations in the Broadkill Beach study area, occurring at densities up to 63,280 individuals/m^2. Watling and Wethe, although they did not report numerical densities, found that this species was also abundant in parts of the bay, including their Station 2-1, near the present study site. However, they found that *G. gemma* was most abundant in moderate to high silt + clay habitats, whereas the present study found the clam significantly correlated with percent sand. The abundances of *Gemma gemma* reported here fall within estimates reported for the species elsewhere. Weinberg (1985) found *G. gemma* to occur at densities of 50,000 to 100,000 individuals/m^2 in coastal Connecticut. Watling and Wethe also reported a small nuculid clam, *Nucula proxima*, to be relatively common along the lower portion of the Bay. The present study found a similar species, *Nucula annulata*, to be relatively common. Some of the specimens of *N. proxima* found by Watling and Wethe may have been what is now called *N. annulata* as the two taxa were not typically distinguished in the early 1970s.

Limited abundance data are available for Station 29 studied by Howe and Leathem. The sampling equipment used during that study was similar to that used during the Broadkill Beach study (0.1-m^2 grab, 0.5-mm mesh sieve). Howe and Leathem (1984) reported polychaete abundances that, in June 1980, were greater than 30,000 individuals/m^2, and molluscs densities of about 6,000 individuals/m^2. Sedimentologically, Station 29 was most similar to station in Broadkill Beach Potential Borrow Area "B". Densities of both taxa in Potential Borrow Area "B" were much lower than reported at Station 29. Annelids averaged about 1300 individuals/m^2 and molluscs about 2000 individuals/m^2 in Potential Borrow Area "B". Note, however, that at Station 29 densities of both groups declined dramatically (to $<$ 1000 individuals/m^2) by August 1980. Therefore, densities in both Broadkill Beach potential borrow areas were with the summer range of densities reported for a relatively nearby area.

The numbers of species found in either potential borrow area are similar to those found for a study of the benthos conducted (using similar sampling gear) near Brown Shoal, located northeast of the Broadkill Beach area, (Foster *et al.,* 1992) during which about 10-40 species per sample were found. Foster *et al.* (1992) also reported annelid and mollusc densities of about 1000 and 4200 individuals/m^2, respectively in May 1991. Densities of these taxa were about 1500 and 270 individuals/m^2 in August 1991.

Live surfclams, *Spisula solidissima*, were uncommon in Potential Borrow Area "A" (occurring at 11 stations; 0-7 individuals per station) and rare in Potential Borrow Area "B" (only three individuals were found among the 16 samples). All individuals of *Spisula* were less than 2 cm in length.

Fish are likely to feed on many of the infaunal animals found in the two potential borrow areas. Some data on the diets of four near bottom or bottom-feeding fish are available. Scup (*Stenotomus chrysops*) were found to feed primarily on molluscs (gastropods and squid) in the vicinity of the Delaware Bay artificial reefs placed near Brown Shoals (Foster *et al.*, 1994). Langton and Bowman (1981) found that the summer flounder (*Paralichthys dentatus*) fed primarily on fish and squid, although their study concerned offshore habitats. Two fish have been reported to feed extensively on mysidacean crustaceans (*Neomysis americanus*). Langton and Bowman (1981) found that windowpane flounder (*Scophthalmus aquosus*) fed primarily on crustaceans with mysids accounting for about 42% of their diet. Foster *et al.* (1994) found that weakfish (*Cynoscion regalis*), caught near the Delaware Bay artificial reefs, consumed *Neomysis americanus*, which comprised 81% of its diet. *Neomysis* was relatively common at some stations in Potential Borrow Area "B" reaching a density of about 290 individuals/m^2 at Station B-2. However, *Neomysis* is relatively common in the Bay (and elsewhere) and it is probable that none of the infaunal organisms found in the two potential borrow areas represent unique sources of food for fish.

Twelve stations in the study area, which comprised the cluster group C as defined by the Bray-Curtis similarity analysis, were found to have relatively high numbers of oligochaetes and capitellid polychaetes. These taxa are typically considered opportunistic and indicative of relatively recently disturbed habitat (Grassle and Grassle, 1974). The occurrence of a disturbance within this part of the study area is unknown. Several former borrow areas are located off Broadkill Beach. It is difficult to coordinate the exact localities of these areas to the present study area because the charts on which the former areas are marked do not have navigational or other coordinates. However, most of the former borrow areas appear to be located within 1 km of shore (estimated from State of Delaware charts provided by the Army Corps of Engineers). Potential Borrow Area "A" is about 2.5 km offshore (Figure 1). Most stations within Potential Borrow Area "B" are more than 1.5 km offshore although Station B-7 is about 1 km offshore (Figure 1). Given the constraints restricting precise determination of the locations of the former borrow areas, most stations within the present study area, with the possible exception of Station B-7, do not appear to be former borrow areas.

With the exception of the large numbers of the small venerid clam *Gemma gemma* in Potential Borrow Area "A", neither potential borrow area is faunistically unusual. The faunas of the two areas differ, but these differences appear explainable in terms of the sedimentological differences between the two areas. Considering faunal and sediment data, Potential Borrow Area "A" is similar to the Control Site just to its north and Potential Borrow Area "B" is similar to the Control Site just to its south. Neither site appears to contain any commercially important species, nor any rare species.

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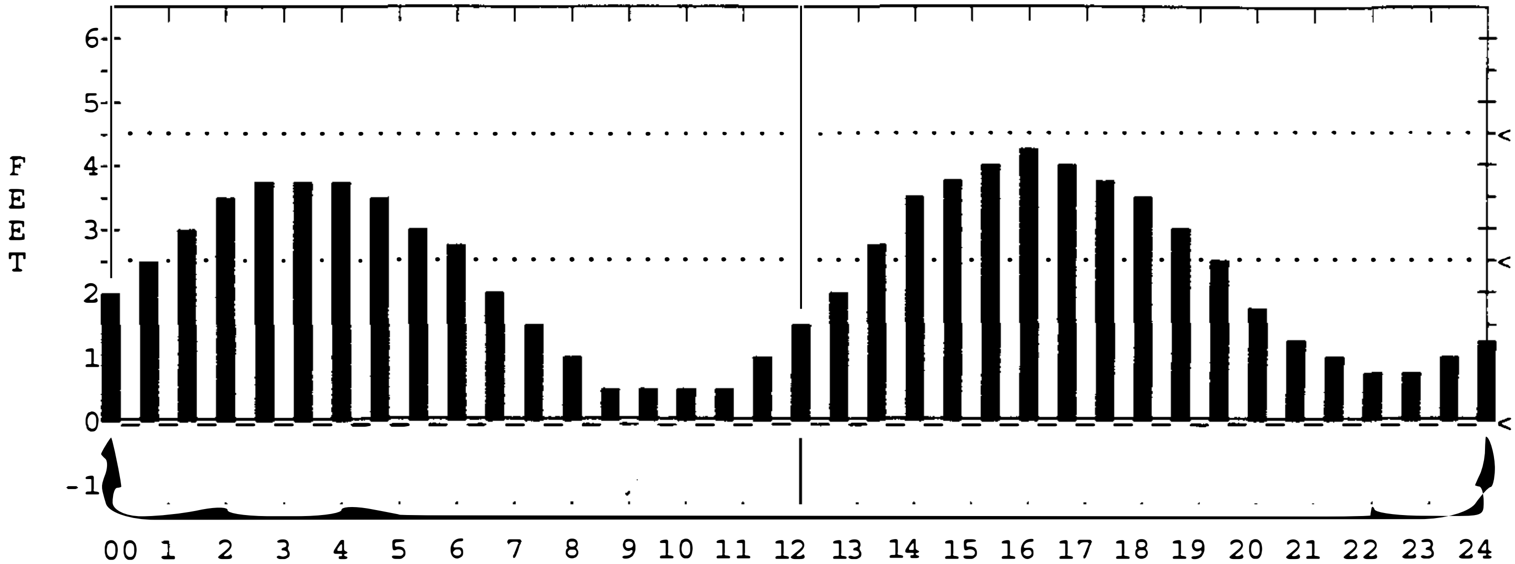
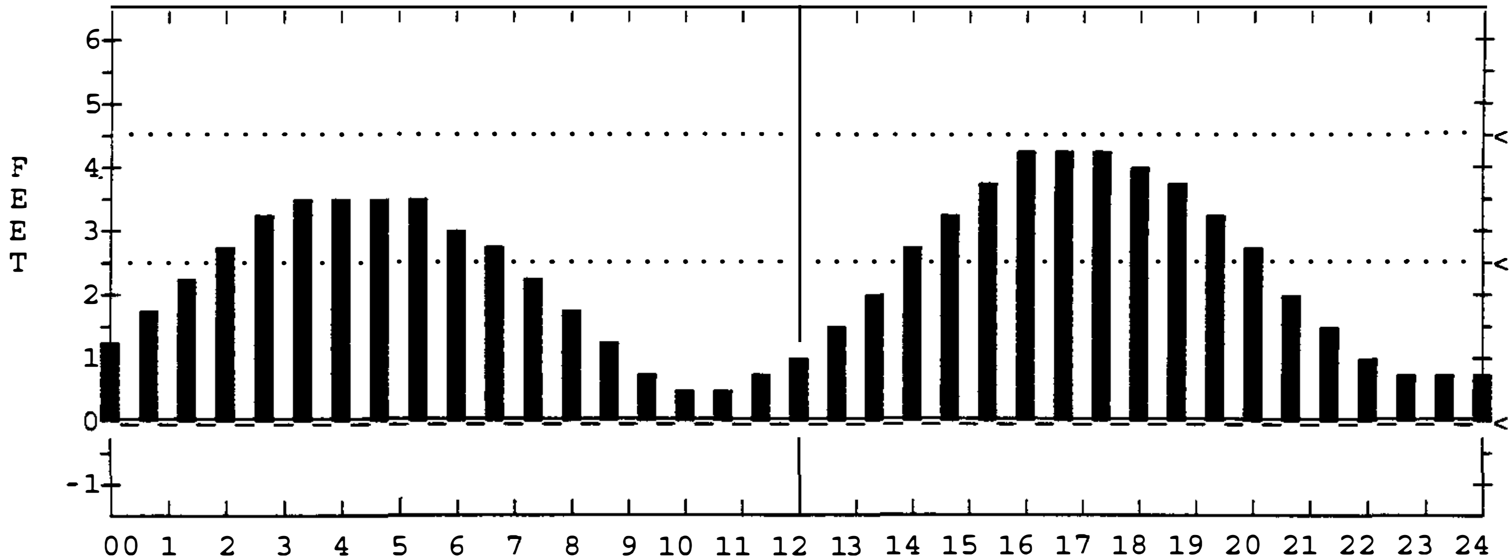
APPENDIX A
TIDE CHART

Roosevelt Inlet Delaware 38°49'N 75°12'W



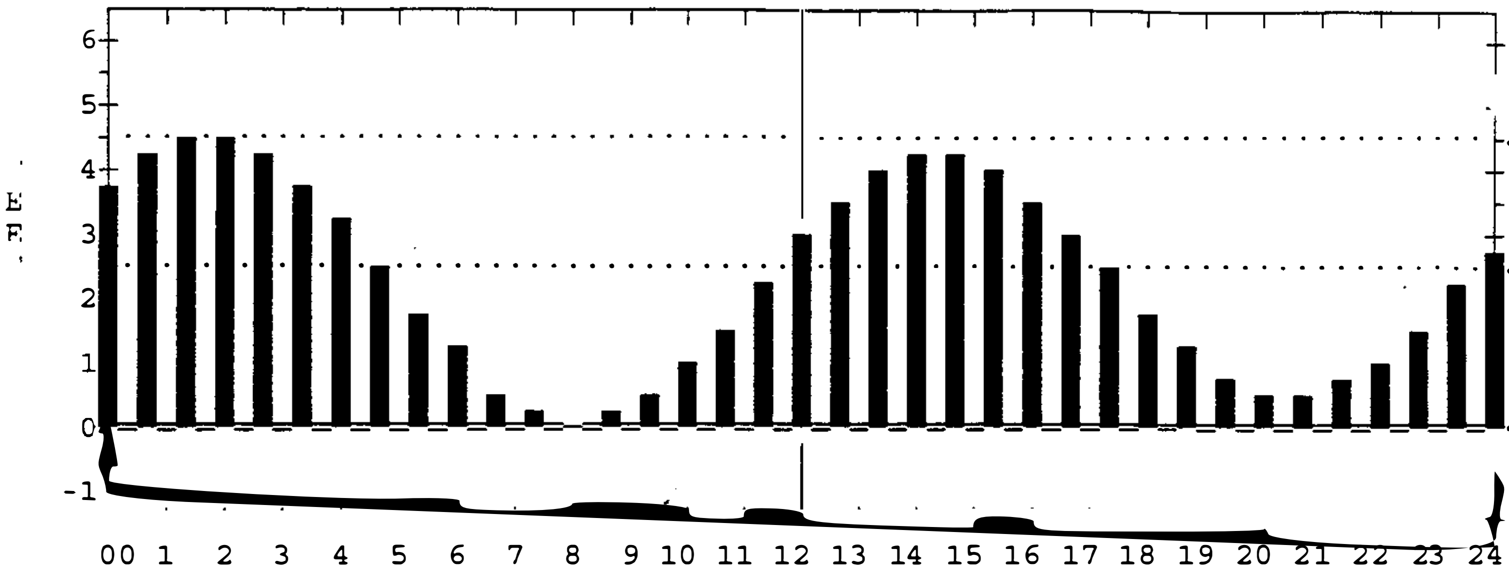
Eastern Daylight Time				High Water		Low Water	
Friday		Jul 1,1994		0317	4.0 ft	0939	.5 ft
	Rise	Transit	Set	1558	4.3 ft	2224	.9 ft
Sun	0540	1305	2030				
Moon	0113	0721	1406				

Roosevelt Inlet Delaware 38°49'N 75°12'W



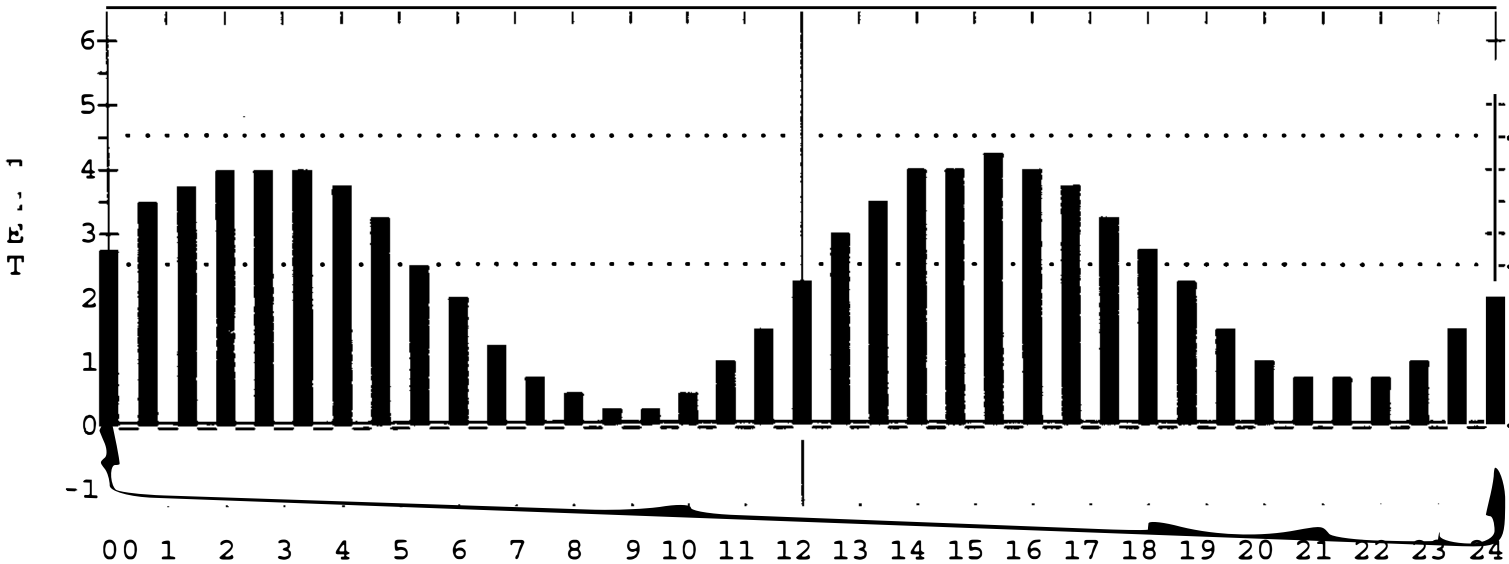
Eastern Daylight Time				High Water		Low Water	
Saturday		Jul 2,1994		0410	3.7 ft	1027	.6 ft
	Rise	Transit	Set	1651	4.4 ft	2323	.9 ft
Sun	0540	1305	2030				
Moon	0113	0804	1503				

Roosevelt Inlet Delaware 38°49'N 75°12'W



Eastern Daylight Time			High Water		Low Water	
Wednesday		Jun 29,1994	0138	4.6 ft	0803	.2 ft
Rise	Transit	Set	1415	4.3 ft	2025	.6 ft
Sun 0539	1305	2030				
Moon 0014	0555	1212				

Roosevelt Inlet Delaware 38°49'N 75°12'W



Eastern Daylight Time			High Water		Low Water	
Thursday		Jun 30,1994	0226	4.3 ft	0851	.4 ft
Rise	Transit	Set	1506	4.3 ft	2124	.8 ft
Sun 0539	1305	2030				
Moon 0043	0638	1309				

APPENDIX B
WATER-QUALITY DATA

Broadkill Beach Station A1

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
35862.18	5297	38.84667	-75.17333	0.11	22.439	27.990		8.31
35872.72		38.84667	-75.17333	0.36	22.471	27.971		8.36
35874.47				0.64	22.485	27.962	7.77	8.37
35876.22		38.84667	-75.17333	0.79	22.488	27.959	7.62	8.38
35877.97		38.84667	-75.17333	0.93	22.477	27.960	7.68	8.38
35879.72		38.84667	-75.17316	1.15	22.422	27.961	7.82	8.39
35881.47		38.84667	-75.17316	1.25	22.349	27.970	7.74	8.39
35883.22		38.84650	-75.17316	1.34	22.310	27.983	7.71	8.39
35884.97		38.84650	-75.17316	1.56	22.130	27.986	7.67	8.39
35886.72		38.84650	-75.17316	1.81	21.977	28.037	7.80	8.39
35888.47				1.97	21.889	28.089	7.78	8.39
35890.22		38.84667	-75.17316	2.10	21.804	28.117	7.65	8.39
35891.97		38.84667	-75.17316	2.24	21.691	28.143	7.73	8.39
35893.72		38.84667	-75.17333	2.50	21.589	28.165	7.63	8.39
35895.47		38.84667	-75.17333	2.74	21.574	28.176	7.42	8.39
35897.22		38.84667	-75.17333	2.79	21.516	28.197	7.28	8.39
35898.97		38.84667	-75.17333	2.86	21.441	28.225	7.23	8.39
35900.72		38.84667	-75.17333	2.93	21.396	28.235	7.22	8.39
35902.47		38.84667	-75.17333	3.14	21.348	28.253	7.01	8.38
35904.22				3.32	21.293	28.270	7.03	8.38
35905.97		38.84667	-75.17333	3.44	21.172	28.316	6.98	8.38
35907.72		38.84667	-75.17333	3.44	21.195	28.310	6.96	8.37
35909.47		38.84667	-75.17333	3.51	21.178	28.321	6.80	8.37
35947.59		38.84667	-75.17333					

Broadkill Beach Station A2

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
28850.32	5297	38.83983	-75.18134	0.43	22.418	28.226		8.09
28862.88		38.83983	-75.18134	0.62	22.396	28.225		8.15
28864.13		38.83983	-75.18134	0.81	22.324	28.207		8.19
28865.39				0.95	22.218	28.216	6.65	8.22
28866.65		38.83983	-75.18150	1.25	22.166	28.228	6.71	8.25
28867.91				1.37	22.137	28.235	6.50	8.27
28869.17		38.83983	-75.18150	1.54	22.126	28.250	7.60	8.28
28870.43		38.83983	-75.18150	1.73	22.120	28.251	7.77	8.29
28871.69				1.89	22.124	28.247	7.84	8.29
28872.95				2.00	22.116	28.252	7.80	8.30
28874.21		38.83983	-75.18150	2.14	22.111	28.260	7.67	8.30
28875.47				2.19	22.107	28.267	7.60	8.30
28876.73		38.83983	-75.18150	2.32	22.107	28.274	7.53	8.30
28877.99				2.43	22.104	28.278	7.55	8.30
28879.25				2.61	22.096	28.284	7.40	8.30
28880.51		38.83983	-75.18150	2.78	22.098	28.286	7.31	8.30
28881.77				2.86	22.099	28.285	7.34	8.30
28883.03		38.83983	-75.18150	2.96	22.093	28.295	7.36	8.30
28884.29		38.83983	-75.18150	3.09	22.092	28.300	7.34	8.30
28885.55				3.16	22.090	28.303	7.29	8.30
28886.81		38.83983	-75.18150	3.29	22.087	28.304	7.19	8.30
28888.07		38.83983	-75.18150	3.35	22.096	28.296	7.11	8.31
28889.33				3.44	22.096	28.299	7.23	8.30
28890.59				3.49	22.090	28.304	7.19	8.31
28891.85				3.60	22.092	28.300	7.21	8.31
28893.11		38.83983	-75.18150	3.68	22.090	28.306	7.24	8.31
28894.37		38.83983	-75.18150	3.82	22.086	28.308	7.07	8.31
28895.63				3.91	22.087	28.307	7.07	8.31
28896.89		38.83983	-75.18150	3.99	22.092	28.303	7.10	8.31
28898.15		38.83983	-75.18150	4.07	22.087	28.308	7.07	8.30
28911.75		38.84000	-75.18150					

Broadkill Beach Station A3

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
25960.82	5297	38.83950	-75.18417	0.11	22.412	28.512	8.23	8.16
25979.34		38.83933	-75.18417	0.28	22.406	28.506	8.24	8.20
25980.34				0.49	22.404	28.504	8.25	8.21
25981.35		38.83933	-75.18417	0.55	22.400	28.501	8.54	8.21
25982.36				0.66	22.400	28.501	8.07	8.22
25983.37		38.83933	-75.18417	0.80	22.398	28.506	7.50	8.23
25984.38				0.93	22.398	28.496	7.26	8.24
25985.38		38.83933	-75.18417	1.19	22.395	28.502	7.09	8.25
25986.39				1.44	22.395	28.500	6.94	8.25
25987.40		38.83933	-75.18417	1.55	22.402	28.495	6.94	8.25
25988.41				1.69	22.395	28.500	6.85	8.25
25989.41		38.83933	-75.18417	1.82	22.395	28.498	6.73	8.25
25990.42				1.97	22.393	28.501	6.75	8.26
25991.43		38.83933	-75.18417	2.15	22.387	28.506	6.72	8.26
25992.44				2.29	22.398	28.497	6.68	8.26
25993.45		38.83933	-75.18417	2.43	22.391	28.505	6.54	8.26
25994.45				2.52	22.389	28.502	6.47	8.26
25995.46		38.83933	-75.18417	2.51	22.393	28.501	6.38	8.26
26015.24		38.83933	-75.18417					

Broadkill Beach Station A4

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
39982.11	5296	38.84467	-75.18034	0.13	23.856	28.541		8.11
39994.48		38.84467	-75.18034	0.39	23.822	28.453		8.18
39995.48				0.51	23.509	28.535		8.21
39996.48		38.84467	-75.18034	0.81	22.652	28.607		8.22
39997.48				0.80	22.367	28.658		8.24
39998.48		38.84467	-75.18034	0.95	22.163	28.693	5.96	8.25
39999.48		38.84467	-75.18034	1.06	22.060	28.712	5.95	8.26
40000.48				1.21	21.985	28.735	6.00	8.26
40001.48		38.84467	-75.18034	1.32	21.943	28.756	6.08	8.26
40002.48				1.33	21.897	28.749	6.59	8.26
40003.48				1.54	21.722	28.750	7.79	8.26
40004.48				1.58	21.694	28.757	7.71	8.26
40005.48		38.84467	-75.18034	1.79	21.648	28.778	7.59	8.26
40006.48				1.84	21.653	28.759	7.62	8.26
40007.48		38.84467	-75.18034	2.09	21.528	28.768	7.63	8.27
40008.48				2.24	21.515	28.764	7.52	8.27
40009.48		38.84467	-75.18034	2.46	21.382	28.775	7.39	8.27
40010.48				2.61	21.336	28.790	7.37	8.27
40011.48		38.84467	-75.18034	2.73	21.303	28.788	7.35	8.27
40012.48				2.88	21.282	28.785	7.40	8.27
40013.48				3.08	21.234	28.787	7.38	8.26
40014.48				3.13	21.202	28.795	7.28	8.26
40015.48		38.84467	-75.18034	3.23	21.189	28.785	7.06	8.26
40016.48				3.48	21.161	28.786	7.05	8.26
40017.48				3.50	21.152	28.794	7.02	8.26
40018.48				3.75	21.126	28.803	7.06	8.26
40019.48		38.84467	-75.18034	3.87	21.124	28.801	7.02	8.26
40020.48				4.01	21.108	28.797	7.07	8.25
40021.48		38.84467	-75.18034	4.23	21.088	28.807	7.21	8.25
40022.48				4.24	21.097	28.806	7.18	8.25
40023.48		38.84467	-75.18034	4.50	21.085	28.802	7.13	8.25
40024.48				4.63	21.086	28.799	7.14	8.25
40039.11		38.84467	-75.18034					

Broadkill Beach Station A5

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
32112.11	5297	38.84000	-75.17867	0.13	22.280	28.049	9.07	8.38
32124.56				0.25	22.301	28.035	9.02	8.38
32125.81		38.84017	-75.17867	0.53	22.309	28.025	8.99	8.38
32127.06		38.84017	-75.17867	0.81	22.318	28.015	8.88	8.38
32128.31				1.00	22.331	28.014	8.00	8.38
32129.56		38.84017	-75.17850	1.16	22.334	28.014	7.63	8.38
32130.81		38.84000	-75.17850	1.28	22.340	28.012	7.77	8.38
32132.06				1.45	22.325	28.013	7.77	8.38
32133.31		38.84000	-75.17850	1.58	22.325	28.005	7.76	8.38
32134.56		38.84000	-75.17850	1.72	22.289	28.017	7.73	8.38
32135.81				1.92	22.264	28.004	7.59	8.39
32137.06		38.84000	-75.17867	2.11	22.189	28.000	7.44	8.38
32138.31				2.21	22.173	28.008	7.51	8.38
32139.56		38.84000	-75.17867	2.27	22.161	28.019	7.37	8.38
32140.81		38.84000	-75.17867	2.55	22.125	28.027	7.32	8.38
32142.06				2.73	22.134	28.020	7.46	8.38
32143.31		38.84000	-75.17850	2.83	22.125	28.026	7.28	8.38
32144.56		38.84000	-75.17850	2.93	22.116	28.028	7.25	8.38
32145.81				3.03	22.103	28.033	7.08	8.38
32147.06		38.84000	-75.17850	3.20	22.079	28.055	7.01	8.38
32148.31				3.28	22.084	28.048	7.10	8.37
32149.56		38.84000	-75.17850	3.39	22.078	28.055	7.22	8.37
32150.81		38.84000	-75.17850	3.51	22.079	28.055	7.21	8.37
32152.06				3.65	22.078	28.058	7.04	8.37
32153.31		38.84000	-75.17850	3.72	22.080	28.055	7.07	8.37
32154.56		38.84000	-75.17850	3.81	22.075	28.058	7.05	8.37
32155.81				3.89	22.085	28.051	7.13	8.37
32157.06		38.84000	-75.17850	3.96	22.080	28.054	6.94	8.37
32158.31		38.84000	-75.17850	4.03	22.080	28.058	6.86	8.37
32159.56				4.08	22.078	28.059	7.04	8.36
32160.81		38.84000	-75.17850	4.17	22.079	28.062	7.06	8.37
32162.06				4.17	22.078	28.066	6.91	8.37
32163.31		38.84000	-75.17850	4.33	22.077	28.069	6.90	8.36
32164.56		38.84000	-75.17850	4.38	22.072	28.071	6.94	8.36
32165.81				4.40	22.074	28.073	6.82	8.36
32167.06		38.84000	-75.17867	4.44	22.072	28.074	6.66	8.36
32179.06		38.84000	-75.17850					

Broadkill Beach Station A6

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
33238.00	5297	38.84117	-75.17750	0.22	22.377	28.082	7.16	8.38
33256.75		38.84117	-75.17733	0.59	22.370	28.076	7.19	8.38
33258.50		38.84117	-75.17733	0.87	22.360	28.073	7.30	8.39
33260.25				1.07	22.313	28.068	7.57	8.39
33262.00		38.84117	-75.17733	1.21	22.315	28.067	7.64	8.39
33263.75				1.31	22.304	28.071	7.78	8.39
33265.50		38.84117	-75.17733	1.45	22.292	28.068	7.81	8.39
33267.25		38.84117	-75.17750	1.63	22.266	28.069	7.78	8.40
33269.00				1.86	22.230	28.071	7.78	8.40
33270.75		38.84117	-75.17750	1.99	22.199	28.077	7.82	8.39
33272.50				2.18	22.170	28.086	7.74	8.39
33274.25		38.84117	-75.17750	2.24	22.158	28.095	7.76	8.39
33276.00		38.84117	-75.17750	2.43	22.150	28.094	7.63	8.39
33277.75		38.84117	-75.17750	2.50	22.139	28.103	7.51	8.38
33279.50		38.84117	-75.17750	2.60	22.142	28.102	7.36	8.39
33281.25		38.84117	-75.17750	2.67	22.139	28.103	7.55	8.39
33283.00		38.84117	-75.17750	2.74	22.138	28.102	7.55	8.38
33284.75		38.84117	-75.17750	2.79	22.134	28.101	7.52	8.39
33286.50		38.84117	-75.17750	2.91	22.137	28.102	7.39	8.39
33288.25		38.84117	-75.17750	2.96	22.129	28.104	7.21	8.39
33290.00		38.84117	-75.17750	3.20	22.129	28.106	7.26	8.38
33291.75		38.84117	-75.17750	3.32	22.126	28.105	7.39	8.38
33293.50				3.40	22.118	28.107	7.24	8.38
33295.25		38.84117	-75.17750	3.48	22.115	28.111	7.29	8.38
33297.00		38.84117	-75.17750	3.53	22.118	28.109	7.34	8.38
33298.75		38.84117	-75.17750	3.60	22.113	28.113	7.39	8.38
33300.50		38.84117	-75.17733	3.66	22.113	28.111	7.15	8.38
33302.25		38.84117	-75.17733	3.73	22.110	28.114	7.14	8.38
33304.00		38.84117	-75.17733	3.83	22.107	28.115	6.89	8.37
33305.75		38.84100	-75.17733	4.00	22.098	28.121	6.90	8.37
33307.50				4.00	22.101	28.120	6.97	8.37
33309.25		38.84117	-75.17733	4.13	22.096	28.122	7.01	8.37
33311.00		38.84117	-75.17750	4.24	22.096	28.124	6.86	8.37
33312.75		38.84117	-75.17750	4.30	22.097	28.122	7.10	8.37
33333.75		38.84100	-75.17733					

Broadkill Beach Station A7

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
34964.01	5296	38.84400	-75.18417	0.12	22.220	28.405		8.27
34968.59		38.84400	-75.18417	0.33	21.761	28.356	5.96	8.26
34970.09				0.58	21.683	28.320	6.04	8.27
34971.59		38.84400	-75.18417	0.70	21.500	28.342	6.75	8.27
34973.09		38.84400	-75.18417	0.85	21.429	28.329	7.77	8.28
34974.59				0.91	21.285	28.370	7.57	8.28
34976.09				1.10	21.157	28.385	7.61	8.28
34977.59		38.84400	-75.18417	1.25	21.105	28.405	7.36	8.28
34979.09		38.84400	-75.18417	1.48	21.019	28.445	7.41	8.29
34980.59		38.84400	-75.18417	1.68	20.971	28.464	7.47	8.29
34982.09				1.84	20.919	28.497	7.59	8.29
34983.59		38.84400	-75.18417	2.00	20.896	28.528	7.56	8.29
34985.09		38.84400	-75.18417	2.04	20.893	28.537	7.51	8.29
34986.59		38.84400	-75.18417	2.18	20.873	28.558	7.45	8.28
34988.09				2.31	20.866	28.579	7.28	8.28
34989.59		38.84400	-75.18417	2.47	20.862	28.590	7.24	8.27
34991.09		38.84400	-75.18417	2.51	20.860	28.591	7.15	8.27
34992.59		38.84400	-75.18417	2.75	20.858	28.603	7.15	8.26
34994.09		38.84400	-75.18417	2.79	20.853	28.606	7.05	8.26
34995.59				2.92	20.849	28.610	7.02	8.25
34997.09		38.84400	-75.18417	3.08	20.859	28.594	7.00	8.25
34998.59		38.84400	-75.18417	3.21	20.860	28.590	6.97	8.25
35000.09		38.84400	-75.18417	3.36	20.856	28.601	6.97	8.25
35001.59				3.52	20.857	28.602	6.92	8.25
35003.09				3.68	20.855	28.605	6.86	8.25
35004.59		38.84400	-75.18417	3.81	20.860	28.605	6.89	8.25
35006.09		38.84400	-75.18417	3.99	20.852	28.608	6.85	8.24
35007.59				4.09	20.854	28.613	6.79	8.24
35009.09		38.84400	-75.18417	4.17	20.861	28.605	6.64	8.24
35010.59		38.84400	-75.18417	4.26	20.855	28.613	6.60	8.24
35012.09				4.39	20.855	28.615	6.66	8.24
35013.59				4.58	20.851	28.615	6.63	8.24
35015.09		38.84400	-75.18433	4.69	20.855	28.616	6.55	8.24
35016.59		38.84400	-75.18433	4.77	20.856	28.615	6.61	8.23
35018.09				4.79	20.857	28.613	6.49	8.23
35019.59				4.79	20.858	28.615	6.47	8.23
35025.59				4.82	20.862	28.611	6.27	8.23
35026.47		38.84400	-75.18433					

Broadkill Beach Station A8

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
33355.62	5296	38.84250	-75.18867	0.09	22.679	28.365		8.23
33361.27		38.84250	-75.18850	0.18	22.847	28.302		8.26
33362.26				0.44	22.657	28.176	5.48	8.25
33363.24		38.84250	-75.18850	0.55	22.241	28.320	5.53	8.25
33364.23				0.73	22.183	28.320	5.73	8.26
33365.21		38.84250	-75.18850	0.88	21.776	28.364	5.89	8.26
33366.20				1.03	21.697	28.345	7.65	8.26
33367.18		38.84250	-75.18867	1.19	21.564	28.384	7.66	8.26
33368.17				1.30	21.516	28.413	7.43	8.26
33369.15		38.84250	-75.18867	1.37	21.518	28.399	7.45	8.26
33370.14				1.41	21.524	28.400	7.52	8.27
33371.12		38.84250	-75.18867	1.52	21.473	28.446	7.41	8.26
33372.11				1.67	21.394	28.495	7.28	8.26
33373.09		38.84250	-75.18867	1.70	21.444	28.462	7.31	8.27
33374.07				1.80	21.382	28.493	7.23	8.27
33375.06		38.84250	-75.18867	1.87	21.385	28.481	7.14	8.27
33376.04				1.95	21.357	28.497	7.11	8.27
33377.03		38.84250	-75.18867	2.05	21.375	28.485	6.85	8.26
33378.01				2.16	21.316	28.490	6.88	8.26
33379.00		38.84250	-75.18867	2.23	21.278	28.515	6.96	8.26
33379.98				2.28	21.264	28.513	7.10	8.26
33380.96		38.84250	-75.18867	2.35	21.216	28.534	7.08	8.26
33381.95				2.31	21.218	28.533	7.02	8.26
33382.93		38.84250	-75.18867	2.49	21.180	28.548	7.06	8.25
33383.92				2.52	21.207	28.539	6.98	8.25
33384.90		38.84250	-75.18867	2.59	21.182	28.539	6.96	8.25
33385.89				2.63	21.171	28.547	6.89	8.25
33386.87		38.84250	-75.18867	2.62	21.150	28.559	6.86	8.24
33387.86				2.68	21.152	28.554	6.80	8.25
33388.84		38.84250	-75.18867	2.68	21.156	28.551	6.59	8.24
33389.82				2.69	21.155	28.552	6.50	8.24
33393.76				2.69	21.159	28.552	6.31	8.24
33394.75		38.84233	-75.18850	2.71	21.155	28.556	6.14	8.24
33395.48		38.84233	-75.18850	2.72	21.166	28.556	6.01	8.24

Broadkill Beach Station A9

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
34754.98	5297	38.84317	-75.17333	0.08	22.353	28.108	6.85	8.38
34763.73		38.84317	-75.17333	0.46	22.345	28.102	6.95	8.38
34765.48		38.84317	-75.17333	0.74	22.316	28.102	6.96	8.38
34767.23		38.84317	-75.17333	0.95	22.286	28.110	6.96	8.38
34768.98		38.84317	-75.17333	1.11	22.260	28.113	7.47	8.38
34770.73		38.84317	-75.17316	1.25	22.212	28.121	7.85	8.38
34772.48		38.84317	-75.17316	1.36	22.178	28.119	7.83	8.39
34774.23		38.84317	-75.17316	1.52	22.134	28.131	7.78	8.39
34775.98				1.67	22.087	28.144	7.65	8.39
34777.73		38.84317	-75.17333	1.84	22.050	28.149	7.48	8.39
34779.48		38.84317	-75.17333	2.08	21.936	28.166	7.54	8.39
34781.23		38.84317	-75.17333	2.22	21.906	28.176	7.64	8.39
34782.98		38.84317	-75.17333	2.37	21.914	28.171	7.50	8.39
34784.73		38.84317	-75.17316	2.46	21.901	28.174	7.56	8.39
34786.48		38.84317	-75.17316	2.60	21.887	28.177	7.48	8.39
34788.23		38.84317	-75.17316	2.76	21.893	28.177	7.61	8.39
34789.98				2.85	21.874	28.178	7.31	8.39
34791.73		38.84317	-75.17316	2.91	21.865	28.184	7.21	8.39
34793.48		38.84317	-75.17316	3.07	21.861	28.182	7.27	8.39
34795.23		38.84317	-75.17316	3.22	21.858	28.181	7.31	8.39
34796.98		38.84317	-75.17316	3.33	21.852	28.181	7.43	8.39
34798.73		38.84317	-75.17316	3.46	21.849	28.182	7.47	8.39
34800.48		38.84317	-75.17316	3.55	21.837	28.184	7.20	8.39
34802.23		38.84317	-75.17316	3.57	21.839	28.184	7.12	8.39
34803.98		38.84317	-75.17316	3.65	21.835	28.184	7.32	8.39
34805.73				3.65	21.840	28.182	7.13	8.39
34807.48		38.84317	-75.17316	3.68	21.835	28.187	6.97	8.39
34809.23		38.84317	-75.17316	3.81	21.839	28.183	7.20	8.39
34810.98		38.84317	-75.17333	3.66	21.841	28.180	7.24	8.39
34812.73		38.84317	-75.17316	3.40	21.836	28.190	7.38	8.39
34814.48		38.84317	-75.17316	3.43	21.835	28.187	7.52	8.39
34816.23		38.84317	-75.17316	3.41	21.835	28.181	7.34	8.39
34817.98		38.84317	-75.17316	3.45	21.837	28.183	7.34	8.39
34819.73				3.60	21.830	28.182	7.07	8.39
34833.36		38.84317	-75.17316					

Broadkill Beach Station A10

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
38860.38	5297	38.84533	-75.17767	0.10	22.143	28.099	6.96	8.39
38870.56		38.84533	-75.17767	0.39	22.124	28.097	7.11	8.38
38872.31		38.84533	-75.17767	0.61	22.106	28.103		8.38
38874.06		38.84533	-75.17750	0.67	22.098	28.101		8.39
38875.81		38.84533	-75.17750	0.85	22.082	28.105	7.11	8.39
38877.56				1.04	22.064	28.103		8.39
38879.31		38.84533	-75.17750	1.08	22.053	28.111	7.21	8.39
38881.06		38.84533	-75.17767	1.16	22.053	28.140	7.90	8.39
38882.81		38.84533	-75.17767	1.40	22.041	28.163	7.92	8.40
38884.56		38.84533	-75.17767	1.46	22.039	28.165	7.80	8.39
38886.31		38.84533	-75.17767	1.56	22.045	28.163	7.67	8.40
38888.06		38.84533	-75.17767	1.72	22.043	28.163	7.76	8.40
38889.81		38.84533	-75.17767	1.76	22.027	28.163	7.90	8.40
38891.56				1.83	22.001	28.169	7.92	8.40
38893.31		38.84533	-75.17767	1.96	22.013	28.163	7.89	8.40
38895.06		38.84533	-75.17767	2.11	22.010	28.169	7.79	8.40
38896.81		38.84533	-75.17767	2.08	22.021	28.164	7.76	8.40
38898.56		38.84533	-75.17767	2.22	21.998	28.168	7.86	8.40
38900.31		38.84533	-75.17767	2.30	21.988	28.165	7.91	8.40
38902.06		38.84533	-75.17767	2.35	22.003	28.168	7.75	8.40
38903.81		38.84533	-75.17750	2.45	22.003	28.167	7.85	8.40
38905.56		38.84533	-75.17767	2.57	22.004	28.166	7.85	8.40
38907.31				2.76	21.998	28.165	7.77	8.40
38909.06		38.84550	-75.17767	2.89	21.979	28.170	7.71	8.40
38910.81		38.84533	-75.17767	3.10	21.950	28.170	7.77	8.40
38912.56		38.84533	-75.17767	3.22	21.948	28.170	7.89	8.40
38914.31		38.84533	-75.17767	3.20	21.942	28.170	7.90	8.40
38916.06		38.84533	-75.17767	3.33	21.936	28.169	7.85	8.40
38917.81		38.84533	-75.17767	3.38	21.929	28.174	7.77	8.40
38919.56		38.84550	-75.17783	3.42	21.929	28.172	7.79	8.40
38921.31				3.47	21.928	28.173	7.81	8.40
38923.06		38.84550	-75.17783	3.56	21.922	28.171	7.67	8.40
38924.81		38.84550	-75.17783	3.59	21.918	28.173	7.68	8.39
38926.56		38.84550	-75.17783	3.74	21.912	28.168	7.55	8.39
38928.31		38.84550	-75.17783	3.84	21.908	28.173	7.50	8.39
38930.06		38.84550	-75.17783	3.99	21.899	28.177	7.63	8.39
38931.81		38.84550	-75.17783	4.12	21.896	28.173	7.81	8.39
38942.06		38.84533	-75.17767					

Broadkill Beach Station A11

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
37379.27	5297	38.84750	-75.17500	0.06	22.449	28.063	6.80	8.05
37392.77		38.84750	-75.17484	0.16	22.501	28.016	6.81	8.24
37394.27				0.35	22.500	28.000	6.73	8.32
37395.77		38.84750	-75.17484	0.62	22.495	27.994		8.34
37397.27				0.71	22.498	27.996		8.36
37398.77		38.84750	-75.17500	0.90	22.490	27.998		8.37
37400.27		38.84750	-75.17500	0.92	22.487	27.997		8.38
37401.77		38.84750	-75.17500	1.08	22.486	27.991		8.38
37403.27				1.13	22.476	27.997	6.98	8.38
37404.77				1.34	22.458	28.003	7.59	8.38
37406.27		38.84750	-75.17500	1.51	22.455	27.997		8.39
37407.77		38.84750	-75.17500	1.58	22.428	28.004	7.74	8.39
37409.27				1.82	22.219	28.005	7.78	8.39
37410.77				1.82	22.128	28.047	7.78	8.40
37412.27		38.84750	-75.17500	1.86	22.079	28.060	7.82	8.39
37413.77		38.84750	-75.17484	1.98	22.041	28.059	7.79	8.40
37415.27				2.21	21.851	28.095	7.85	8.40
37416.77		38.84750	-75.17500	2.27	21.610	28.169	7.84	8.40
37418.27		38.84750	-75.17500	2.32	21.511	28.207	7.85	8.39
37419.77		38.84750	-75.17500	2.41	21.497	28.208	7.57	8.39
37421.27				2.50	21.465	28.224	7.51	8.39
37422.77		38.84750	-75.17500	2.57	21.464	28.226	7.47	8.39
37424.27				2.61	21.454	28.232	7.47	8.39
37425.77		38.84750	-75.17500	2.66	21.420	28.248	7.30	8.38
37427.27				2.77	21.378	28.262	7.26	8.38
37428.77		38.84750	-75.17500	2.79	21.375	28.265	7.22	8.38
37430.27		38.84750	-75.17500	2.71	21.353	28.273	7.20	8.38
37431.77		38.84750	-75.17500	2.87	21.337	28.276	7.12	8.38
37433.27				2.90	21.329	28.283	7.15	8.38
37434.77				2.93	21.305	28.288	7.18	8.37
37436.27		38.84750	-75.17500	3.05	21.293	28.292	7.29	8.37
37437.77		38.84750	-75.17500	3.20	21.270	28.295	7.43	8.37
37439.27				3.26	21.264	28.299	7.18	8.37
37440.77		38.84750	-75.17500	3.34	21.258	28.305	7.34	8.37
37460.02		38.84750	-75.17500					

Broadkill Beach Station A12

Time	Date	Latitude	Longitude	Depth	Temper	Salini	Disso	pH
s				m	C	PSU	mg/L	pH
36114.51	5296	38.84300	-75.18317	0.06		26.771		8.24
36137.14		38.84300	-75.18333	0.31	21.878	27.228	6.24	8.24
36138.14				0.45	21.672	27.188	6.37	8.25
36139.14		38.84300	-75.18333	0.66	21.591	26.545	6.46	8.26
36140.14				0.75	21.457	26.421	6.30	8.26
36141.14		38.84300	-75.18333	0.80	21.381	26.506	6.65	8.27
36142.14				0.84	21.371	26.542	8.00	8.27
36143.14		38.84300	-75.18333	0.98	21.376	26.493	7.83	8.27
36144.14				1.08	21.232	26.570	7.81	8.27
36145.14		38.84300	-75.18333	1.23	21.128	26.607	7.67	8.27
36146.14				1.41	21.072	26.660	7.59	8.27
36147.14		38.84300	-75.18333	1.62	20.974	26.655	7.43	8.27
36148.14				1.71	20.977	26.733	7.51	8.27
36149.14		38.84300	-75.18333	1.90	20.957	26.764	7.50	8.27
36150.14				1.97	20.947	26.769	7.54	8.27
36151.14		38.84300	-75.18333	2.11	20.940	26.788	7.58	8.27
36152.14				2.23	20.929	26.792	7.46	8.27
36153.14		38.84300	-75.18333	2.34	20.933	26.809	7.32	8.26
36154.14				2.40	20.923	26.805	7.27	8.27
36155.14		38.84300	-75.18333	2.51	20.927	26.838	7.34	8.27
36156.14				2.63	20.910	26.859	7.29	8.26
36157.14		38.84300	-75.18333	2.72	20.910	26.876	7.31	8.26
36158.14				2.89	20.912	26.892	7.13	8.26
36159.14		38.84300	-75.18333	3.04	20.905	26.908	6.91	8.26
36160.14				3.20	20.903	26.927	6.83	8.26
36161.14		38.84300	-75.18333	3.24	20.910	26.925	7.13	8.26
36162.14				3.48	20.899	26.971	7.15	8.26
36163.14		38.84300	-75.18333	3.55	20.898	26.959	7.04	8.26
36164.14				3.64	20.887	26.990	7.02	8.26
36165.14		38.84300	-75.18333	3.87	20.884	26.982	7.01	8.26
36166.14				3.96	20.889	27.018	6.99	8.26
36167.14		38.84300	-75.18333	4.16	20.891	27.032	7.02	8.25
36168.14				4.24	20.880	27.065	7.19	8.25
36169.14		38.84300	-75.18333	4.38	20.886	27.080	7.07	8.25
36170.14				4.42	20.875	27.089	7.12	8.25
36183.01		38.84283	-75.18350					

Broadkill Beach Station A13

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
30588.29	5297	38.83917	-75.17972	0.43	22.386	28.121		8.24
30598.59		38.83917	-75.17950	0.82	22.321	28.124	6.96	8.30
30600.84		38.83917	-75.17950	1.25	22.229	28.145	6.98	8.33
30603.09		38.83917	-75.17950	1.49	22.184	28.170	7.17	8.34
30605.34		38.83917	-75.17950	1.67	22.174	28.174	7.76	8.34
30607.59		38.83917	-75.17950	1.84	22.151	28.184	7.58	8.34
30609.84		38.83917	-75.17950	1.88	22.145	28.190	7.47	8.34
30612.09		38.83917	-75.17950	1.98	22.144	28.192	7.37	8.34
30614.34		38.83917	-75.17950	2.12	22.126	28.200	7.16	8.34
30616.59		38.83917	-75.17950	2.16	22.131	28.197	7.22	8.34
30618.84		38.83917	-75.17950	2.22	22.124	28.202	7.13	8.34
30621.09		38.83917	-75.17950	2.30	22.127	28.201	7.23	8.34
30623.34		38.83917	-75.17950	2.36	22.124	28.201	7.24	8.34
30625.59		38.83917	-75.17950	2.48	22.119	28.206	7.29	8.34
30627.84		38.83917	-75.17941	2.56	22.120	28.209	7.10	8.34
30630.09		38.83917	-75.17934	2.63	22.121	28.205	7.26	8.34
30632.34		38.83917	-75.17934	2.71	22.114	28.206	7.20	8.34
30634.59		38.83917	-75.17934	2.77	22.122	28.204	7.09	8.34
30636.84		38.83917	-75.17934	2.82	22.120	28.204	7.27	8.34
30639.09		38.83917	-75.17934	2.88	22.114	28.207	7.12	8.34
30641.34		38.83917	-75.17934	2.92	22.116	28.209	6.92	8.34
30643.59		38.83917	-75.17934	2.92	22.111	28.212	6.89	8.34
30645.84		38.83917	-75.17934	2.99	22.112	28.209	6.87	8.34
30648.09		38.83917	-75.17934	3.09	22.109	28.212	6.92	8.34
30650.34		38.83917	-75.17934	3.14	22.107	28.211	7.13	8.34
30652.59		38.83917	-75.17934	3.24	22.110	28.214	7.20	8.34
30654.84		38.83917	-75.17934	3.31	22.113	28.209	6.91	8.35
30657.09		38.83917	-75.17934	3.37	22.105	28.215	6.95	8.34
30659.34		38.83917	-75.17934	3.48	22.108	28.211	7.11	8.34
30661.59		38.83917	-75.17934	3.54	22.106	28.213	7.03	8.34
30663.84		38.83917	-75.17934	3.60	22.110	28.212	7.14	8.34
30666.09		38.83917	-75.17934	3.66	22.109	28.215	7.09	8.34
30668.34		38.83917	-75.17934	3.73	22.106	28.216	7.19	8.34
30670.59		38.83917	-75.17934	3.78	22.107	28.214	7.07	8.34
30672.84		38.83917	-75.17934	3.97	22.107	28.213	7.04	8.34
30675.09		38.83917	-75.17934	4.08	22.105	28.218	7.16	8.34
30677.34		38.83917	-75.17934	4.21	22.106	28.219	7.10	8.34
30679.59		38.83917	-75.17934	4.28	22.106	28.216	7.16	8.34
30681.84		38.83917	-75.17934	4.30	22.106	28.217	7.02	8.34
30701.34		38.83917	-75.17934					

Broadkill Beach Station A14

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
27443.23	5297	38.83833	-75.18100	0.25	22.416	28.272	6.64	8.27
27451.67		38.83833	-75.18100	0.52	22.357	28.406	6.52	8.27
27453.68		38.83833	-75.18100	0.85	22.318	28.412	6.87	8.27
27455.70		38.83833	-75.18100	1.11	22.304	28.417	7.44	8.28
27457.71		38.83833	-75.18100	1.34	22.303	28.418	7.34	8.29
27459.73		38.83833	-75.18100	1.51	22.304	28.414	7.12	8.29
27461.74		38.83833	-75.18100	1.67	22.296	28.420	6.97	8.29
27463.76		38.83833	-75.18100	1.87	22.293	28.422	7.06	8.29
27465.78		38.83833	-75.18100	2.00	22.296	28.418	6.94	8.29
27467.79		38.83833	-75.18100	2.11	22.293	28.420	6.67	8.29
27469.81		38.83833	-75.18100	2.19	22.288	28.421	6.67	8.29
27471.82		38.83833	-75.18100	2.31	22.288	28.422	6.29	8.29
27473.84		38.83833	-75.18100	2.45	22.289	28.422	6.57	8.29
27475.85		38.83833	-75.18100	2.53	22.291	28.421	6.91	8.29
27477.87		38.83833	-75.18100	2.62	22.286	28.424	6.69	8.29
27479.88		38.83833	-75.18100	2.75	22.281	28.424	6.75	8.29
27481.90		38.83833	-75.18100	2.83	22.285	28.420	6.65	8.29
27483.92		38.83833	-75.18100	2.90	22.284	28.420	6.67	8.29
27485.93		38.83833	-75.18100	2.96	22.285	28.423	6.74	8.29
27487.95		38.83833	-75.18100	3.04	22.282	28.423	6.65	8.29
27489.96		38.83833	-75.18100	3.10	22.287	28.418	6.70	8.29
27491.98		38.83833	-75.18100	3.18	22.278	28.424	6.49	8.30
27493.99		38.83817	-75.18100	3.23	22.284	28.423	6.67	8.29
27496.01		38.83817	-75.18100	3.25	22.289	28.419	6.67	8.29
27498.03		38.83817	-75.18100	3.33	22.289	28.417	6.75	8.29
27500.04		38.83817	-75.18100	3.37	22.281	28.421	6.54	8.29
27502.06		38.83817	-75.18100	3.43	22.282	28.421	6.75	8.29
27504.07		38.83817	-75.18100	3.49	22.286	28.418	6.73	8.29
27506.09		38.83817	-75.18100	3.56	22.287	28.421	6.65	8.29
27508.10		38.83817	-75.18100	3.58	22.285	28.420	6.55	8.29
27510.12		38.83817	-75.18100	3.63	22.285	28.421	6.26	8.29
27514.15		38.83817	-75.18117	3.68	22.288	28.416	6.59	8.30
27516.17		38.83817	-75.18117	3.71	22.283	28.419	6.69	8.30
27518.18		38.83817	-75.18117	3.68	22.285	28.417	6.74	8.30
27535.69		38.83817	-75.18117					

Broadkill Beach Station B1

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
60861.13	5296	38.83117	-75.17939	0.15	21.409	28.902		8.34
60874.57		38.83117	-75.17950	0.46	21.382	29.045	7.30	8.34
60876.57		38.83117	-75.17950	0.77	21.354	29.048	7.29	8.34
60878.57		38.83117	-75.17950	0.93	21.352	29.050	7.98	8.34
60880.57		38.83117	-75.17950	1.06	21.344	29.052	8.01	8.34
60882.57		38.83117	-75.17950	1.16	21.328	29.051	7.92	8.34
60884.57		38.83117	-75.17950	1.24	21.310	29.039	7.82	8.34
60886.57		38.83117	-75.17950	1.29	21.260	29.047	7.87	8.34
60888.57		38.83117	-75.17950	1.41	21.240	29.054	7.85	8.35
60890.57		38.83117	-75.17934	1.53	21.232	29.049	7.65	8.35
60892.57		38.83117	-75.17934	1.68	21.210	29.059	7.62	8.35
60894.57		38.83117	-75.17934	1.87	21.193	29.065	7.64	8.35
60896.57		38.83117	-75.17950	2.00	21.185	29.071	7.65	8.35
60898.57		38.83117	-75.17950	2.13	21.192	29.069	7.72	8.35
60900.57		38.83117	-75.17950	2.21	21.185	29.075	7.67	8.35
60902.57		38.83117	-75.17950	2.31	21.190	29.075	7.85	8.35
60904.57		38.83117	-75.17950	2.51	21.194	29.079	7.90	8.36
60906.57		38.83117	-75.17950	2.64	21.194	29.081	7.84	8.36
60908.57		38.83117	-75.17950	2.69	21.199	29.078	7.77	8.36
60910.57		38.83117	-75.17950	2.80	21.201	29.078	7.85	8.36
60912.57		38.83117	-75.17950	2.95	21.198	29.083	7.73	8.36
60914.57		38.83117	-75.17950	3.10	21.176	29.088	7.66	8.36
60916.57		38.83117	-75.17950	3.28	21.125	29.094	7.70	8.36
60918.57		38.83117	-75.17934	3.45	21.113	29.082	7.87	8.36
60920.57		38.83117	-75.17950	3.64	21.023	29.095	7.67	8.35
60922.57		38.83117	-75.17950	3.74	21.026	29.095	7.38	8.35
60924.57		38.83117	-75.17934	3.84	21.022	29.093	7.33	8.35
60926.57		38.83117	-75.17934	3.95	21.014	29.105	7.19	8.34
60928.57		38.83117	-75.17934	4.04	20.995	29.098	6.95	8.34
60930.57		38.83117	-75.17934	4.10	20.979	29.098	6.66	8.34
60932.57		38.83117	-75.17934	4.24	20.970	29.099	6.89	8.33
60964.45		38.83117	-75.17950					

Broadkill Beach Station B2

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
41914.06	5297	38.83044	-75.16917	0.17	22.414	28.650	6.56	8.27
41921.38		38.83033	-75.16917	0.41	22.435	28.639	6.68	8.27
41923.38		38.83033	-75.16917	0.73	22.451	28.628	7.05	8.28
41925.38		38.83033	-75.16917	0.94	22.450	28.627	7.49	8.29
41927.38		38.83050	-75.16933	1.15	22.433	28.628	7.57	8.29
41929.38		38.83050	-75.16933	1.34	22.430	28.630	7.46	8.29
41931.38		38.83050	-75.16933	1.52	22.421	28.629	7.38	8.29
41933.38		38.83050	-75.16917	1.78	22.409	28.626	7.46	8.30
41935.38		38.83050	-75.16933	1.96	22.385	28.630	7.34	8.30
41937.38		38.83050	-75.16917	2.11	22.374	28.634	7.36	8.30
41939.38		38.83033	-75.16917	2.21	22.369	28.631	7.33	8.30
41941.38		38.83033	-75.16917	2.33	22.367	28.631	7.38	8.30
41943.38		38.83050	-75.16917	2.53	22.361	28.632	7.41	8.30
41945.38		38.83050	-75.16917	2.63	22.352	28.630	7.34	8.30
41947.38		38.83050	-75.16917	2.81	22.344	28.630	7.30	8.30
41949.38		38.83050	-75.16933	2.97	22.326	28.631	7.39	8.30
41951.38		38.83050	-75.16933	3.12	22.319	28.633	7.37	8.30
41953.38		38.83033	-75.16933	3.28	22.313	28.632	7.24	8.30
41955.38		38.83033	-75.16917	3.58	22.299	28.631	7.16	8.29
41957.38		38.83050	-75.16917	3.88	22.290	28.630	7.08	8.29
41959.38		38.83050	-75.16917	4.04	22.284	28.633	7.10	8.29
41961.38		38.83050	-75.16917	4.20	22.286	28.631	7.04	8.29
41963.38		38.83050	-75.16917	4.32	22.284	28.632	7.09	8.29
41965.38		38.83050	-75.16933	4.32	22.284	28.633	7.02	8.29
41967.38		38.83050	-75.16917	3.83	22.287	28.635	7.05	8.29
41969.38		38.83033	-75.16917	3.78	22.288	28.631	6.87	8.29
41971.38		38.83033	-75.16917	3.78	22.291	28.631	6.92	8.29
41973.38		38.83033	-75.16917	3.80	22.286	28.635	7.13	8.29
41975.38		38.83033	-75.16917	3.80	22.290	28.630	7.10	8.29
41977.38		38.83033	-75.16917	3.80	22.287	28.632	7.04	8.29
41979.38		38.83050	-75.16917	3.86	22.288	28.635	7.09	8.29
42009.13		38.83050	-75.16917					

Broadkill Beach Station B3

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
40762.52	5297	38.83200	-75.16933	0.12	22.427	28.559	6.80	8.34
40769.43				0.37	22.374	28.570	6.73	8.31
40770.98		38.83200	-75.16933	0.62	22.351	28.605	7.07	8.30
40772.68		38.83200	-75.16933	0.80	22.320	28.609	7.34	8.30
40774.18		38.83200	-75.16933	0.93	22.307	28.610	7.10	8.30
40775.68		38.83200	-75.16933	0.98	22.315	28.608	7.19	8.30
40777.18				1.07	22.303	28.609	7.18	8.30
40778.68		38.83200	-75.16933	1.28	22.293	28.602	7.04	8.30
40780.18		38.83200	-75.16933	1.35	22.275	28.604	7.16	8.29
40781.68		38.83200	-75.16933	1.47	22.264	28.601	7.16	8.29
40783.18				1.64	22.258	28.599	7.12	8.30
40784.68		38.83200	-75.16950	1.80	22.245	28.601	7.12	8.29
40786.18		38.83200	-75.16950	1.94	22.235	28.609	7.01	8.29
40787.68		38.83200	-75.16950	2.09	22.239	28.604	6.89	8.29
40789.18				2.24	22.246	28.604	6.92	8.29
40790.68		38.83200	-75.16933	2.36	22.246	28.605	6.98	8.29
40792.18		38.83183	-75.16933	2.42	22.243	28.604	6.99	8.29
40793.68		38.83183	-75.16917	2.48	22.237	28.600	6.98	8.29
40795.18				2.55	22.232	28.606	6.88	8.29
40796.68		38.83183	-75.16917	2.53	22.235	28.601	6.87	8.29
40798.18		38.83200	-75.16917	2.58	22.232	28.597	6.87	8.29
40799.68		38.83200	-75.16933	2.62	22.228	28.603	6.78	8.29
40801.18				2.76	22.244	28.603	6.75	8.29
40802.68		38.83200	-75.16933	2.99	22.260	28.604	6.79	8.29
40804.18		38.83200	-75.16933	3.12	22.264	28.602	6.85	8.29
40805.68		38.83200	-75.16933	3.24	22.254	28.605	6.81	8.29
40807.18		38.83200	-75.16933	3.17	22.259	28.602	6.89	8.29
40808.68				3.36	22.246	28.604	6.80	8.29
40810.18		38.83200	-75.16933	3.41	22.242	28.601	6.71	8.29
40811.68		38.83200	-75.16933	3.37	22.235	28.605	6.85	8.29
40813.18		38.83200	-75.16933	3.48	22.227	28.606	6.96	8.29
40814.68				3.45	22.229	28.599	6.95	8.29
40816.18		38.83200	-75.16933	3.60	22.229	28.593	6.89	8.29
40817.68		38.83183	-75.16933	3.80	22.219	28.596	6.85	8.29
40819.18		38.83200	-75.16933	3.88	22.224	28.596	6.79	8.29
40820.68				4.02	22.224	28.598	6.81	8.29
40822.18		38.83200	-75.16933	4.21	22.219	28.598	6.82	8.29
40838.31		38.83200	-75.16950					

Broadkill Beach Station B4

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
55404.78	5296	38.82850	-75.18967	0.12	21.888	28.913		8.36
55409.86				0.30	21.909	28.948		8.37
55411.36		38.82850	-75.18967	0.57	21.921	28.946		8.38
55412.86		38.82850	-75.18967	0.86	21.942	28.938		8.39
55414.36		38.82850	-75.18967	1.03	21.912	28.939		8.39
55415.86				1.13	21.889	28.940		8.40
55417.36		38.82850	-75.18967	1.38	21.712	28.974		8.40
55418.86		38.82850	-75.18983	1.53	21.664	28.966		8.39
55420.36		38.82850	-75.18967	1.72	21.559	29.013		8.39
55421.86				1.78	21.534	29.018		8.39
55423.36		38.82850	-75.18967	1.90	21.513	29.031		8.38
55424.86		38.82850	-75.18967	2.07	21.531	29.021		8.38
55426.36		38.82850	-75.18983	2.14	21.526	29.030		8.38
55427.86				2.21	21.519	29.033		8.37
55429.36		38.82850	-75.18983	2.33	21.508	29.037		8.37
55430.86		38.82850	-75.18983	2.40	21.487	29.042		8.37
55432.36		38.82850	-75.18967	2.49	21.463	29.047		8.37
55433.86				2.57	21.436	29.047		8.37
55435.36		38.82850	-75.18983	2.61	21.413	29.055		8.37
55436.86		38.82850	-75.18967	2.76	21.401	29.049	7.55	8.36
55438.36		38.82850	-75.18967	2.78	21.405	29.058	7.58	8.36
55439.86				2.82	21.398	29.055	7.61	8.36
55441.36		38.82850	-75.18967	2.88	21.396	29.054	7.48	8.36
55442.86		38.82850	-75.18967	2.92	21.394	29.054	8.00	8.36
55444.36		38.82850	-75.18967	2.92	21.386	29.056	7.96	8.36
55445.86				3.07	21.372	29.058	7.80	8.36
55447.36		38.82850	-75.18967	3.10	21.373	29.060	7.83	8.35
55448.86		38.82850	-75.18967	3.15	21.358	29.062	7.74	8.35
55450.36		38.82850	-75.18967	3.18	21.366	29.057	7.87	8.35
55451.86		38.82850	-75.18967	3.32	21.364	29.059	7.89	8.35
55453.36				3.53	21.361	29.060		8.35
55454.86		38.82850	-75.18967	3.61	21.366	29.056	8.02	8.35
55456.36		38.82850	-75.18967	3.75	21.364	29.058	7.96	8.36
55457.86		38.82850	-75.18967	3.97	21.355	29.059	7.98	8.35
55459.36				4.16	21.357	29.057	8.01	8.35
55460.86		38.82850	-75.18967	4.33	21.359	29.052	7.96	8.35
55462.36		38.82850	-75.18967	4.39	21.358	29.056	8.00	8.35
55478.74		38.82850	-75.18967	3.99	21.364	29.052	7.72	8.35

Broadkill Beach Station B5

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
58606.76	5296	38.82673	-75.18005	0.05	21.337	29.110		7.75
58616.65		38.82667	-75.18000	0.29	21.118	29.134		7.96
58618.40		38.82667	-75.18000	0.65	21.067	29.140	6.74	8.12
58620.15				0.89	21.052	29.144	6.80	8.19
58621.90		38.82667	-75.18000	1.09	21.030	29.147		8.24
58623.65		38.82667	-75.18000	1.29	21.035	29.141	6.78	8.27
58625.40				1.43	21.012	29.155	7.47	8.29
58627.15		38.82683	-75.18017	1.58	20.991	29.149	8.17	8.30
58628.90		38.82683	-75.18017	1.68	20.972	29.147	8.01	8.31
58630.65		38.82667	-75.18000	1.84	20.954	29.153	7.80	8.31
58632.40				1.95	20.942	29.143	7.63	8.31
58634.15				2.02	20.935	29.138	7.76	8.32
58635.90		38.82667	-75.18000	2.08	20.912	29.148	7.66	8.32
58637.65		38.82667	-75.18017	2.16	20.913	29.150	7.75	8.32
58639.40		38.82667	-75.18017	2.21	20.917	29.148	7.80	8.32
58641.15		38.82683	-75.18017	2.46	20.881	29.141	7.94	8.32
58642.90		38.82667	-75.18017	2.75	20.834	29.147	7.65	8.32
58644.65		38.82683	-75.18017	2.85	20.831	29.149	7.52	8.31
58646.40		38.82683	-75.18017	2.99	20.823	29.142	7.39	8.31
58648.15		38.82683	-75.18017	3.09	20.811	29.151	7.59	8.31
58649.90				3.22	20.817	29.139	7.38	8.31
58651.65				3.32	20.805	29.141	7.42	8.31
58653.40		38.82683	-75.18017	3.41	20.782	29.140	7.33	8.31
58655.15				3.57	20.749	29.148	7.22	8.31
58656.90		38.82683	-75.18000	3.64	20.751	29.148	7.41	8.31
58658.65		38.82683	-75.18017	3.69	20.744	29.151	7.33	8.31
58660.40		38.82683	-75.18017	3.82	20.714	29.161	7.50	8.31
58662.15		38.82683	-75.18017	4.03	20.705	29.159	7.56	8.31
58663.90				4.06	20.706	29.155	7.44	8.31
58665.65		38.82667	-75.18017	4.15	20.699	29.160	7.35	8.31
58667.40		38.82667	-75.18017	4.34	20.685	29.161	7.47	8.31
58669.15				4.58	20.675	29.156	7.52	8.31
58670.90		38.82667	-75.18017	4.76	20.670	29.158	7.41	8.31
58672.65		38.82667	-75.18000	4.81	20.668	29.156	7.35	8.31
58674.40		38.82683	-75.18017	4.89	20.663	29.158	7.47	8.31
58676.15		38.82667	-75.18000	5.02	20.655	29.163	7.57	8.31
58677.90				5.03	20.657	29.155	7.57	8.31
58693.40		38.82667	-75.18000	4.71	20.659	29.160	6.98	8.30

Broadkill Beach Station B6

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
62775.68	5296	38.82717	-75.17717	0.05	21.545	29.030		8.15
62788.63		38.82717	-75.17717	0.22	21.583	29.019		8.28
62789.88		38.82717	-75.17717	0.51	21.586	29.016		8.32
62791.13				0.69	21.592	29.005		8.34
62792.38		38.82717	-75.17717	0.90	21.591	29.005		8.35
62793.63				1.01	21.586	29.010		8.35
62794.88		38.82717	-75.17717	1.17	21.584	29.006		8.36
62796.13		38.82717	-75.17717	1.26	21.564	29.021		8.36
62797.38				1.37	21.560	29.020		8.36
62798.63		38.82717	-75.17717	1.50	21.561	29.017	7.19	8.36
62799.88		38.82717	-75.17717	1.67	21.547	29.025	7.29	8.36
62801.13				1.80	21.534	29.012	7.29	8.36
62802.38		38.82717	-75.17700	1.93	21.519	29.019	7.08	8.36
62803.63				2.05	21.515	29.018	7.91	8.36
62804.88		38.82717	-75.17700	2.10	21.514	29.019	7.80	8.36
62806.13		38.82717	-75.17717	2.20	21.505	29.015	7.94	8.36
62807.38				2.37	21.470	29.020	7.99	8.36
62808.63		38.82717	-75.17717	2.46	21.403	29.039	7.93	8.36
62809.88		38.82717	-75.17717	2.54	21.331	29.030	7.89	8.36
62811.13				2.71	21.231	29.036	7.81	8.36
62812.38		38.82717	-75.17717	2.87	21.210	29.043	7.89	8.35
62813.63				2.98	21.216	29.031	7.87	8.35
62814.88		38.82717	-75.17717	3.13	21.206	29.033	7.74	8.34
62816.13		38.82717	-75.17717	3.22	21.190	29.039	7.72	8.34
62817.38				3.30	21.174	29.041	7.62	8.34
62818.63		38.82717	-75.17717	3.40	21.149	29.055	7.59	8.34
62819.88		38.82717	-75.17717	3.52	21.127	29.058	7.47	8.34
62821.13				3.57	21.128	29.058	7.22	8.34
62822.38		38.82717	-75.17717	3.66	21.128	29.054	7.37	8.34
62823.63		38.82717	-75.17717	3.77	21.115	29.061	7.45	8.34
62824.88				3.88	21.108	29.060	7.35	8.33
62826.13		38.82717	-75.17717	3.97	21.101	29.060	7.32	8.34
62827.38				4.03	21.088	29.066	7.36	8.33
62828.63		38.82717	-75.17717	4.05	21.082	29.069	7.46	8.34
62829.88		38.82717	-75.17717	4.10	21.078	29.070	7.49	8.33
62831.13				4.21	21.074	29.071	7.38	8.33
62832.38		38.82717	-75.17717	4.22	21.076	29.072	7.35	8.33
62833.63		38.82717	-75.17717	4.28	21.076	29.061	7.13	8.33
62844.38		38.82717	-75.17717					

Broadkill Beach Station B7

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
52549.03	5296	38.82383	-75.19200	0.07	22.317	28.613		8.18
52555.57		38.82383	-75.19200	0.28	22.430	28.601		8.23
52557.32				0.54	22.471	28.582		8.25
52559.07				0.74	22.475	28.574		8.26
52560.82		38.82383	-75.19200	0.86	22.460	28.574		8.27
52562.57		38.82383	-75.19200	0.97	22.470	28.571		8.28
52564.32				1.07	22.456	28.577	7.21	8.28
52566.07		38.82383	-75.19200	1.19	22.463	28.582	7.32	8.28
52567.82		38.82383	-75.19200	1.26	22.467	28.579		8.29
52569.57		38.82383	-75.19200	1.39	22.456	28.576		8.29
52571.32		38.82383	-75.19217	1.46	22.429	28.579	7.33	8.29
52573.07				1.52	22.417	28.579	7.24	8.29
52574.82		38.82383	-75.19200	1.63	22.402	28.580		8.29
52576.57		38.82383	-75.19200	1.72	22.389	28.577	7.13	8.29
52578.32		38.82383	-75.19200	1.89	22.345	28.588	7.12	8.29
52580.07		38.82383	-75.19200	1.96	22.326	28.593	7.22	8.29
52581.82		38.82383	-75.19183	2.14	22.283	28.593	7.55	8.29
52583.57		38.82383	-75.19200	2.38	22.244	28.602		8.29
52585.32		38.82383	-75.19200	2.49	22.238	28.605		8.29
52587.07				2.58	22.234	28.605	7.87	8.29
52588.82		38.82383	-75.19200	2.62	22.232	28.601	7.87	8.29
52590.57		38.82383	-75.19200	2.69	22.217	28.606	7.86	8.30
52592.32				2.78	22.202	28.609	7.87	8.30
52594.07		38.82383	-75.19200	2.90	22.182	28.619	7.86	8.30
52595.82		38.82383	-75.19200	2.99	22.189	28.613	7.78	8.30
52597.57		38.82383	-75.19200	3.11	22.177	28.620	7.61	8.30
52599.32		38.82383	-75.19200	3.19	22.168	28.619	7.69	8.30
52601.07				3.25	22.166	28.626	7.72	8.30
52602.82				3.33	22.164	28.625	7.72	8.30
52604.57		38.82383	-75.19200	3.39	22.160	28.626	7.86	8.30
52606.32		38.82383	-75.19200	3.56	22.146	28.636	7.83	8.30
52608.07		38.82383	-75.19200	3.63	22.150	28.634	7.85	8.30
52609.82		38.82383	-75.19200	3.68	22.146	28.635	7.82	8.30
52611.57				3.83	22.138	28.636	7.55	8.30
52613.32		38.82383	-75.19200	3.98	22.141	28.640	7.60	8.30
52615.07		38.82383	-75.19200	4.18	22.143	28.642	7.56	8.31
52616.82				4.31	22.140	28.644	7.32	8.31
52618.57		38.82383	-75.19200	4.43	22.132	28.647	7.40	8.31
52620.32		38.82383	-75.19200	4.51	22.137	28.642	7.65	8.31
52635.57		38.82383	-75.19200	4.24	22.136	28.651	7.82	8.31

Broadkill Beach Station B8

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
57391.87	5296	38.82633	-75.18344	0.12	21.169	29.137		8.28
57398.22				0.19	21.166	29.136		8.29
57399.47				0.34	21.151	29.138		8.30
57400.72				0.60	21.130	29.146		8.30
57401.97		38.82633	-75.18333	0.80	21.124	29.144		8.31
57403.22		38.82633	-75.18350	0.97	21.110	29.141	7.55	8.31
57404.47				1.14	21.099	29.144	7.61	8.31
57405.72				1.39	21.086	29.146	7.48	8.31
57406.97		38.82633	-75.18350	1.61	21.029	29.157	7.93	8.31
57408.22				1.82	21.017	29.145	7.82	8.31
57409.47		38.82633	-75.18333	2.04	20.996	29.146	7.80	8.31
57410.72		38.82633	-75.18333	2.26	20.989	29.152	7.88	8.31
57411.97				2.49	20.989	29.148	7.91	8.31
57413.22				2.70	20.986	29.149	7.92	8.31
57414.47				2.94	20.969	29.143	7.94	8.31
57415.72		38.82633	-75.18350	3.14	20.953	29.150	7.82	8.31
57416.97				3.26	20.955	29.138	7.75	8.31
57418.22				3.41	20.945	29.133	7.55	8.31
57419.47		38.82633	-75.18350	3.50	20.944	29.133	7.51	8.31
57420.72		38.82633	-75.18350	3.64	20.934	29.137	7.44	8.31
57421.97				3.75	20.930	29.143	7.46	8.30
57423.22		38.82633	-75.18350	3.94	20.924	29.144	7.31	8.30
57424.47				4.03	20.916	29.147	7.19	8.30
57425.72		38.82633	-75.18350	4.19	20.921	29.138	7.22	8.30
57426.97				4.17	20.923	29.134	7.38	8.30
57428.22				4.38	20.900	29.139	7.27	8.30
57429.47		38.82633	-75.18350	4.39	20.914	29.134	7.41	8.30
57430.72				4.56	20.914	29.133	7.48	8.30
57431.97				4.56	20.910	29.131	7.48	8.30
57433.22		38.82650	-75.18367	4.75	20.890	29.132	7.24	8.30
57434.47				4.75	20.888	29.140	7.06	8.30
57435.72		38.82633	-75.18350	4.83	20.888	29.142	7.15	8.30
57436.97		38.82633	-75.18350	4.94	20.900	29.133	7.19	8.30
57438.22				5.13	20.901	29.135	7.15	8.30
57439.47		38.82633	-75.18350	5.15	20.892	29.138	7.14	8.30
57440.72		38.82633	-75.18350	5.16	20.884	29.146	7.33	8.30
57455.22		38.82633	-75.18333					

Broadkill Beach Station B9

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
54224.09	5296	38.82644	-75.18722	0.24	21.899	29.005		8.35
54235.18		38.82633	-75.18733	0.36	21.901	28.993		8.37
54236.68				0.75	21.815	28.994		8.38
54238.18		38.82633	-75.18733	1.07	21.737	28.997		8.39
54239.68		38.82633	-75.18733	1.24	21.575	29.046		8.39
54241.18				1.39	21.521	29.056		8.39
54242.68				1.53	21.498	29.059		8.38
54244.18		38.82633	-75.18733	1.72	21.487	29.067		8.39
54245.68		38.82633	-75.18733	1.87	21.453	29.072		8.38
54247.18				2.00	21.433	29.083		8.38
54248.68				2.19	21.414	29.088		8.38
54250.18		38.82633	-75.18733	2.28	21.407	29.088		8.38
54251.68		38.82633	-75.18733	2.44	21.352	29.097		8.37
54253.18				2.53	21.341	29.089		8.37
54254.68		38.82633	-75.18733	2.74	21.316	29.086		8.37
54256.18		38.82633	-75.18716	2.86	21.315	29.084		8.36
54257.68		38.82633	-75.18716	2.98	21.308	29.086		8.36
54259.18		38.82633	-75.18716	3.06	21.302	29.090		8.36
54260.68				3.15	21.301	29.084		8.36
54262.18		38.82633	-75.18716	3.27	21.296	29.084	7.74	8.36
54263.68		38.82633	-75.18716	3.37	21.295	29.089		8.36
54265.18				3.38	21.300	29.091	7.63	8.36
54266.68		38.82650	-75.18716	3.51	21.291	29.094	7.66	8.36
54268.18		38.82633	-75.18716	3.62	21.298	29.080	7.75	8.36
54269.68		38.82633	-75.18716	3.68	21.290	29.080	7.97	8.35
54271.18		38.82633	-75.18716	3.77	21.285	29.078	7.76	8.35
54272.68				3.80	21.288	29.078	7.86	8.35
54274.18		38.82633	-75.18716	3.94	21.285	29.079	7.86	8.35
54275.68		38.82633	-75.18716	3.98	21.287	29.078	7.81	8.35
54277.18		38.82633	-75.18716	4.11	21.289	29.076	7.93	8.35
54278.68				4.21	21.285	29.074	7.97	8.35
54280.18		38.82633	-75.18716	4.22	21.284	29.078	7.94	8.35
54281.68		38.82633	-75.18716	4.36	21.287	29.070	7.83	8.35
54283.18		38.82650	-75.18716	4.42	21.282	29.075	7.78	8.35
54284.68				4.53	21.273	29.076	7.76	8.35
54286.18		38.82650	-75.18716	4.70	21.278	29.070	7.82	8.35
54287.68		38.82633	-75.18716	4.73	21.271	29.076	7.96	8.34
54289.18		38.82633	-75.18716	4.86	21.276	29.070	7.77	8.34
54298.05		38.82633	-75.18733					

Broadkill Beach Station B10

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
59884.12	5296	38.82983	-75.18000	0.08	21.297	29.068		8.27
59900.54		38.83000	-75.18000	0.24	21.245	29.126		8.34
59902.04		38.83000	-75.18000	0.45	21.230	29.124		8.34
59903.54				0.72	21.208	29.124		8.34
59905.04		38.83000	-75.18000	0.84	21.210	29.129		8.34
59906.54		38.83000	-75.18000	0.95	21.175	29.128		8.35
59908.04		38.83000	-75.18000	1.10	21.157	29.133		8.35
59909.54				1.23	21.118	29.127		8.35
59911.04		38.83000	-75.18000	1.28	21.102	29.133		8.36
59912.54		38.83000	-75.18000	1.39	21.070	29.134		8.36
59914.04		38.83000	-75.18000	1.57	21.060	29.130	6.75	8.36
59915.54				1.71	21.044	29.134	6.49	8.36
59917.04		38.83000	-75.18000	1.91	21.031	29.128	6.71	8.36
59918.54		38.83000	-75.18000	2.16	20.998	29.134	7.86	8.36
59920.04		38.83000	-75.18000	2.30	21.005	29.126	8.10	8.35
59921.54		38.83000	-75.18000	2.43	20.994	29.128	7.94	8.35
59923.04				2.67	20.979	29.121	7.74	8.35
59924.54		38.83000	-75.18000	2.83	20.958	29.124	7.73	8.34
59926.04		38.83000	-75.18000	2.99	20.946	29.123	7.69	8.34
59927.54		38.83000	-75.18000	3.10	20.935	29.120	7.64	8.34
59929.04				3.18	20.944	29.127	7.51	8.34
59930.54		38.83000	-75.18000	3.28	20.954	29.125	7.45	8.34
59932.04		38.83000	-75.18000	3.36	20.947	29.114	7.48	8.34
59933.54		38.83000	-75.18000	3.37	20.946	29.121	7.35	8.33
59935.04				3.40	20.942	29.117	7.60	8.33
59936.54		38.83000	-75.18000	3.61	20.911	29.107	7.68	8.33
59938.04		38.83000	-75.18000	3.68	20.883	29.120	7.62	8.33
59939.54		38.83000	-75.18000	3.82	20.884	29.120	7.66	8.33
59941.04				3.96	20.849	29.117	7.64	8.33
59942.54		38.83000	-75.18000	3.97	20.844	29.123	7.56	8.32
59944.04		38.83000	-75.18017	4.13	20.822	29.124	7.34	8.32
59945.54		38.83000	-75.18017	4.19	20.812	29.128	7.15	8.32
59947.04				4.21	20.813	29.130	7.24	8.32
59948.54		38.83000	-75.18000	4.32	20.812	29.130	7.41	8.32
59950.04		38.83000	-75.18000	4.38	20.809	29.127	7.41	8.32
59962.04		38.83000	-75.18017					

Broadkill Beach Station B11

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
43145.61	5297	38.82950	-75.16634	0.14	22.551	28.139		8.23
43157.71				0.33	22.510	28.053		8.34
43159.46		38.82950	-75.16634	0.73	22.483	28.098		8.37
43161.21		38.82950	-75.16634	0.94	22.379	28.149		8.39
43162.96		38.82950	-75.16634	1.13	22.394	28.136		8.40
43164.71		38.82950	-75.16650	1.16	22.408	28.119		8.41
43166.46		38.82950	-75.16650	1.27	22.389	28.134		8.41
43168.21		38.82950	-75.16650	1.50	22.352	28.165		8.41
43169.96		38.82950	-75.16650	1.72	22.315	28.189		8.41
43171.71				1.94	22.317	28.186		8.42
43173.46		38.82950	-75.16650	2.20	22.286	28.215		8.41
43175.21		38.82950	-75.16650	2.29	22.217	28.255		8.41
43176.96		38.82950	-75.16634	2.43	22.096	28.343	8.11	8.41
43178.71		38.82950	-75.16634	2.48	21.912	28.451		8.40
43180.46		38.82950	-75.16634	2.52	21.841	28.488	8.13	8.39
43182.21		38.82950	-75.16634	2.60	21.828	28.496	8.16	8.39
43183.96		38.82950	-75.16634	2.63	21.827	28.498	8.19	8.38
43185.71				2.77	21.806	28.507		8.39
43187.46		38.82950	-75.16634	2.88	21.748	28.538	8.24	8.38
43189.21		38.82950	-75.16634	3.02	21.720	28.543	8.21	8.37
43190.96		38.82950	-75.16634	3.16	21.659	28.560	7.95	8.37
43192.71		38.82950	-75.16634	3.22	21.611	28.583	7.83	8.36
43194.46		38.82950	-75.16634	3.27	21.580	28.591	7.73	8.35
43196.21		38.82950	-75.16650	3.35	21.516	28.614	7.59	8.35
43197.96		38.82950	-75.16650	3.40	21.517	28.614	7.57	8.35
43199.71				3.49	21.509	28.611	7.46	8.34
43201.46		38.82950	-75.16634	3.60	21.479	28.624	7.11	8.34
43203.21		38.82950	-75.16634	3.62	21.476	28.622	7.06	8.34
43204.96		38.82950	-75.16634	3.69	21.456	28.631	7.37	8.33
43206.71		38.82950	-75.16634	3.77	21.454	28.633	7.28	8.33
43208.46		38.82950	-75.16634	3.83	21.457	28.633	7.15	8.33
43210.21		38.82950	-75.16634	3.95	21.437	28.634	7.26	8.33
43211.96		38.82950	-75.16634	4.02	21.415	28.644	7.22	8.33
43213.71		38.82950	-75.16634	4.09	21.423	28.642	7.30	8.33
43215.46				4.24	21.415	28.649	7.17	8.32
43217.21		38.82950	-75.16634	4.27	21.394	28.653	7.24	8.32
43218.96		38.82950	-75.16634	4.43	21.392	28.649	7.29	8.32
43220.71		38.82950	-75.16634	4.56	21.379	28.655	7.24	8.32
43234.21		38.82950	-75.16634					

Broadkill Beach Station B12

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
67259.63	5296	38.82917	-75.17133	0.02	22.001	28.905	7.06	8.35
67269.98		38.82917	-75.17117	0.25	22.068	28.800	6.99	8.34
67271.23		38.82917	-75.17117	0.59	22.095	28.790	7.02	8.34
67272.48				0.71	22.111	28.780	7.31	8.34
67273.73		38.82917	-75.17117	0.92	22.111	28.778	7.76	8.34
67274.98				1.13	22.112	28.772	7.75	8.35
67276.23		38.82917	-75.17133	1.28	22.104	28.775	7.81	8.34
67277.48		38.82917	-75.17117	1.43	22.087	28.784	7.76	8.35
67278.73				1.50	22.084	28.786	7.68	8.34
67279.98		38.82917	-75.17133	1.60	22.085	28.785	7.71	8.34
67281.23		38.82917	-75.17133	1.78	22.083	28.783	7.76	8.35
67282.48				1.89	22.074	28.784	7.63	8.35
67283.73		38.82917	-75.17133	2.00	22.068	28.787	7.48	8.34
67284.98				2.08	22.059	28.791	7.45	8.35
67286.23		38.82917	-75.17133	2.21	22.051	28.792	7.32	8.35
67287.48		38.82917	-75.17133	2.33	22.049	28.791	7.34	8.35
67288.73				2.41	22.040	28.791	7.16	8.35
67289.98		38.82917	-75.17133	2.49	22.028	28.794	6.99	8.35
67291.23		38.82917	-75.17133	2.52	22.015	28.798	7.02	8.35
67292.48				2.58	22.015	28.800	7.22	8.35
67293.73		38.82917	-75.17133	2.61	22.015	28.799	7.20	8.35
67294.98				2.84	21.994	28.805	7.10	8.35
67296.23		38.82917	-75.17117	2.88	21.990	28.807	7.08	8.35
67297.48		38.82917	-75.17133	3.08	21.990	28.800	7.14	8.35
67298.73				3.13	21.977	28.808	7.20	8.35
67299.98		38.82917	-75.17133	3.23	21.978	28.803	7.54	8.35
67301.23		38.82900	-75.17133	3.30	21.965	28.810	7.49	8.35
67302.48				3.28	21.970	28.805	7.47	8.35
67303.73		38.82917	-75.17133	3.43	21.963	28.813	7.44	8.35
67304.98				3.45	21.962	28.808	7.31	8.35
67306.23		38.82917	-75.17133	3.66	21.960	28.808	7.31	8.34
67307.48		38.82917	-75.17117	3.80	21.945	28.813	7.49	8.34
67308.73				4.00	21.930	28.812	7.54	8.35
67309.98		38.82917	-75.17117	4.11	21.909	28.814	7.54	8.34
67311.23		38.82917	-75.17117	4.11	21.899	28.818	7.52	8.34
67324.48		38.82917	-75.17133					

Broadkill Beach Station B13

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
63764.52	5296	38.82700	-75.17300	0.08	21.589	29.020	4.73	8.36
63772.19		38.82700	-75.17300	0.18	21.602	29.013	4.75	8.36
63773.69				0.41	21.613	29.010	4.93	8.37
63775.19		38.82700	-75.17300	0.65	21.625	29.003	6.33	8.37
63776.69		38.82700	-75.17300	0.76	21.630	29.004	7.67	8.37
63778.19		38.82700	-75.17300	0.85	21.637	29.003	7.72	8.37
63779.69		38.82700	-75.17300	1.05	21.638	29.005	7.72	8.37
63781.19				1.23	21.642	29.002	7.85	8.37
63782.69		38.82700	-75.17300	1.36	21.639	29.003	7.91	8.37
63784.19		38.82700	-75.17300	1.49	21.617	29.004	7.91	8.37
63785.69				1.63	21.590	28.999	7.97	8.37
63787.19		38.82700	-75.17300	1.82	21.502	29.002	7.99	8.37
63788.69		38.82700	-75.17300	1.90	21.443	29.008	7.91	8.36
63790.19		38.82700	-75.17300	2.01	21.418	29.009	7.79	8.36
63791.69		38.82700	-75.17300	2.08	21.390	29.016	7.82	8.36
63793.19				2.24	21.334	29.024	7.68	8.36
63794.69		38.82700	-75.17300	2.41	21.288	29.022	7.52	8.35
63796.19		38.82700	-75.17300	2.54	21.220	29.046	7.61	8.35
63797.69		38.82700	-75.17300	2.63	21.218	29.049	7.55	8.35
63799.19				2.70	21.204	29.053	7.60	8.35
63800.69		38.82700	-75.17316	2.81	21.196	29.057	7.72	8.35
63802.19		38.82700	-75.17316	2.82	21.187	29.063	7.57	8.35
63803.69		38.82700	-75.17316	2.92	21.179	29.064	7.52	8.35
63805.19				2.97	21.167	29.070	7.37	8.34
63806.69		38.82717	-75.17316	3.02	21.158	29.070	7.23	8.34
63808.19		38.82717	-75.17316	3.10	21.144	29.075	7.40	8.34
63809.69		38.82717	-75.17300	3.17	21.136	29.070	7.47	8.34
63811.19				3.24	21.114	29.081	7.20	8.34
63812.69		38.82717	-75.17300	3.39	21.100	29.083	7.05	8.35
63814.19		38.82717	-75.17316	3.49	21.095	29.088	7.10	8.34
63815.69		38.82717	-75.17316	3.57	21.095	29.090	7.13	8.34
63817.19				3.62	21.088	29.092	7.29	8.34
63818.69		38.82717	-75.17316	3.62	21.081	29.095	7.27	8.34
63820.19		38.82700	-75.17300	3.78	21.063	29.095	7.23	8.34
63821.69		38.82717	-75.17300	3.84	21.062	29.094	7.15	8.34
63823.19				3.96	21.053	29.098	6.90	8.34
63824.69		38.82717	-75.17300	4.06	21.055	29.096	7.04	8.34
63826.19		38.82717	-75.17300	4.04	21.055	29.096	7.40	8.34
63827.69		38.82700	-75.17300	4.15	21.044	29.105	7.58	8.34
63829.19				4.17	21.050	29.099	7.54	8.35
63830.69		38.82700	-75.17300	4.24	21.046	29.101	7.32	8.34
63837.81		38.82700	-75.17316					

Broadkill Beach Station B14

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
61834.92	5296	38.82900	-75.17577	0.16	21.319	29.037		8.32
61844.55		38.82900	-75.17567	0.57	21.301	29.058		8.34
61846.83		38.82900	-75.17583	0.85	21.296	29.060		8.34
61849.12		38.82900	-75.17583	1.02	21.286	29.064		8.35
61851.40		38.82900	-75.17583	1.18	21.283	29.064		8.35
61853.69		38.82900	-75.17583	1.40	21.276	29.070		8.36
61855.97		38.82900	-75.17583	1.54	21.264	29.078		8.36
61858.26		38.82900	-75.17583	1.80	21.253	29.081		8.37
61860.54		38.82900	-75.17567	2.01	21.242	29.085		8.37
61862.83		38.82900	-75.17567	2.17	21.211	29.088		8.37
61865.12		38.82900	-75.17583	2.27	21.161	29.101		8.37
61867.39		38.82900	-75.17583	2.37	21.150	29.107		8.37
61869.68		38.82900	-75.17583	2.61	21.130	29.104		8.37
61871.96		38.82900	-75.17583	2.76	21.095	29.105		8.37
61874.25		38.82900	-75.17583	2.86	21.052	29.097		8.36
61876.54		38.82900	-75.17583	3.10	20.985	29.108		8.35
61878.82		38.82900	-75.17583	3.30	20.951	29.117		8.35
61881.11		38.82900	-75.17567	3.47	20.919	29.111		8.34
61883.39		38.82900	-75.17583	3.61	20.904	29.118		8.34
61885.68		38.82900	-75.17583	3.64	20.907	29.117		8.34
61887.96		38.82900	-75.17567	3.70	20.899	29.118		8.34
61890.25		38.82900	-75.17567	3.78	20.901	29.116		8.33
61892.54		38.82900	-75.17567	4.02	20.885	29.120		8.34
61894.82		38.82900	-75.17567	4.07	20.886	29.116		8.33
61897.11		38.82900	-75.17567	4.19	20.869	29.122		8.33
61899.39		38.82900	-75.17567	4.25	20.863	29.117		8.33
61942.32		38.82900	-75.17567	3.85	20.884	29.116		8.33

Broadkill Beach Station B15

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
64776.20	5296	38.82950	-75.17184	0.08	21.802	28.882	6.82	8.30
64784.30		38.82950	-75.17200	0.32	21.852	28.868		8.35
64786.05		38.82950	-75.17200	0.61	21.850	28.867	7.16	8.35
64787.80		38.82950	-75.17200	0.73	21.856	28.861	7.43	8.34
64789.55		38.82950	-75.17200	0.94	21.847	28.860	8.02	8.34
64791.30		38.82950	-75.17200	1.05	21.846	28.859	7.92	8.34
64793.05		38.82950	-75.17200	1.21	21.837	28.860	7.86	8.35
64794.80				1.35	21.805	28.867	7.87	8.35
64796.55		38.82950	-75.17200	1.52	21.768	28.869	7.75	8.34
64798.30		38.82950	-75.17200	1.81	21.686	28.889	7.65	8.34
64800.05		38.82950	-75.17200	1.88	21.662	28.901	7.56	8.34
64801.80		38.82950	-75.17200	2.04	21.632	28.910	7.41	8.34
64803.55		38.82950	-75.17184	2.19	21.618	28.909	7.60	8.34
64805.30		38.82933	-75.17184	2.36	21.574	28.924	7.52	8.33
64807.05				2.44	21.553	28.931	7.48	8.34
64808.80		38.82933	-75.17184	2.56	21.523	28.939	7.31	8.33
64810.55		38.82933	-75.17200	2.72	21.497	28.943	7.26	8.33
64812.30		38.82950	-75.17200	2.78	21.478	28.951	7.21	8.33
64814.05		38.82950	-75.17200	2.85	21.457	28.957	7.32	8.33
64815.80		38.82950	-75.17200	2.83	21.434	28.963	7.41	8.33
64817.55		38.82950	-75.17200	2.98	21.421	28.962	7.31	8.33
64819.30		38.82950	-75.17200	3.16	21.410	28.967	7.27	8.33
64821.05		38.82950	-75.17200	3.29	21.389	28.972	7.31	8.32
64822.80				3.36	21.375	28.976	7.45	8.32
64824.55		38.82950	-75.17200	3.54	21.357	28.976	7.40	8.32
64826.30		38.82950	-75.17200	3.65	21.345	28.977	7.44	8.32
64828.05		38.82950	-75.17216	3.75	21.335	28.983	7.33	8.32
64829.80		38.82950	-75.17200	3.89	21.331	28.978	7.32	8.32
64831.55		38.82950	-75.17200	4.21	21.311	28.983	7.29	8.32
64833.30		38.82950	-75.17200	4.33	21.309	28.984	7.25	8.32
64835.05				4.38	21.303	28.984	7.20	8.32
64836.80		38.82950	-75.17184	4.28	21.299	28.988	7.39	8.32
64838.55		38.82950	-75.17200	4.06	21.304	28.983	7.30	8.32
64840.30		38.82950	-75.17200	4.07	21.305	28.984	7.26	8.32
64842.05		38.82950	-75.17200	4.01	21.309	28.985	7.21	8.32
64843.80		38.82950	-75.17200	4.06	21.315	28.984	7.26	8.32
64845.55		38.82950	-75.17200	4.05	21.308	28.984	7.07	8.32
64847.30		38.82950	-75.17200	4.09	21.305	28.988	6.96	8.32
64850.80		38.82950	-75.17200	4.12	21.309	28.987	7.09	8.32
64854.30		38.82950	-75.17200	4.13	21.303	28.990	7.09	8.32
64857.42		38.82950	-75.17200	4.13	21.308	28.985	7.03	8.32

Broadkill Beach Station B16

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
66220.46	5296	38.83033	-75.17284	0.07	21.935	28.846	5.89	8.37
66231.13		38.83033	-75.17267	0.28	21.975	28.827	5.74	8.35
66232.63				0.55	21.984	28.820	6.10	8.34
66234.13		38.83033	-75.17267	0.78	21.992	28.812	6.98	8.34
66235.63		38.83033	-75.17267	0.91	21.986	28.811	7.49	8.34
66237.13		38.83033	-75.17267	1.17	21.978	28.810	7.67	8.34
66238.63				1.39	21.972	28.807	7.74	8.34
66240.13		38.83033	-75.17267	1.63	21.956	28.810	7.69	8.34
66241.63		38.83033	-75.17267	1.78	21.914	28.819	7.65	8.33
66243.13		38.83033	-75.17267	1.91	21.886	28.823	7.60	8.34
66244.63				2.01	21.905	28.819	7.50	8.33
66246.13		38.83033	-75.17267	2.13	21.907	28.821	7.40	8.34
66247.63		38.83033	-75.17267	2.19	21.913	28.821	7.22	8.33
66249.13		38.83033	-75.17267	2.33	21.910	28.817	7.12	8.34
66250.63				2.45	21.886	28.824	7.12	8.34
66252.13		38.83033	-75.17284	2.49	21.863	28.829	7.04	8.34
66253.63		38.83033	-75.17284	2.66	21.854	28.836	7.02	8.34
66255.13		38.83033	-75.17284	2.77	21.841	28.831	7.28	8.33
66256.63				2.88	21.818	28.840	7.39	8.33
66258.13		38.83033	-75.17284	3.02	21.802	28.840	7.38	8.33
66259.63		38.83033	-75.17284	3.08	21.796	28.844	7.41	8.33
66261.13		38.83033	-75.17284	3.15	21.792	28.845	7.51	8.33
66262.63				3.36	21.786	28.847	7.48	8.33
66264.13		38.83033	-75.17284	3.49	21.779	28.843	7.38	8.33
66265.63		38.83033	-75.17284	3.61	21.772	28.848	7.37	8.33
66267.13		38.83033	-75.17284	3.77	21.759	28.854	7.41	8.33
66268.63				3.86	21.753	28.848	7.45	8.33
66270.13		38.83033	-75.17284	3.98	21.747	28.851	7.39	8.33
66271.63		38.83033	-75.17267	4.02	21.737	28.857	7.43	8.33
66273.13		38.83017	-75.17267	4.09	21.743	28.853	7.30	8.33
66274.63				4.18	21.737	28.853	7.35	8.33
66276.13		38.83017	-75.17267	4.14	21.733	28.853	7.24	8.33
66277.63		38.83033	-75.17284	3.91	21.734	28.855	7.19	8.33
66279.13		38.83033	-75.17284	3.87	21.733	28.851	7.19	8.33
66280.63				3.92	21.730	28.860	6.99	8.33
66282.13		38.83033	-75.17284	3.90	21.737	28.854	6.94	8.33
66283.63		38.83033	-75.17284	3.91	21.734	28.856	7.09	8.33
66285.13		38.83033	-75.17267	3.88	21.734	28.856	7.29	8.33
66286.63				3.88	21.748	28.853	7.13	8.33
66288.13		38.83033	-75.17284	3.95	21.774	28.848	7.14	8.33
66289.63		38.83033	-75.17284	3.85	21.785	28.843	7.12	8.33
66291.13		38.83033	-75.17284	3.90	21.775	28.852	7.09	8.33
66292.63				3.94	21.771	28.845	7.18	8.33
66293.76		38.83033	-75.17284					

Broadkill Beach Station C1

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
29207.47	5296	38.85033	-75.18850	0.09	21.404	28.066		8.18
29211.79		38.85033	-75.18850	0.20	21.312	28.103	6.50	8.23
29212.79				0.30	21.263	28.093	6.60	8.22
29213.79		38.85033	-75.18850	0.37	21.223	28.095	7.37	8.22
29214.79				0.36	21.207	28.100	8.01	8.23
29215.79		38.85033	-75.18850	0.48	21.216	28.096	8.10	8.24
29216.79				0.62	21.169	28.106	7.74	8.24
29217.79		38.85033	-75.18850	0.78	21.156	28.107	7.62	8.25
29218.79				0.86	21.157	28.104	7.46	8.25
29219.79		38.85033	-75.18850	0.97	21.145	28.107	7.33	8.25
29220.79				1.08	21.126	28.120	7.32	8.26
29221.79		38.85033	-75.18850	1.17	21.127	28.113	7.42	8.26
29222.79				1.34	21.118	28.118	7.35	8.26
29223.79		38.85033	-75.18850	1.46	21.115	28.118	7.06	8.26
29224.79				1.56	21.118	28.115	6.90	8.26
29225.79		38.85033	-75.18850	1.72	21.103	28.123	6.84	8.26
29226.79				1.81	21.101	28.126	6.68	8.26
29227.79		38.85033	-75.18833	1.87	21.097	28.129	6.65	8.26
29228.79				1.99	21.085	28.132	6.71	8.26
29229.79		38.85033	-75.18833	2.04	21.086	28.133	6.71	8.26
29230.79				2.16	21.083	28.134	6.66	8.27
29231.79		38.85033	-75.18833	2.21	21.083	28.138	6.45	8.27
29232.79				2.25	21.089	28.139	6.54	8.26
29233.79		38.85033	-75.18850	2.38	21.092	28.132	6.75	8.27
29234.79				2.46	21.086	28.139	6.66	8.27
29235.79		38.85033	-75.18850	2.46	21.085	28.136	6.40	8.27
29236.79				2.55	21.079	28.142	6.14	8.27
29237.79		38.85033	-75.18850	2.63	21.078	28.142	6.23	8.27
29238.79				2.63	21.077	28.139	6.53	8.27
29239.79		38.85033	-75.18850	2.65	21.083	28.134	6.66	8.27
29240.79				2.64	21.092	28.135	6.65	8.27
29241.79		38.85033	-75.18850	2.67	21.087	28.138	6.50	8.27
29242.79				2.70	21.085	28.141	6.67	8.27
29243.79		38.85033	-75.18850	2.82	21.083	28.138	6.80	8.27
29244.79				2.94	21.074	28.140	6.70	8.27
29245.79		38.85033	-75.18850	3.05	21.076	28.144	6.57	8.27
29246.79				3.17	21.070	28.143	6.48	8.27
29247.79		38.85033	-75.18850	3.25	21.072	28.148	6.53	8.27
29248.79				3.28	21.072	28.143	6.50	8.27
29249.79		38.85033	-75.18833	3.20	21.073	28.144	6.59	8.27
29250.79				3.11	21.071	28.142	6.67	8.27
29251.79		38.85033	-75.18833	3.12	21.072	28.147	6.54	8.27
29252.79				3.19	21.075	28.146	6.41	8.27
29253.79		38.85033	-75.18833	3.16	21.077	28.142	6.51	8.27
29254.79				3.19	21.078	28.143	6.67	8.27
29255.79		38.85017	-75.18833	3.20	21.076	28.148	6.91	8.27
29257.41		38.85017	-75.18833					

Broadkill Beach Station C2

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
30570.67	5296	38.85167	-75.19183	0.13	21.097	28.027		8.06
30578.86				0.41	21.073	28.092		8.10
30579.86		38.85150	-75.19183	0.66	21.063	28.115		8.12
30580.86		38.85150	-75.19183	0.91	21.043	28.126		8.15
30581.86				1.24	21.033	28.140	5.85	8.17
30582.86		38.85150	-75.19183	1.52	21.011	28.160	5.63	8.18
30583.86				1.80	21.013	28.162	5.25	8.20
30584.86		38.85150	-75.19167	2.06	21.012	28.164	4.97	8.21
30585.86				2.17	21.007	28.171	5.01	8.21
30586.86		38.85150	-75.19167	2.26	21.010	28.167	5.03	8.22
30587.86				2.41	21.004	28.178	5.01	8.22
30588.86		38.85150	-75.19167	2.56	20.994	28.184	4.97	8.23
30589.86				2.71	20.996	28.183	4.90	8.23
30590.86		38.85150	-75.19167	2.92	20.990	28.190	4.87	8.23
30591.86				3.06	20.987	28.198	4.87	8.23
30592.86		38.85150	-75.19183	3.23	20.987	28.199	4.86	8.23
30593.86				3.31	20.987	28.201	4.84	8.23
30594.86		38.85150	-75.19183					

Broadkill Beach Station C3

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
30528.06	5296	38.84833	-75.19578	0.10	22.468	28.509		8.18
30535.97				0.28	22.458	28.496	6.53	8.23
30537.47		38.84833	-75.19566	0.57	21.914	28.462	7.12	8.23
30538.97		38.84833	-75.19566	0.73	21.793	28.478	8.02	8.24
30540.47		38.84833	-75.19566	0.82	21.805	28.489	7.42	8.24
30541.97				0.85	21.795	28.491	7.32	8.25
30543.47		38.84833	-75.19566	0.84	21.766	28.464	7.35	8.25
30544.97				0.88	21.728	28.479	7.27	8.25
30546.47		38.84833	-75.19566	0.88	21.764	28.471	6.85	8.25
30547.97				0.91	21.768	28.472	6.74	8.25
30549.47		38.84833	-75.19566	1.14	21.694	28.478	6.86	8.25
30550.97		38.84833	-75.19583	1.45	21.596	28.480	6.74	8.26
30552.47				1.62	21.550	28.489	6.64	8.25
30553.97				1.74	21.519	28.480	6.76	8.26
30555.47		38.84833	-75.19583	1.90	21.511	28.476	6.71	8.26
30556.97		38.84833	-75.19583	1.98	21.495	28.476	6.46	8.26
30558.47		38.84833	-75.19566	2.16	21.444	28.468	6.35	8.25
30559.97				2.30	21.414	28.453	6.37	8.25
30561.47				2.40	21.385	28.465	6.45	8.24
30562.97		38.84850	-75.19566	2.50	21.400	28.455	6.43	8.24
30564.47		38.84833	-75.19566	2.60	21.380	28.456	6.65	8.24
30565.97				2.71	21.332	28.459	6.66	8.24
30567.47		38.84833	-75.19566	2.84	21.324	28.455	6.47	8.24
30568.97		38.84833	-75.19566	3.00	21.317	28.455	6.38	8.24
30570.47		38.84833	-75.19566	3.08	21.313	28.453	6.41	8.23
30571.97				3.17	21.309	28.454	6.28	8.23
30573.47		38.84833	-75.19566	3.29	21.301	28.455	6.28	8.23
30574.97		38.84833	-75.19566	3.45	21.268	28.478	6.39	8.23
30576.47		38.84833	-75.19566	3.58	21.241	28.501	6.38	8.23
30577.97				3.64	21.247	28.499	6.14	8.23
30579.47				3.63	21.244	28.500	5.87	8.22
30580.97		38.84833	-75.19566	3.61	21.237	28.505	5.88	8.22
30582.47				3.66	21.236	28.503	6.00	8.22
30583.97		38.84833	-75.19566	3.66	21.241	28.503	5.76	8.22
30585.47				3.67	21.232	28.506	5.55	8.22
30586.97		38.84833	-75.19566	3.64	21.233	28.504	5.41	8.22
30588.47		38.84833	-75.19566	3.62	21.235	28.501	5.73	8.22
30589.97		38.84833	-75.19583	3.57	21.240	28.503	5.72	8.22
30591.47				3.60	21.228	28.515	5.60	8.21
30592.97				3.63	21.230	28.513	5.50	8.21
30596.85		38.84850	-75.19583					

Broadkill Beach Station C4

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
27670.78	5296	38.85058	-75.19217	0.06	21.151	28.073		8.25
27674.63				0.21	21.168	28.050	9.61	8.26
27675.38				0.31	21.165	28.055	8.43	8.25
27676.12		38.85067	-75.19217	0.38	21.165	28.059	8.28	8.25
27676.85				0.60	21.137	28.054	8.55	8.26
27677.59		38.85067	-75.19217	0.85	21.085	28.096	8.68	8.25
27678.33				0.99	21.090	28.093	8.74	8.25
27679.07				1.18	21.080	28.099	8.09	8.25
27679.80		38.85050	-75.19217	1.34	21.076	28.104	7.74	8.25
27680.54				1.46	21.062	28.118	7.50	8.25
27681.28				1.58	21.050	28.121	7.36	8.25
27682.02		38.85050	-75.19217	1.82	21.048	28.133	7.21	8.25
27682.76				1.96	21.036	28.141	7.07	8.25
27683.49		38.85050	-75.19217	2.05	21.048	28.137	6.94	8.25
27684.23				2.21	21.038	28.148	6.95	8.25
27684.97				2.35	21.038	28.146	6.95	8.25
27685.71		38.85067	-75.19217	2.50	21.031	28.159	6.90	8.25
27686.45				2.63	21.029	28.165	6.90	8.25
27687.19				2.67	21.029	28.165	6.91	8.25
27687.93		38.85067	-75.19217	2.70	21.029	28.163	6.87	8.25
27688.66				2.76	21.031	28.161	6.83	8.25
27689.40		38.85067	-75.19217	2.87	21.028	28.170	6.83	8.25
27690.14				3.02	21.017	28.179	6.84	8.25
27690.88				3.18	21.024	28.172	6.78	8.25
27691.62		38.85067	-75.19217	3.26	21.017	28.181	6.73	8.25
27692.35				3.32	21.019	28.184	6.72	8.24
27693.09		38.85050	-75.19217	3.46	21.024	28.187	6.61	8.24
27693.83				3.57	21.026	28.184	6.46	8.25

Broadkill Beach Station C5

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
31867.06	5296	38.84600	-75.19283	0.12	21.804	28.519		8.24
31871.93		38.84600	-75.19267	0.31	21.950	28.453	8.03	8.24
31872.93				0.28	21.948	28.444	7.98	8.24
31873.93		38.84600	-75.19283	0.56	21.711	28.453	8.64	8.24
31874.93				0.72	21.556	28.444	9.23	8.24
31875.93		38.84600	-75.19283	0.82	21.519	28.389	8.26	8.25
31876.93				0.95	21.403	28.452	7.58	8.25
31877.93		38.84600	-75.19283	1.10	21.394	28.432	7.39	8.25
31878.93				1.24	21.392	28.419	7.36	8.26
31879.93		38.84600	-75.19283	1.36	21.328	28.433	7.29	8.26
31880.93				1.53	21.266	28.453	7.28	8.26
31881.93		38.84600	-75.19283	1.63	21.242	28.459	7.24	8.26
31882.93				1.77	21.251	28.446	7.11	8.26
31883.93		38.84600	-75.19283	1.86	21.255	28.444	6.96	8.26
31884.93				2.01	21.209	28.463	6.75	8.26
31885.93		38.84600	-75.19283	2.13	21.177	28.482	6.59	8.25
31886.93				2.22	21.171	28.483	6.45	8.25
31887.93		38.84600	-75.19283	2.31	21.173	28.485	6.35	8.25
31888.93				2.44	21.153	28.506	6.29	8.25
31889.93		38.84600	-75.19283	2.59	21.157	28.509	6.29	8.24
31890.93				2.74	21.152	28.512	6.30	8.24
31891.93		38.84600	-75.19283	2.86	21.155	28.522	6.22	8.24
31892.93				2.96	21.152	28.534	6.25	8.23
31893.93		38.84600	-75.19283	3.06	21.163	28.537	6.22	8.23
31894.93				3.14	21.166	28.540	6.14	8.23
31895.93		38.84600	-75.19267	3.20	21.164	28.550	6.06	8.22
31896.93				3.29	21.180	28.578	6.06	8.23
31897.93		38.84600	-75.19267	3.43	21.196	28.583	6.01	8.22
31898.93				3.48	21.189	28.592	6.08	8.22
31899.93		38.84600	-75.19283	3.57	21.189	28.592	6.26	8.22
31900.93				3.70	21.189	28.593	6.28	8.22
31901.93		38.84600	-75.19283	3.73	21.186	28.602	6.32	8.22
31902.93				3.84	21.184	28.606	6.19	8.21
31903.93		38.84600	-75.19283	3.74	21.187	28.579	6.09	8.21
31904.93				3.68	21.178	25.582	6.02	8.20
31905.93		38.84600	-75.19283	3.71	21.184	24.595	6.10	8.21
31906.93				3.82	21.184	23.803	6.05	8.20
31907.93		38.84600	-75.19283	3.91	21.182	27.468	5.90	8.20
31908.93				3.93	21.189	28.569	6.05	8.20
31913.93		38.84600	-75.19283	3.73	21.188	28.558	6.06	8.20

Broadkill Beach Station C6

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
43280.23	5296	38.82125	-75.17500	0.08	23.671	27.611		8.28
43283.18		38.82117	-75.17500	0.23	23.673	27.643		8.30
43284.68				0.30	23.584	27.654		8.31
43286.18		38.82117	-75.17500	0.47	23.182	27.812		8.31
43287.68		38.82117	-75.17500	0.63	23.010	27.881		8.32
43289.18		38.82117	-75.17500	0.76	22.553	28.024		8.32
43290.68				0.88	22.085	28.209		8.33
43292.18		38.82117	-75.17500	1.10	21.822	28.356		8.34
43293.68		38.82117	-75.17500	1.33	21.720	28.417		8.33
43295.18		38.82117	-75.17500	1.63	21.388	28.660	7.62	8.33
43296.68				1.89	21.323	28.709	7.62	8.33
43298.18		38.82117	-75.17500	2.18	21.241	28.785	7.60	8.31
43299.68		38.82117	-75.17516	2.40	21.123	28.889	7.85	8.30
43301.18		38.82117	-75.17516	2.64	21.092	28.918	8.00	8.29
43302.68				2.88	21.079	28.928	7.79	8.29
43304.18		38.82117	-75.17516	3.10	21.051	28.949	7.63	8.28
43305.68		38.82117	-75.17516	3.20	21.041	28.958	7.45	8.28
43307.18		38.82117	-75.17516	3.30	21.033	28.969	7.47	8.27
43308.68				3.41	21.018	28.976	7.49	8.27
43310.18		38.82117	-75.17516	3.50	21.014	28.978	7.41	8.27
43311.68		38.82117	-75.17516	3.64	21.008	28.981	7.37	8.26
43313.18		38.82117	-75.17516	3.73	21.002	28.986	7.13	8.26
43314.68				3.89	21.000	28.985	7.20	8.26
43316.18		38.82117	-75.17516	3.97	20.991	28.994	7.20	8.26
43317.68		38.82117	-75.17516	4.11	20.988	28.994	7.17	8.25
43319.18		38.82117	-75.17516	4.19	20.984	28.997	6.76	8.25
43320.68		38.82117	-75.17516	4.22	20.986	28.996	7.02	8.25
43322.18				4.30	20.987	28.997	7.09	8.25
43323.68		38.82117	-75.17516	4.37	20.980	28.998	7.18	8.25
43325.18		38.82117	-75.17516	4.50	20.983	28.998	6.85	8.25
43326.68		38.82117	-75.17516	4.53	20.982	29.001	6.92	8.25
43328.18				4.70	20.980	28.998	7.02	8.24
43329.68		38.82117	-75.17516	4.73	20.979	29.002	7.14	8.25
43331.18		38.82117	-75.17516	4.81	20.982	28.938	7.10	8.24

Broadkill Beach Station C7

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
44417.41	5296	38.82045	-75.17778	0.18	22.119	28.524		8.24
44427.91		38.82033	-75.17758	0.47	22.080	28.543		8.30
44430.41		38.82033	-75.17750	0.73	22.041	28.550		8.31
44432.91		38.82033	-75.17750	0.97	21.956	28.579		8.31
44435.41		38.82033	-75.17750	1.21	21.820	28.633		8.32
44437.91		38.82033	-75.17750	1.35	21.692	28.687		8.32
44440.41		38.82033	-75.17750	1.48	21.635	28.718	7.63	8.32
44442.91		38.82033	-75.17750	1.66	21.574	28.751	7.72	8.32
44445.41		38.82033	-75.17750	1.80	21.463	28.804	7.90	8.31
44447.91		38.82033	-75.17750	1.94	21.400	28.836	7.78	8.31
44450.41		38.82033	-75.17750	2.12	21.332	28.872	7.78	8.31
44452.91		38.82033	-75.17750	2.25	21.292	28.894	7.58	8.31
44455.41		38.82033	-75.17750	2.36	21.262	28.914	7.61	8.30
44457.91		38.82033	-75.17750	2.43	21.238	28.925	7.33	8.30
44460.41		38.82033	-75.17750	2.56	21.222	28.939	7.20	8.29
44462.91		38.82033	-75.17750	2.64	21.210	28.947	7.32	8.29
44465.41		38.82033	-75.17750	2.76	21.200	28.954	7.23	8.29
44467.91		38.82033	-75.17750	2.93	21.198	28.953	7.23	8.28
44470.41		38.82033	-75.17750	2.99	21.198	28.955	7.17	8.28
44472.91		38.82033	-75.17750	3.06	21.190	28.963	7.21	8.28
44475.41		38.82033	-75.17733	3.10	21.187	28.963	7.38	8.28
44477.91		38.82033	-75.17733	3.18	21.174	28.969	7.18	8.27
44480.41		38.82033	-75.17733	3.32	21.175	28.969	7.15	8.27
44482.91		38.82033	-75.17733	3.45	21.164	28.980	7.53	8.27
44485.41		38.82033	-75.17733	3.58	21.158	28.988	7.56	8.27
44487.91		38.82017	-75.17733	3.65	21.158	28.988	7.42	8.26
44490.41		38.82017	-75.17733	3.77	21.157	28.988	7.41	8.26
44492.91		38.82017	-75.17733	3.85	21.162	28.982	7.13	8.26
44495.41		38.82017	-75.17733	3.94	21.164	28.985	6.93	8.26
44497.91		38.82017	-75.17733	4.10	21.155	28.987	6.84	8.26
44500.41		38.82017	-75.17733	4.24	21.157	28.989	7.02	8.26
44502.91		38.82017	-75.17733	4.37	21.155	28.991	7.30	8.26
44505.41		38.82017	-75.17733	4.44	21.158	28.989	7.21	8.26
44507.91		38.82017	-75.17733	4.52	21.158	28.989	7.19	8.26
44510.41		38.82017	-75.17733	4.62	21.153	28.993	7.24	8.26
44512.91		38.82017	-75.17733	4.70	21.153	28.993	6.92	8.25
44515.41		38.82017	-75.17733	4.75	21.153	28.993	7.17	8.25
44517.91		38.82017	-75.17733	4.82	21.153	28.995	7.04	8.25
44520.41		38.82017	-75.17733	4.94	21.152	28.993	7.06	8.25
44522.91		38.82017	-75.17733	5.03	21.154	28.992	6.99	8.25
44525.41		38.82017	-75.17733	5.11	21.151	28.987	7.14	8.25
44537.53		38.82017	-75.17733					

Broadkill Beach Station C8

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
41787.10	5296	38.82217	-75.17667	0.11	21.893	28.919		8.19
41798.68		38.82217	-75.17650	0.32	21.834	28.936		8.27
41800.18		38.82217	-75.17650	0.58	21.716	28.934		8.28
41801.68				0.69	21.629	28.930	6.97	8.29
41803.18		38.82217	-75.17650	0.81	21.576	28.941	6.82	8.29
41804.68				0.93	21.574	28.942	6.76	8.29
41806.18		38.82217	-75.17650	1.12	21.523	28.947	7.82	8.30
41807.68				1.28	21.489	28.930	7.76	8.30
41809.18		38.82217	-75.17650	1.48	21.310	28.962	7.67	8.29
41810.68		38.82217	-75.17650	1.73	21.241	28.950	7.67	8.28
41812.18				1.85	21.185	28.970	7.77	8.27
41813.68				1.98	21.178	28.977	7.79	8.27
41815.18		38.82217	-75.17650	2.14	21.159	28.983	7.76	8.26
41816.68				2.38	21.092	28.987	7.69	8.26
41818.18		38.82217	-75.17650	2.59	21.077	28.993	7.46	8.26
41819.68				2.77	21.069	28.994	7.48	8.25
41821.18		38.82217	-75.17650	2.94	21.054	29.001	7.61	8.25
41822.68		38.82217	-75.17650	3.13	21.054	28.996	7.60	8.24
41824.18		38.82217	-75.17650	3.24	21.046	29.001	7.57	8.24
41825.68				3.39	21.052	28.999	7.54	8.24
41827.18		38.82217	-75.17650	3.58	21.036	29.001	7.57	8.23
41828.68				3.70	21.037	29.006	7.57	8.24
41830.18		38.82217	-75.17667	3.87	21.037	29.005	7.46	8.23
41831.68		38.82233	-75.17667	4.05	21.035	29.002	7.51	8.23
41833.18				4.26	21.032	29.006	7.56	8.23
41834.68		38.82233	-75.17667	4.45	21.035	29.006	7.57	8.23
41836.18		38.82233	-75.17667	4.50	21.045	29.000	7.59	8.23
41837.68		38.82233	-75.17667	4.72	21.044	29.002	7.53	8.23
41839.18				4.89	21.044	29.002	7.61	8.23
41856.56		38.82233	-75.17667					

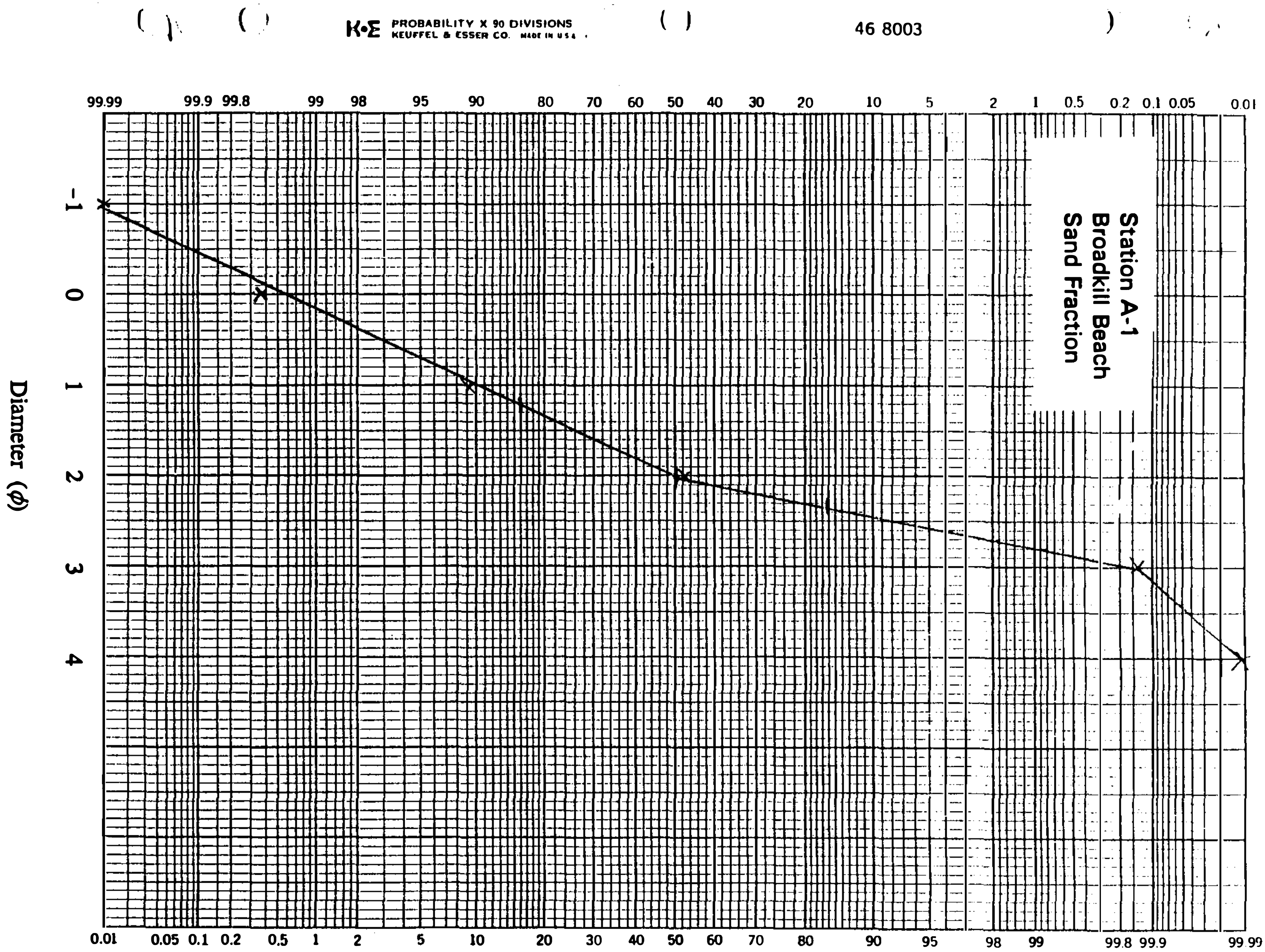
Broadkill Beach Station C9

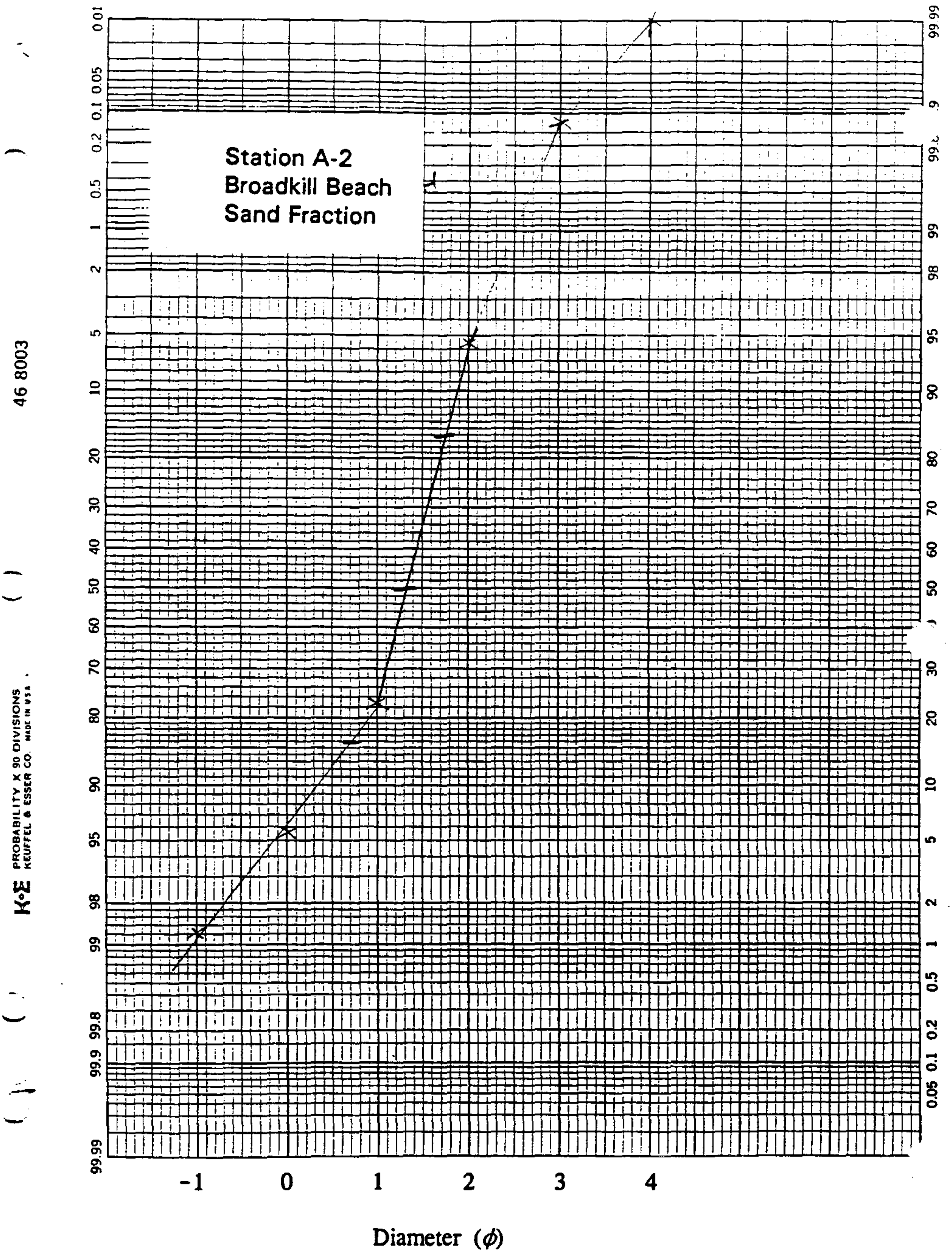
Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
45797.01	5296	38.82150	-75.17367	0.12	21.664	28.087		8.27
45809.59		38.82150	-75.17350	0.24	21.611	28.124		8.28
45811.09				0.41	21.621	28.129		8.29
45812.59				0.71	21.573	28.140		8.29
45814.09		38.82150	-75.17367	0.79	21.468	28.185		8.30
45815.59		38.82150	-75.17367	1.01	21.438	28.202		8.30
45817.09				1.20	21.337	28.228		8.30
45818.59		38.82150	-75.17367	1.28	21.256	28.271	7.07	8.30
45820.09		38.82150	-75.17367	1.40	21.194	28.306	7.02	8.30
45821.59		38.82150	-75.17367	1.58	21.182	28.317	6.99	8.30
45823.09				1.74	21.179	28.328	7.13	8.30
45824.59		38.82167	-75.17367	1.83	21.140	28.354	8.12	8.30
45826.09		38.82150	-75.17367	2.02	21.077	28.372	8.05	8.30
45827.59		38.82167	-75.17367	2.11	21.035	28.408	8.09	8.30
45829.09				2.28	21.011	28.423	8.10	8.29
45830.59				2.48	20.984	28.437	7.84	8.29
45832.09		38.82167	-75.17367	2.67	20.945	28.465	7.95	8.29
45833.59		38.82167	-75.17367	2.83	20.924	28.480	8.04	8.29
45835.09				3.02	20.904	28.502	7.96	8.28
45836.59		38.82167	-75.17367	3.21	20.866	28.527	8.04	8.28
45838.09		38.82167	-75.17367	3.41	20.860	28.540	8.05	8.28
45839.59		38.82167	-75.17384	3.63	20.842	28.555	7.78	8.27
45841.09				3.74	20.839	28.560	7.82	8.27
45842.59		38.82167	-75.17384	4.00	20.824	28.577	7.68	8.27
45844.09		38.82167	-75.17384	4.15	20.824	28.584	7.65	8.27
45845.59		38.82167	-75.17384	4.27	20.817	28.594	7.65	8.26
45847.09				4.40	20.814	28.595	7.62	8.26
45848.59		38.82167	-75.17367	4.51	20.811	28.601	7.58	8.26
45850.09		38.82150	-75.17367	4.68	20.807	28.614	7.40	8.26
45851.59		38.82150	-75.17367	4.81	20.801	28.619	7.42	8.26
45853.09				4.96	20.803	28.624	7.54	8.26
45854.59		38.82150	-75.17367	5.12	20.804	28.626	7.56	8.26
45856.09		38.82150	-75.17367	5.18	20.803	28.630	7.50	8.26
45870.47		38.82150	-75.17367					

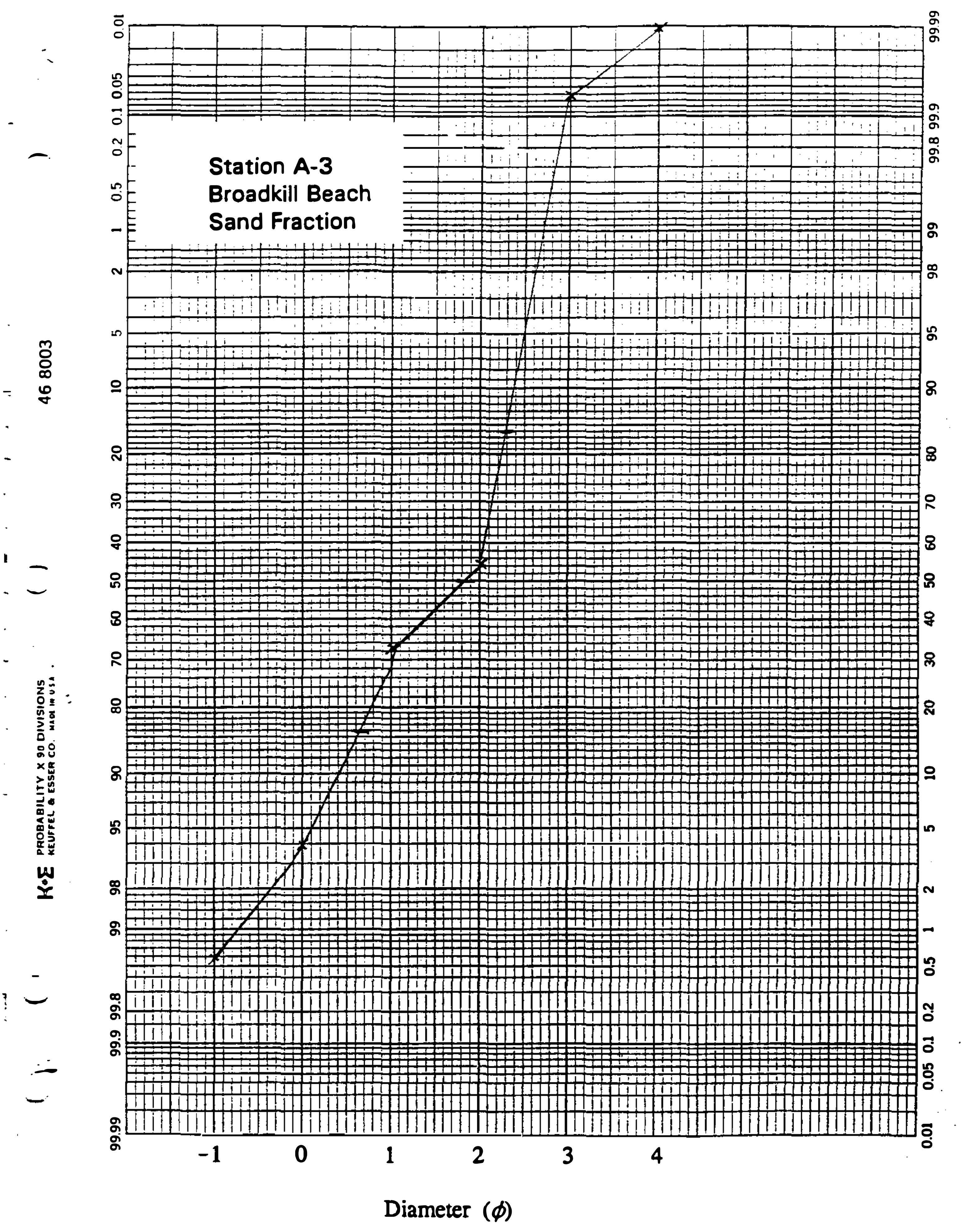
Broadkill Beach Station C10

Time s	Date	Latitude	Longitude	Depth m	Temper C	Salini PSU	Disso mg/L	pH pH
46964.11	5296	38.81983	-75.16723	0.22	20.683	28.917		8.25
46979.66				0.33	20.611	28.929	7.22	8.26
46980.91		38.81983	-75.16734	0.52	20.583	28.941	7.11	8.26
46982.16		38.81983	-75.16734	0.67	20.558	28.943	6.94	8.27
46983.41				0.89	20.546	28.905	7.24	8.27
46984.66		38.81983	-75.16734	1.04	20.542	28.920	8.18	8.28
46985.91		38.81983	-75.16734	1.19	20.531	28.924	8.02	8.28
46987.16				1.35	20.533	28.935	7.91	8.28
46988.41		38.81983	-75.16734	1.40	20.538	28.939	7.86	8.28
46989.66				1.57	20.514	28.930	7.88	8.28
46990.91		38.81983	-75.16734	1.71	20.498	28.934	7.88	8.28
46992.16		38.81983	-75.16734	1.88	20.495	28.931	7.81	8.28
46993.41				2.09	20.493	28.934	7.74	8.28
46994.66		38.81983	-75.16734	2.19	20.490	28.941	7.78	8.28
46995.91		38.81983	-75.16734	2.37	20.485	28.940	7.84	8.28
46997.16				2.50	20.488	28.944	7.66	8.28
46998.41		38.81983	-75.16734	2.67	20.484	28.943	7.62	8.28
46999.66				2.87	20.484	28.944	7.68	8.28
47000.91		38.81983	-75.16734	2.99	20.484	28.948	7.68	8.28
47002.16		38.81983	-75.16734	3.15	20.488	28.946	7.60	8.28
47003.41				3.32	20.481	28.954	7.61	8.28
47004.66		38.81983	-75.16734	3.52	20.484	28.949	7.51	8.28
47005.91		38.81983	-75.16734	3.59	20.485	28.947	7.61	8.28
47007.16				3.73	20.477	28.948	7.48	8.28
47008.41		38.81983	-75.16734	3.83	20.479	28.951	7.60	8.28
47009.66		38.81983	-75.16734	3.97	20.478	28.957	7.69	8.28
47010.91				4.14	20.477	28.954	7.63	8.28
47012.16		38.81983	-75.16734	4.19	20.485	28.958	7.54	8.28
47013.41				4.25	20.481	28.961	7.32	8.28
47014.66		38.81983	-75.16734	4.39	20.482	28.963	7.48	8.28
47015.91		38.81983	-75.16734	4.50	20.483	28.962	7.55	8.28
47017.16				4.60	20.485	28.961	7.50	8.28
47018.41		38.81983	-75.16734	4.71	20.484	28.964	7.51	8.28
47019.66		38.81983	-75.16734	4.74	20.482	28.962	7.40	8.28
47020.91				4.86	20.480	28.968	7.48	8.28
47022.16		38.81983	-75.16734	4.91	20.483	28.966	7.28	8.28
47033.16		38.81983	-75.16734					

APPENDIX C
CUMULATIVE GRAIN-SIZE DISTRIBUTION PLOTS

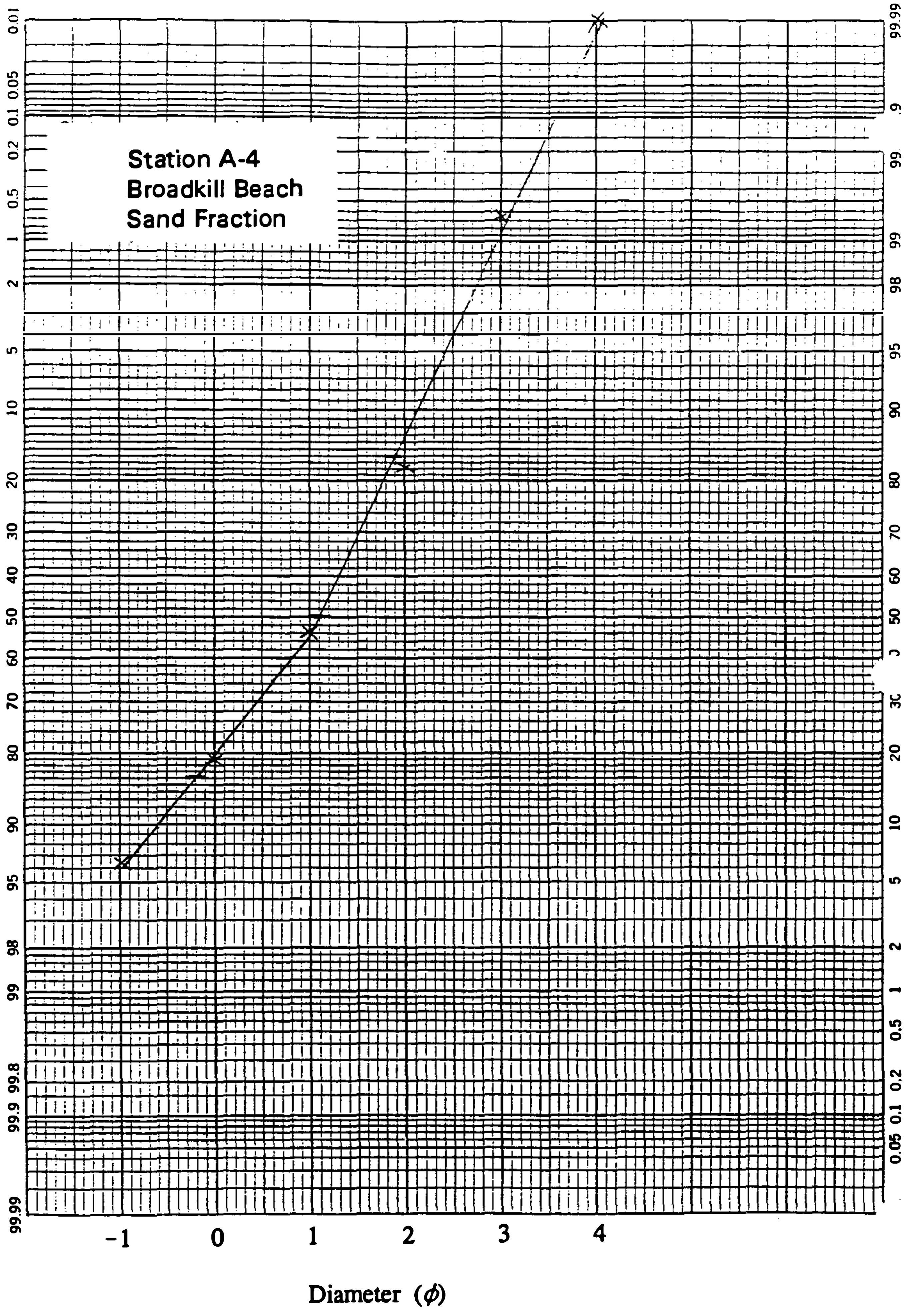

K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station A-1
Broadkill Beach
Sand Fraction
Diameter (φ)
-1
0
1
2
3
4
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99


Station A-2
Broadkill Beach
Sand Fraction
46 8003
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
−1
0
1
2
3
4
Diameter (ϕ)

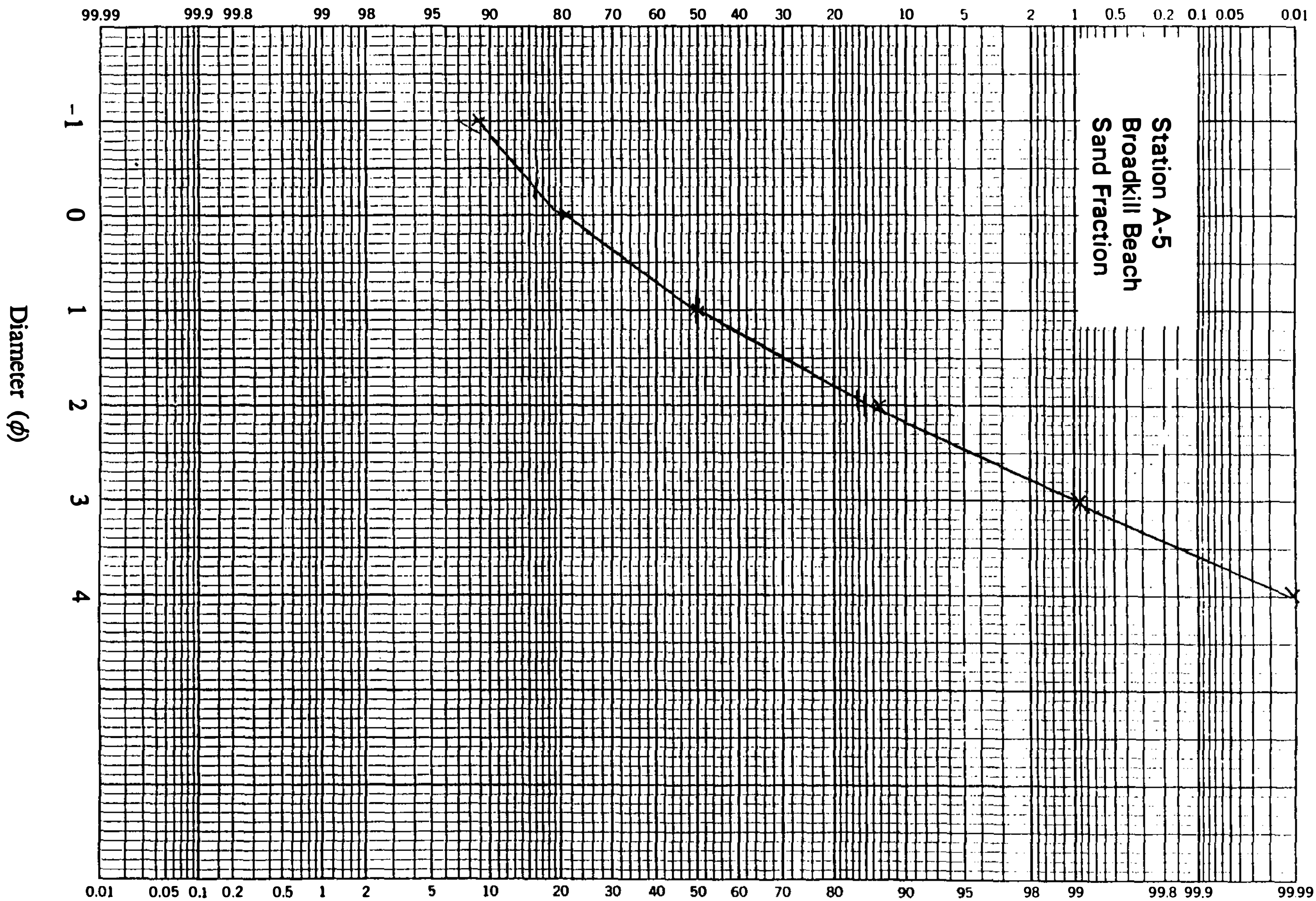

K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station A-3
Broadkill Beach
Sand Fraction
Diameter (φ)
-1
0
1
2
3
4

612

K•E PROBABILITY X 90 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 8003

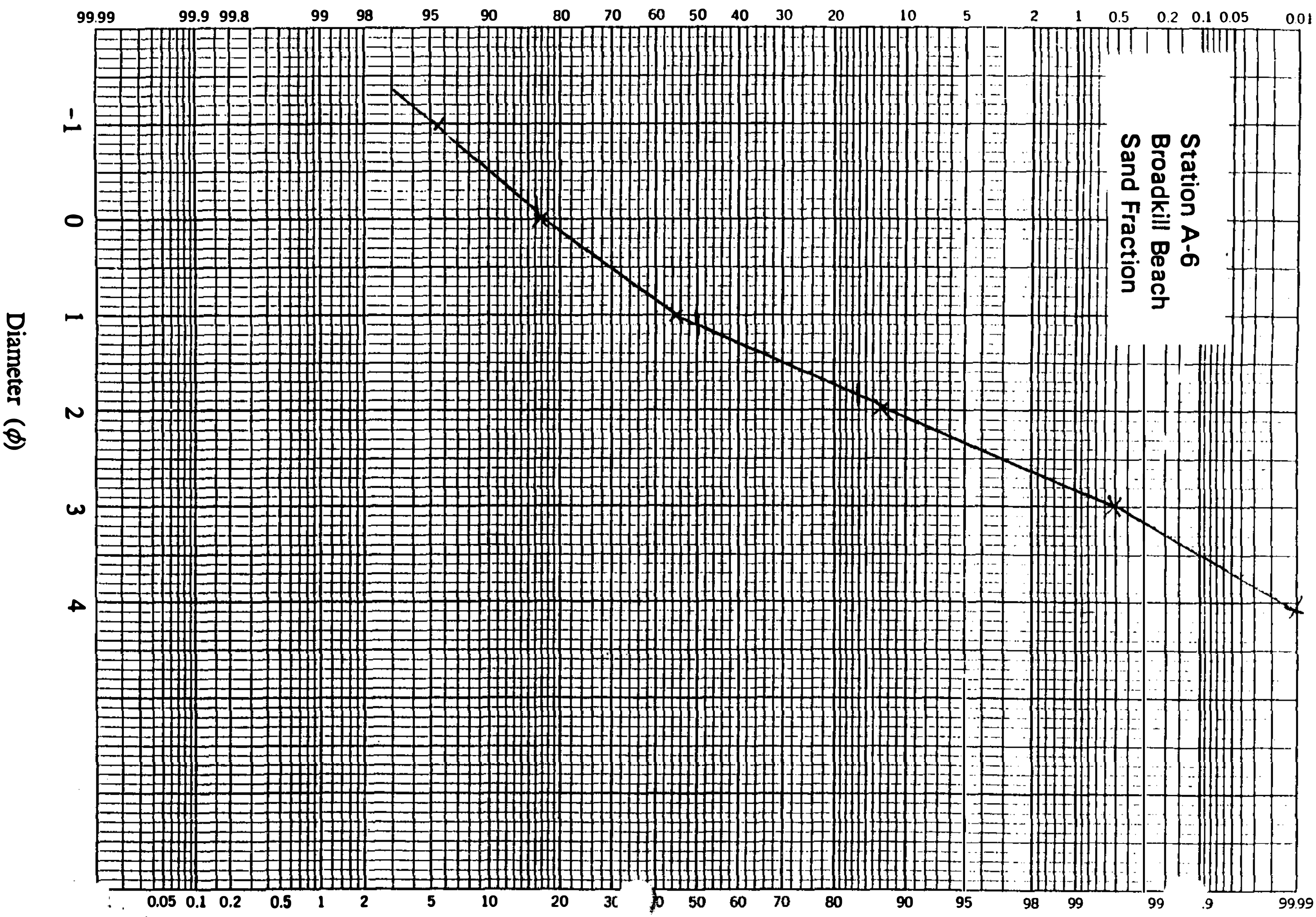


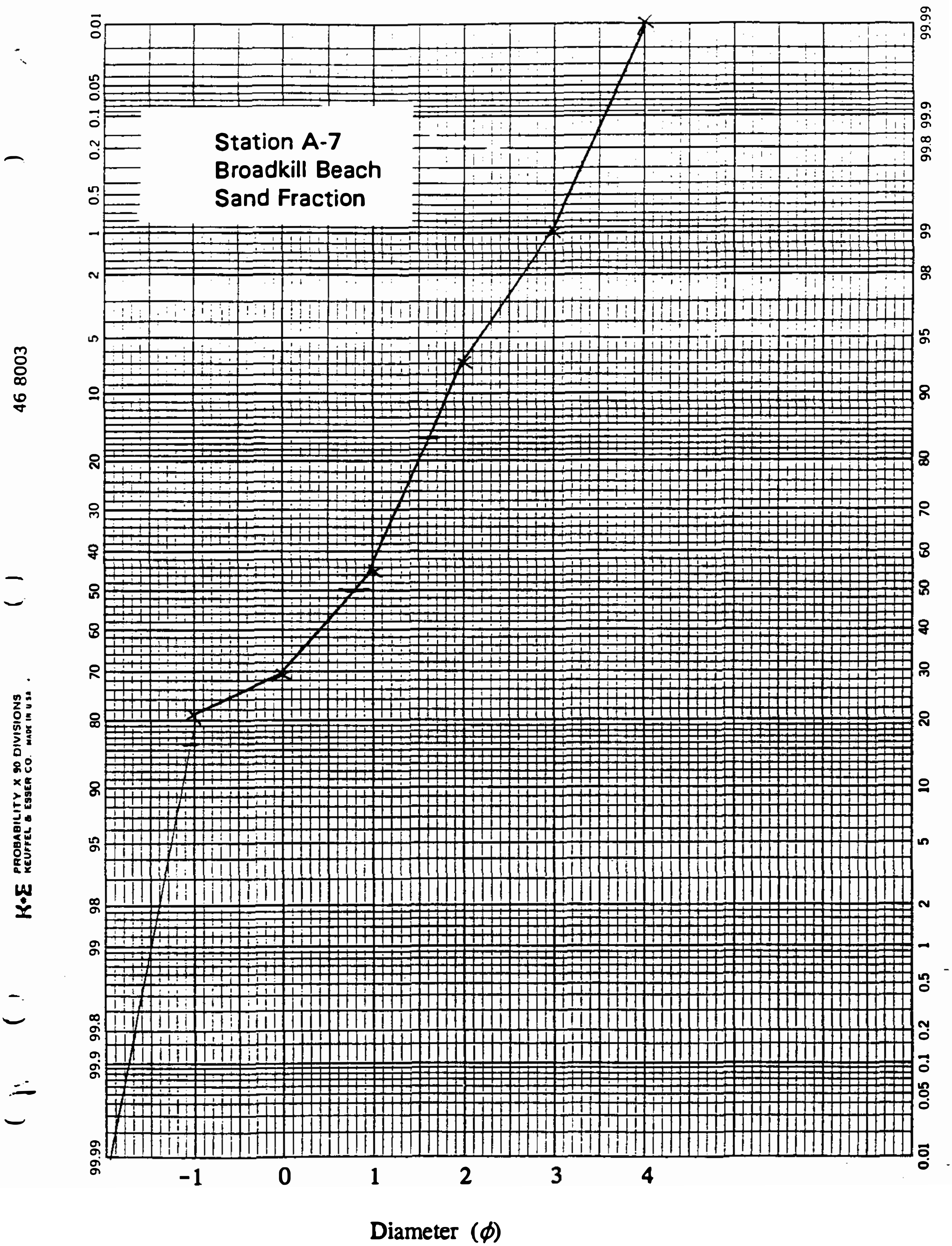
K+E PROBABILITY X 90 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 8003



K·E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

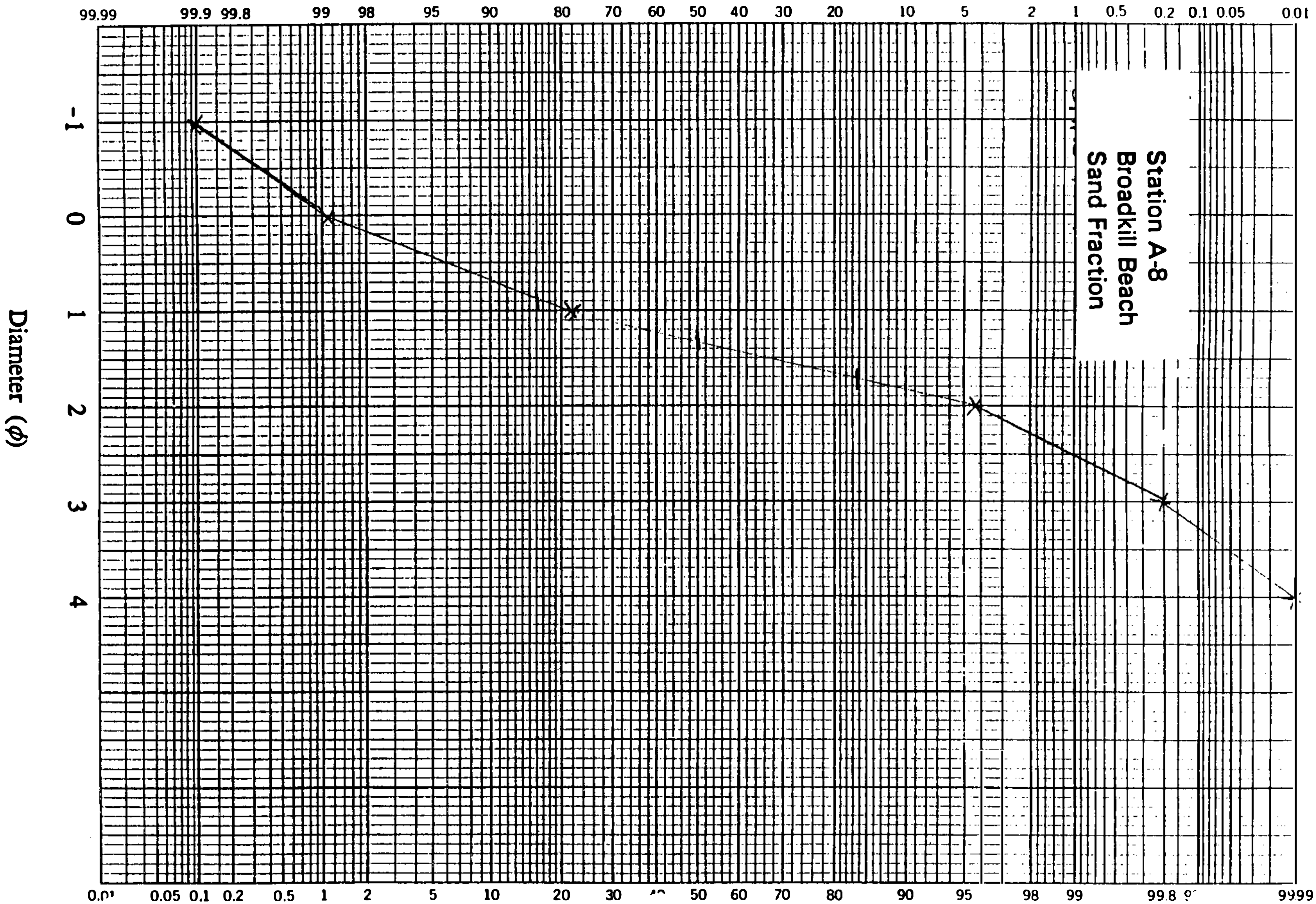
46 8003

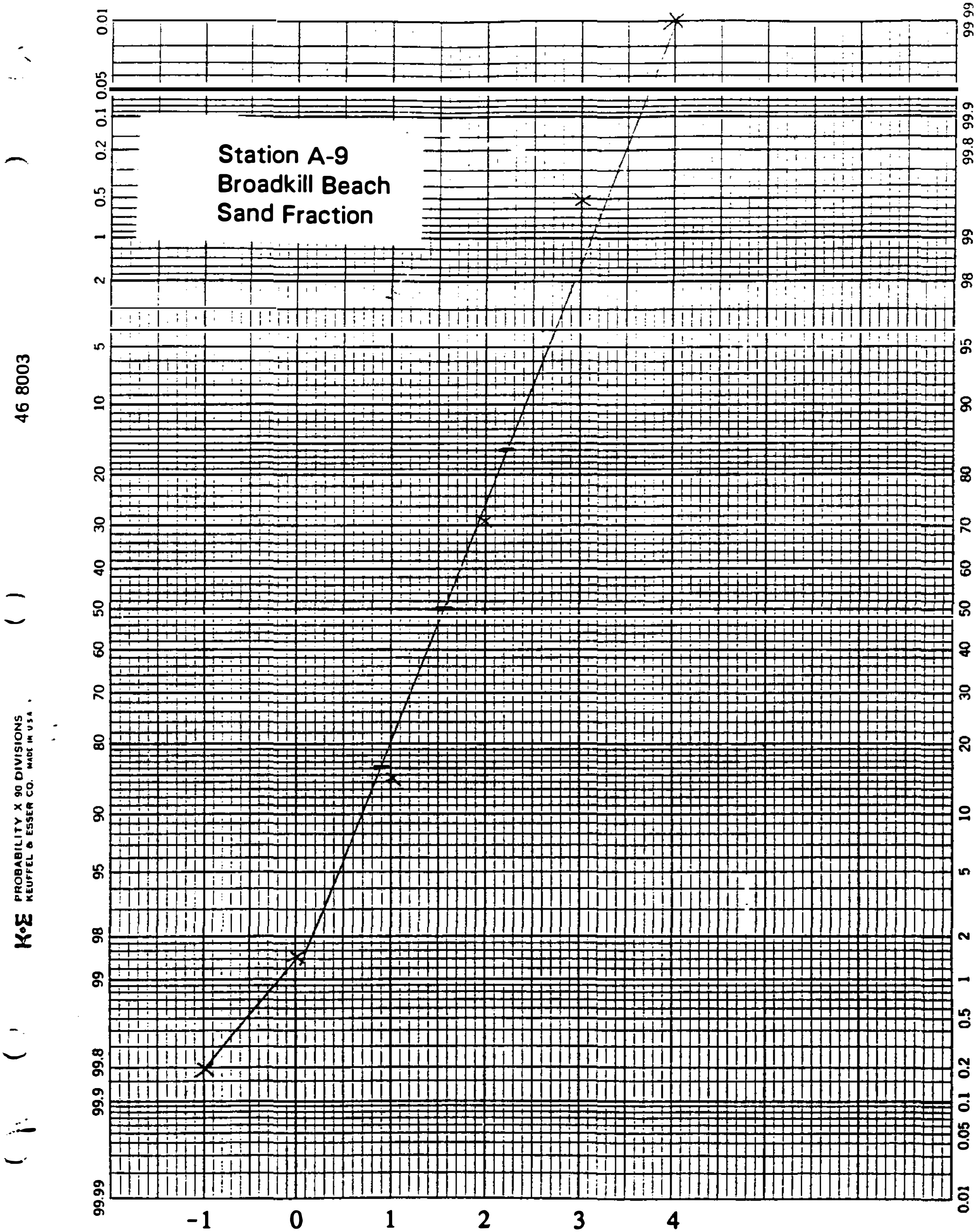


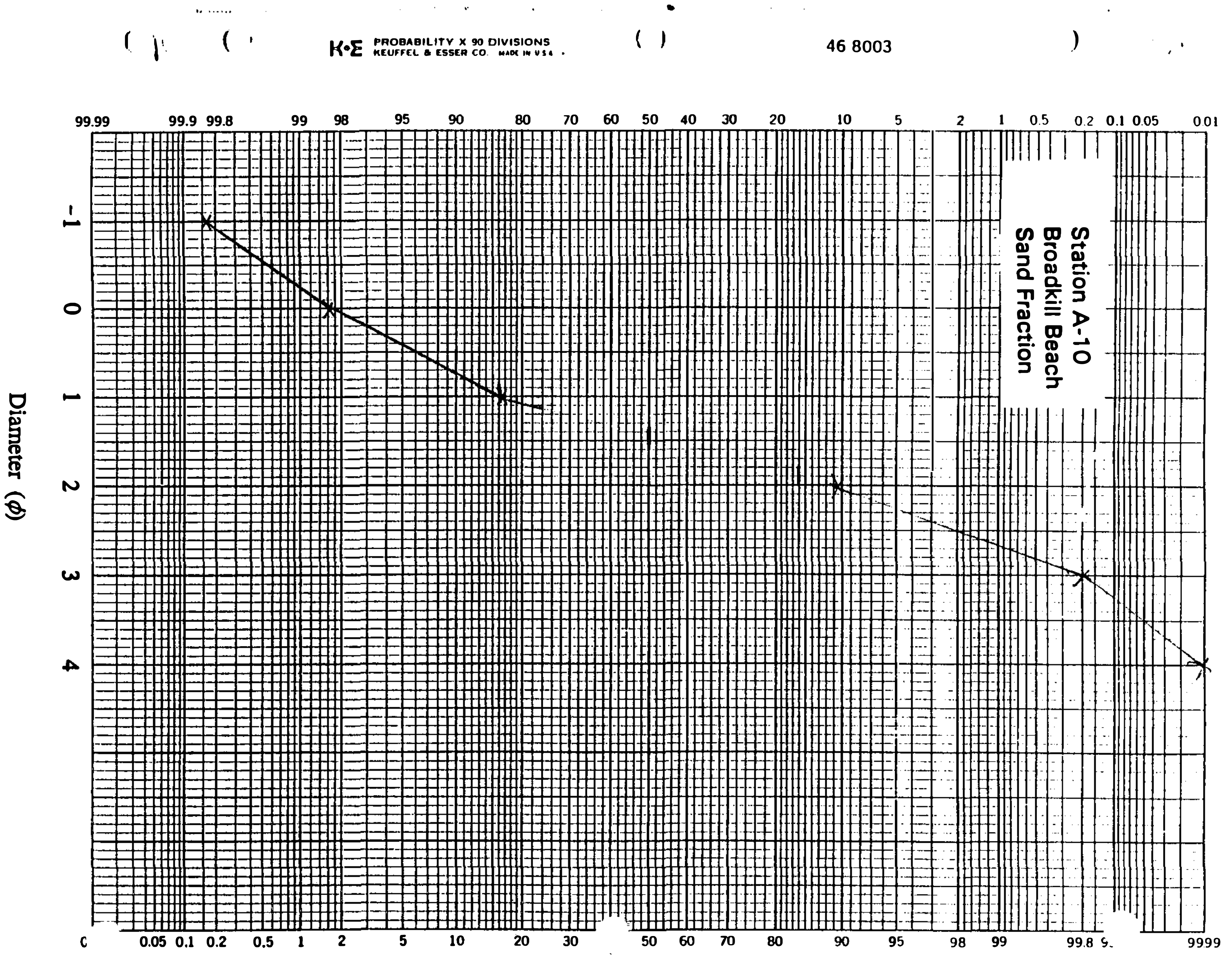


Station A-7
Broadkill Beach
Sand Fraction
Diameter (φ)
-1
0
1
2
3
4
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003

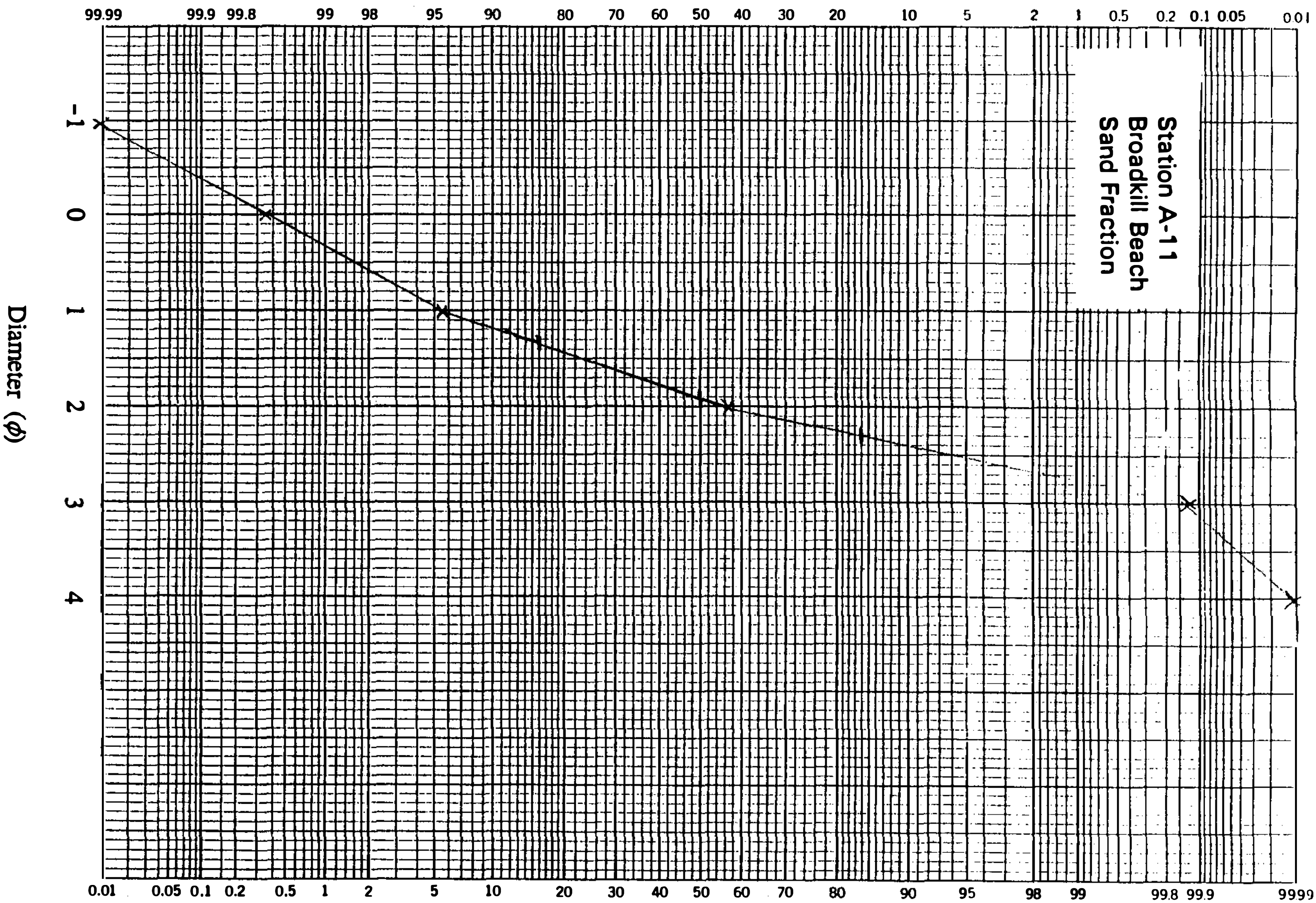
K·E PROBABILITY X 90 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 8003




Station A-9
Broadkill Beach
Sand Fraction
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
-1
0
1
2
3
4
Diameter (ϕ)
46 8003
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

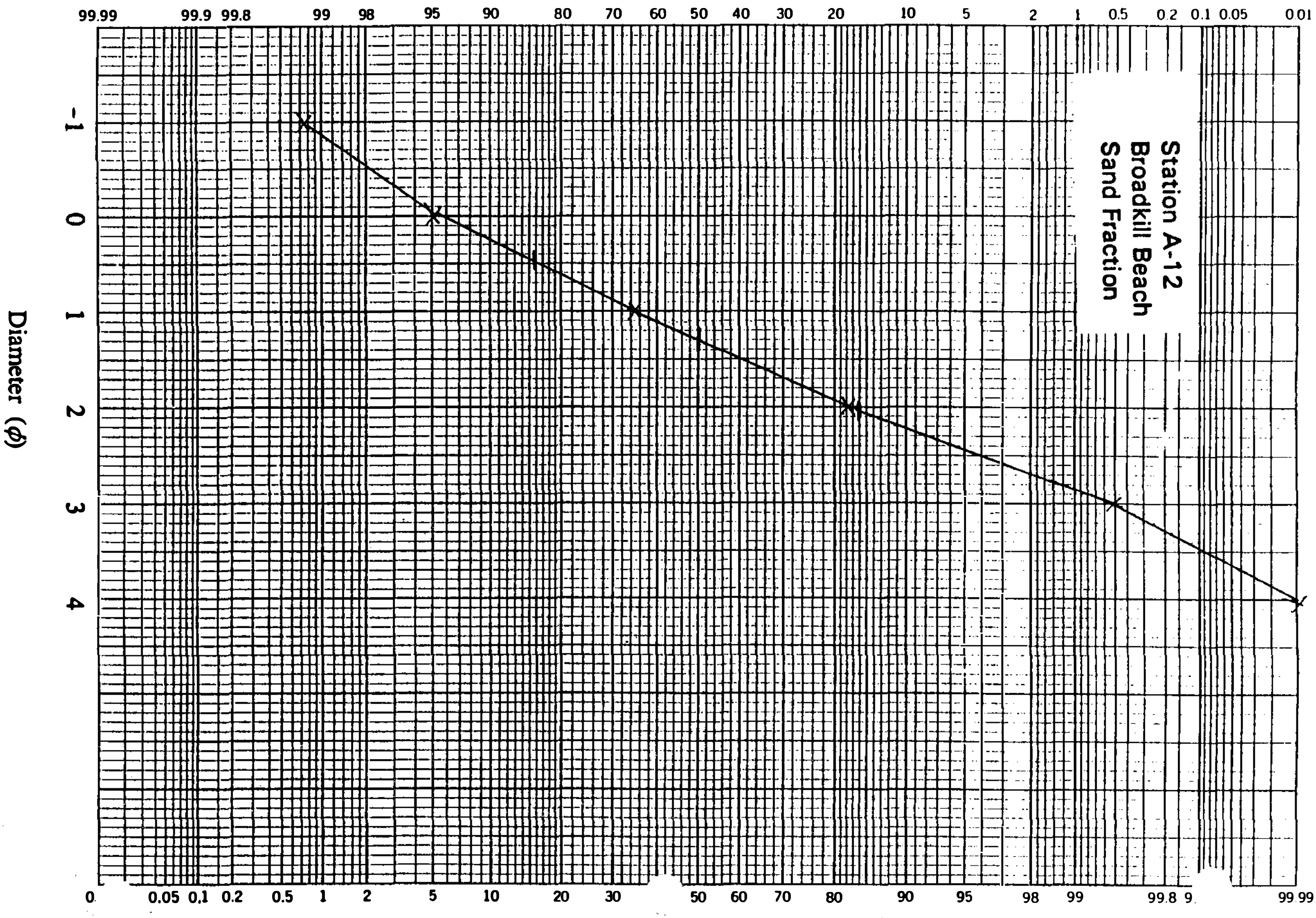

K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station A-10
Broadkill Beach
Sand Fraction
Diameter (φ)
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.05 0.1 0.2 0.5 1 2 5 10 20 30 50 60 70 80 90 95 98 99 99.8 9999
-1 0 1 2 3 4

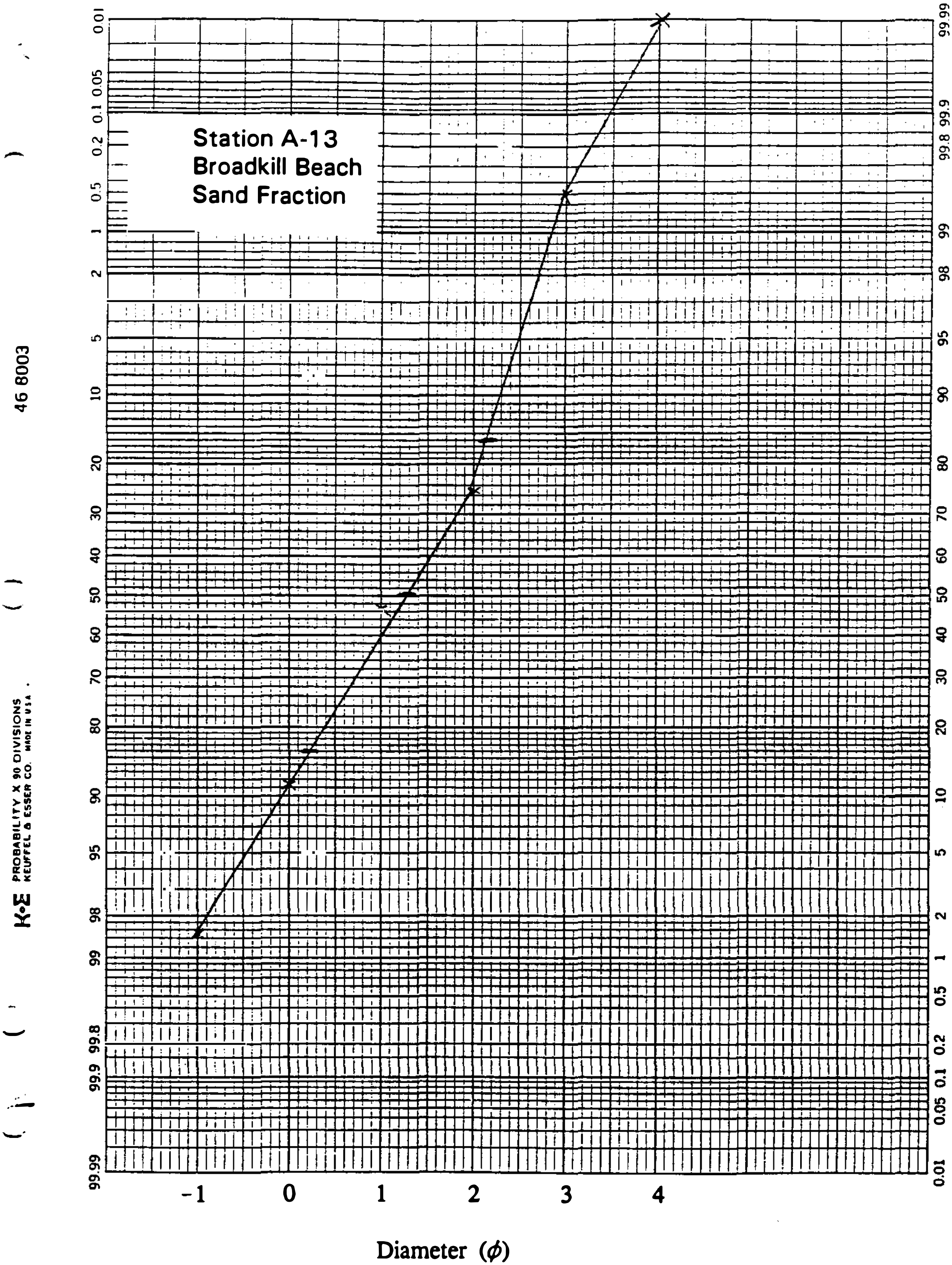
K•E PROBABILITY X 90 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 8003



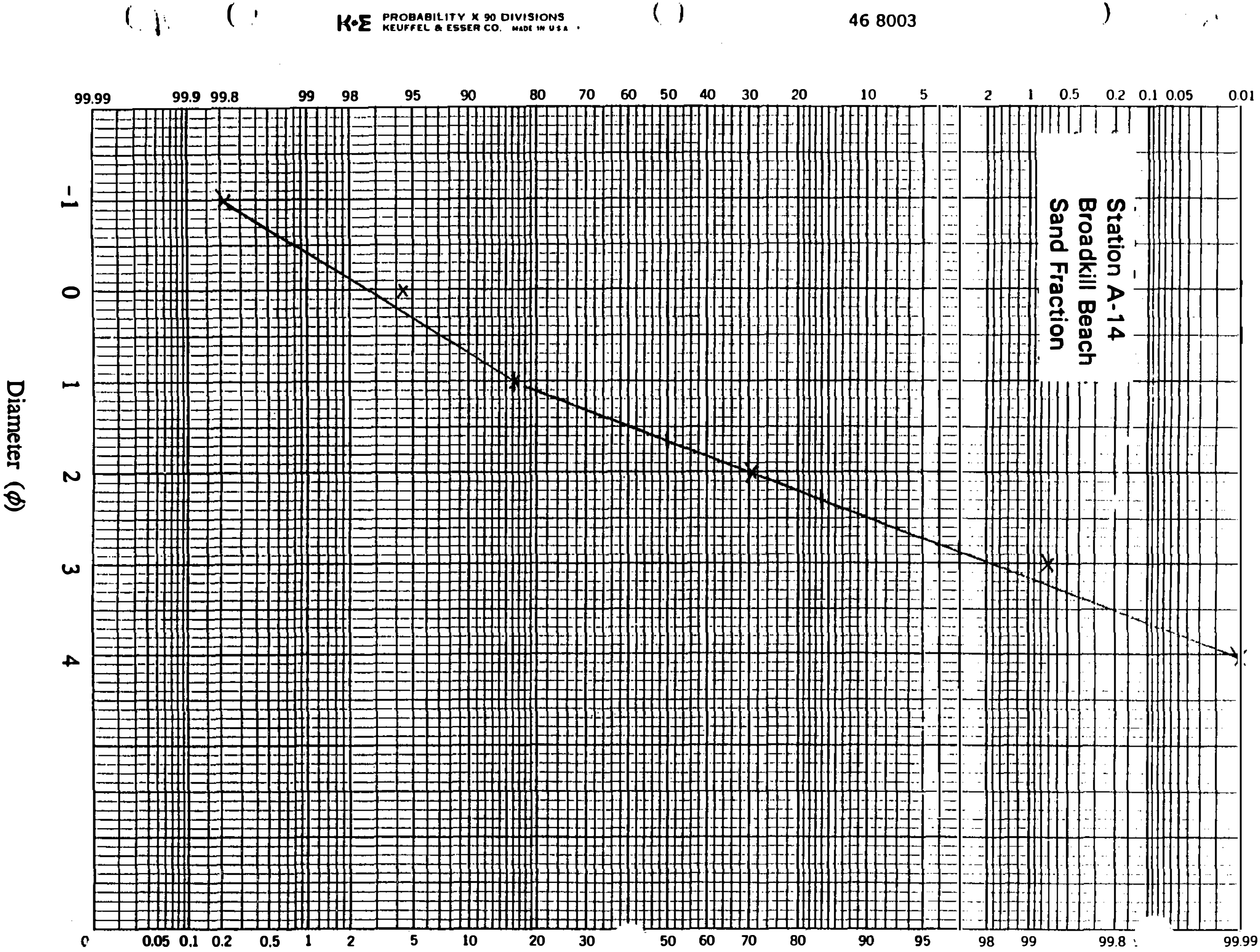
K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

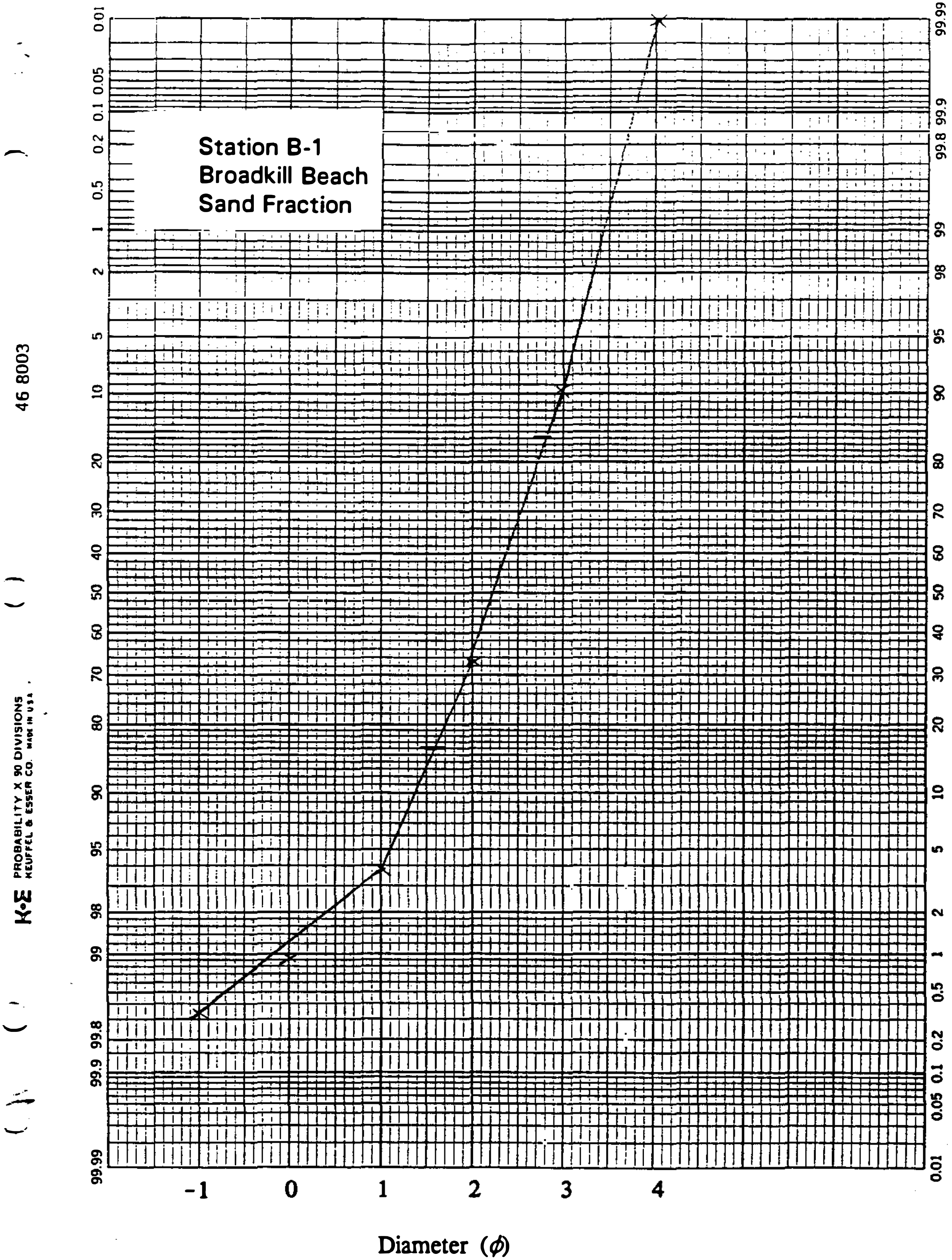
46 8003




Station A-13
Broadkill Beach
Sand Fraction
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
-1
0
1
2
3
4
Diameter (ϕ)
46 8003
K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

682

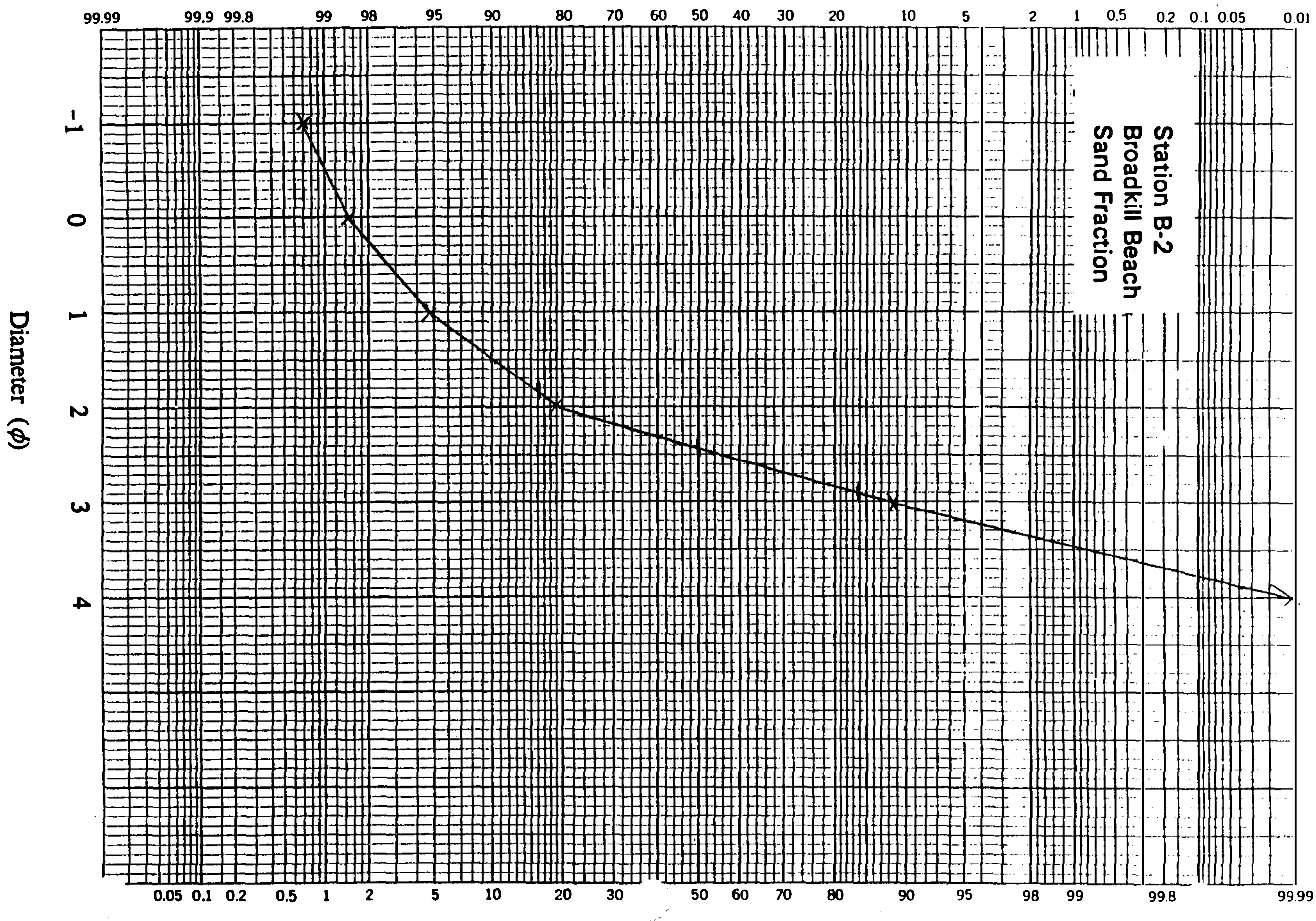

K·E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station A-14
Broadkill Beach
Sand Fraction
Diameter (φ)
-1
0
1
2
3
4
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0 0.05 0.1 0.2 0.5 1 2 5 10 20 30 50 60 70 80 90 95 98 99 99.8 99.99

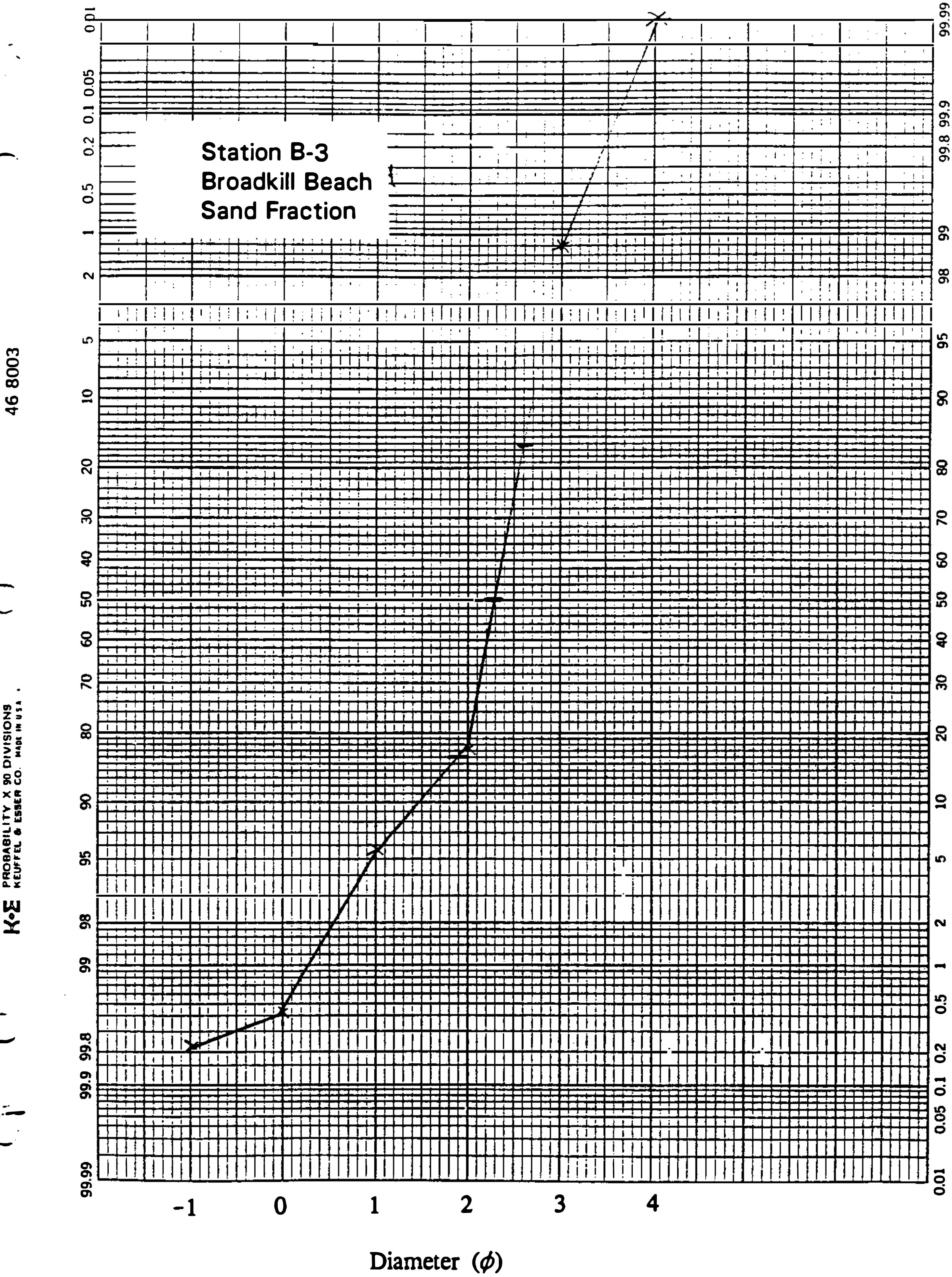


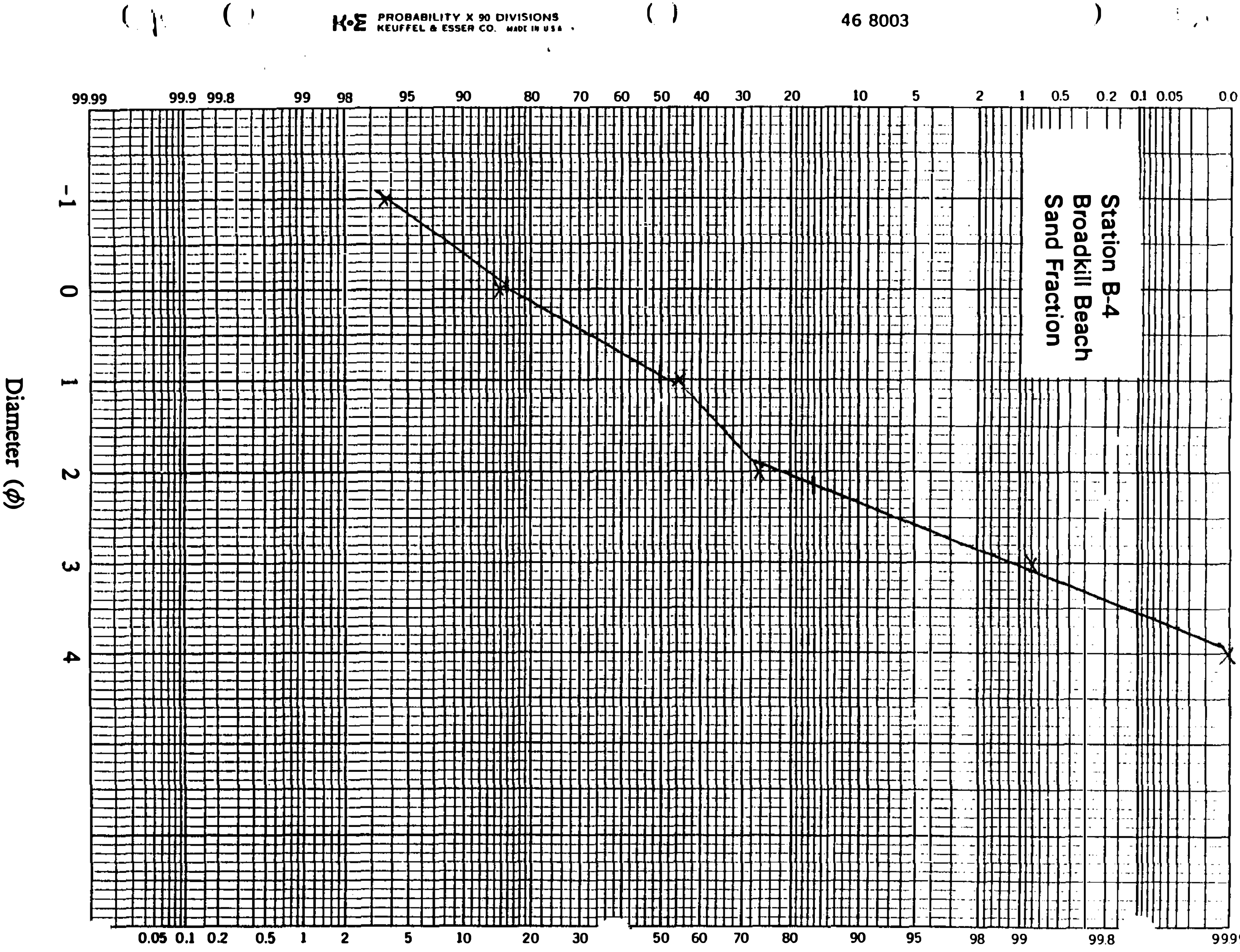
Station B-1
Broadkill Beach
Sand Fraction
Diameter (ϕ)
-1
0
1
2
3
4
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003

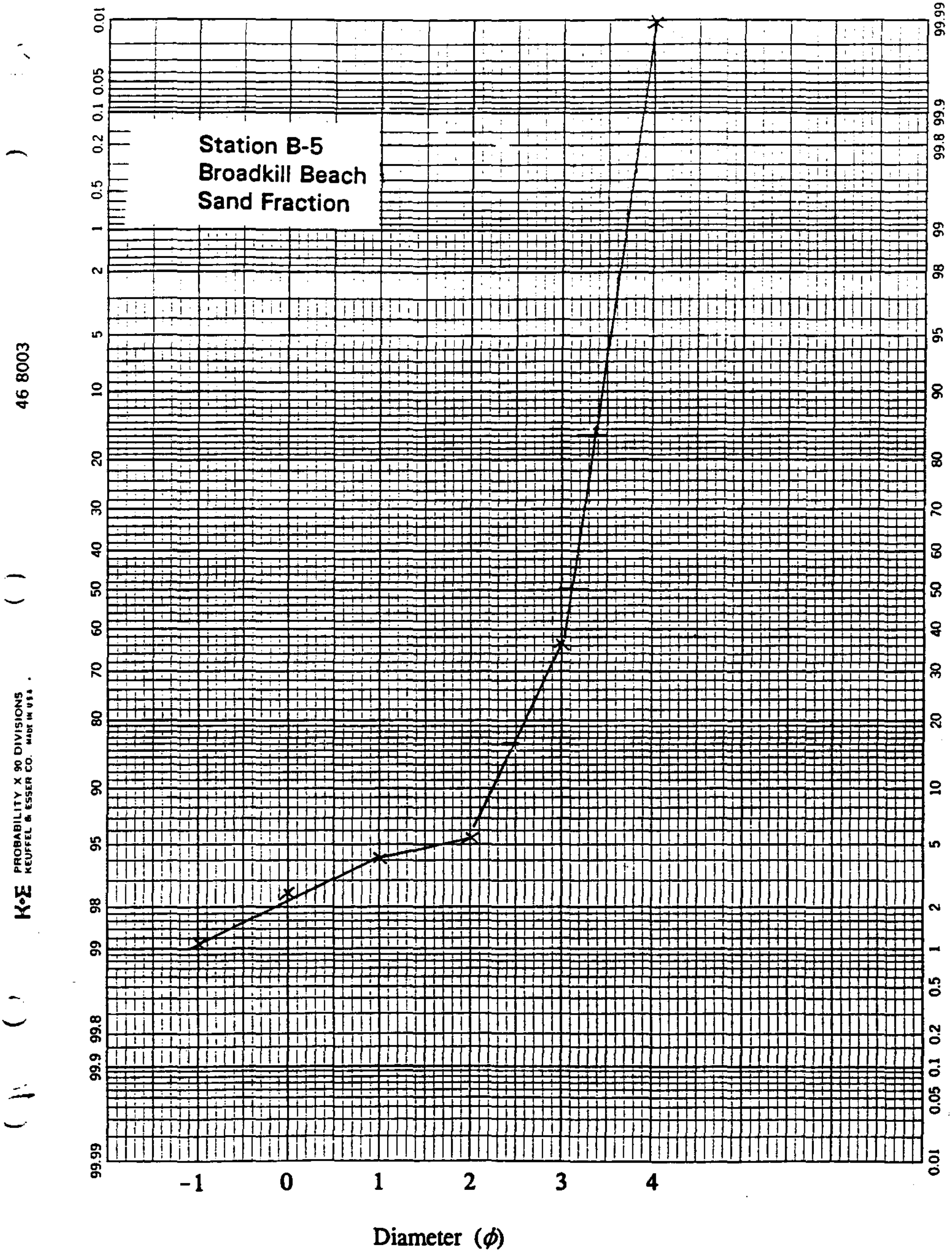
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8003

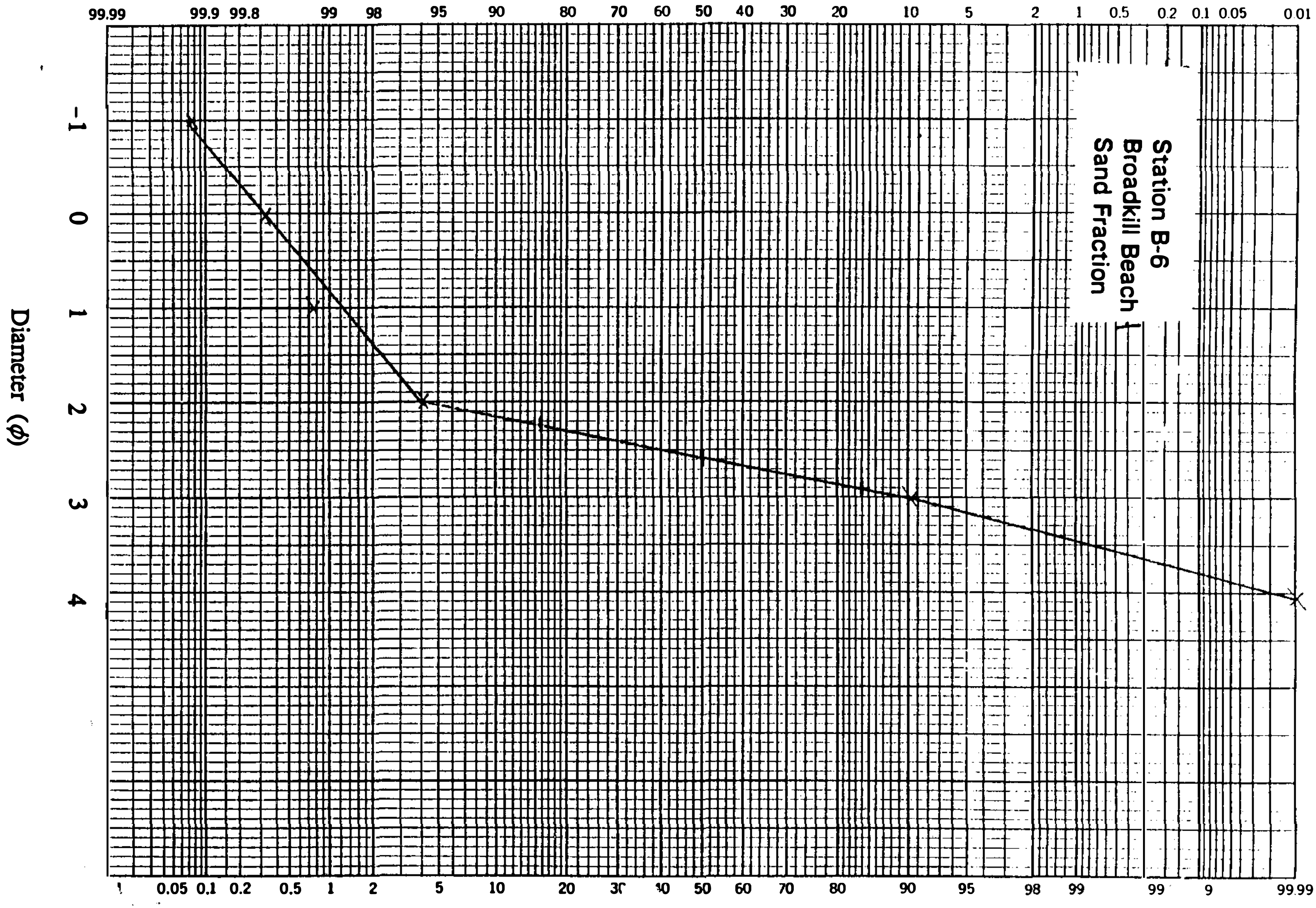


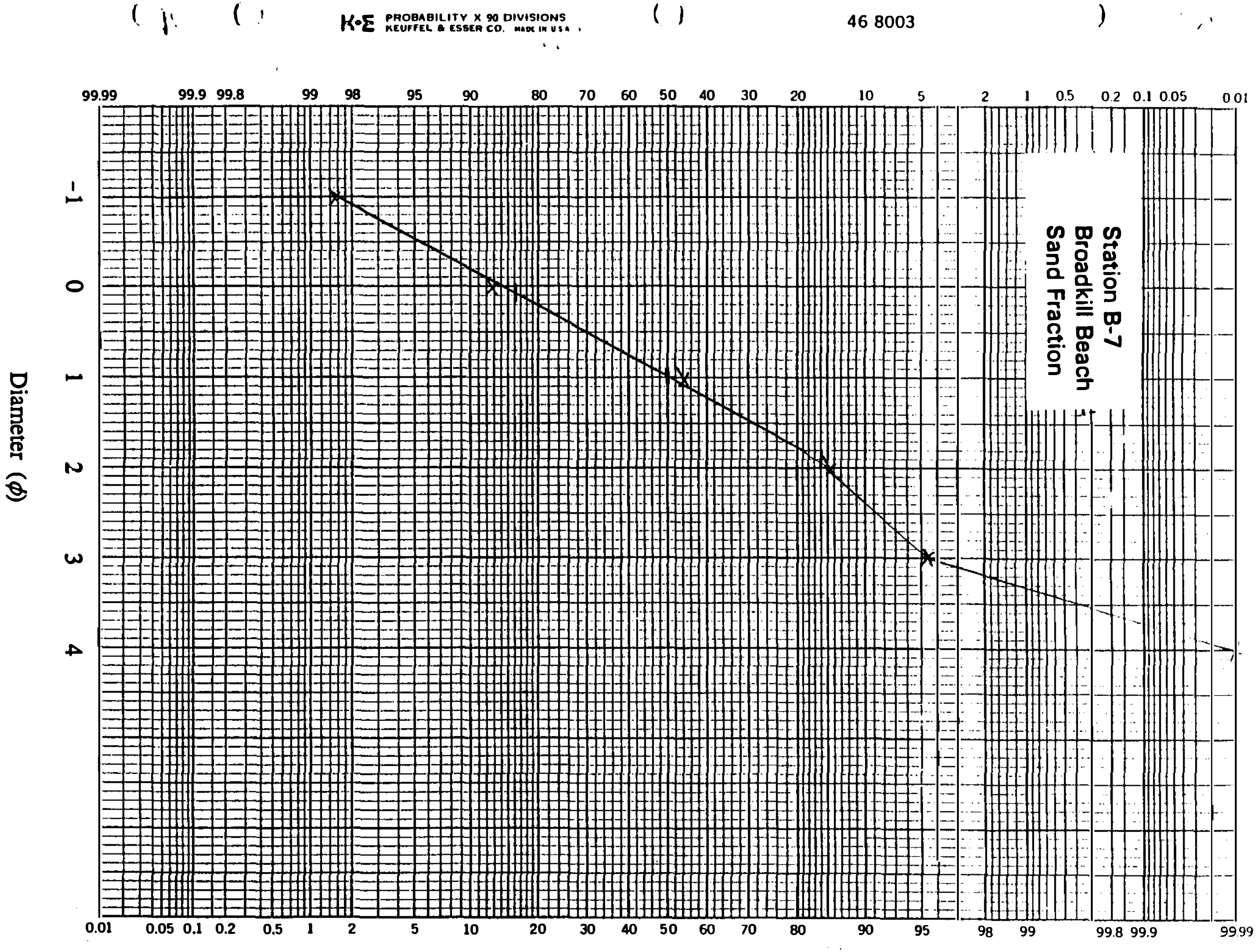

Station B-3
Broadkill Beach
Sand Fraction
-1
0
1
2
3
4
Diameter (ϕ)
46 8003
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.


K·E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.05 0.1 0.2 0.5 1 2 5 10 20 30 50 60 70 80 90 95 98 99 99.8 99.99
-1 0 1 2 3 4
Diameter (φ)
Station B-4
Broadkill Beach
Sand Fraction


Station B-5
Broadkill Beach
Sand Fraction
-1
0
1
2
3
4
Diameter (ϕ)
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003

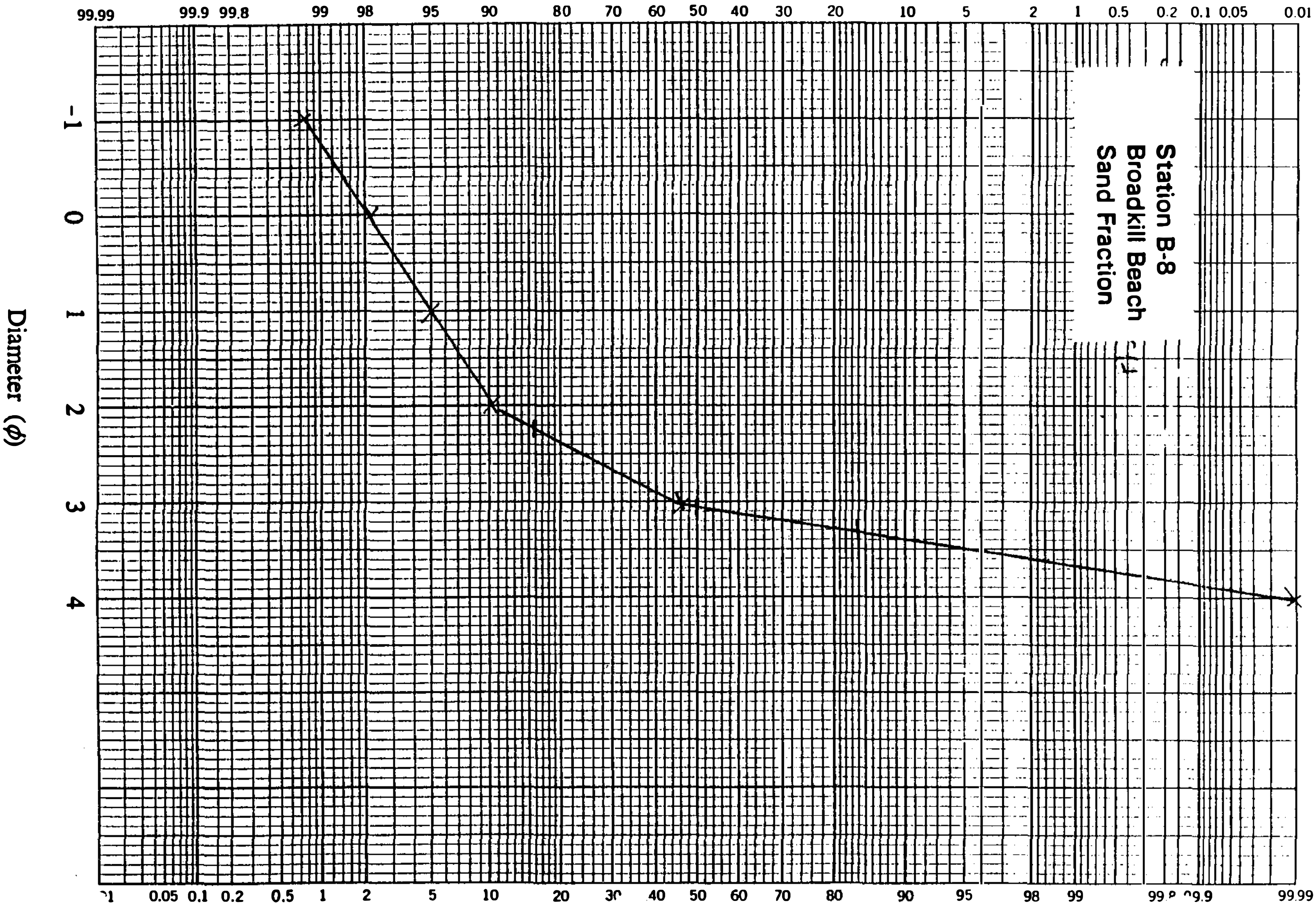
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003

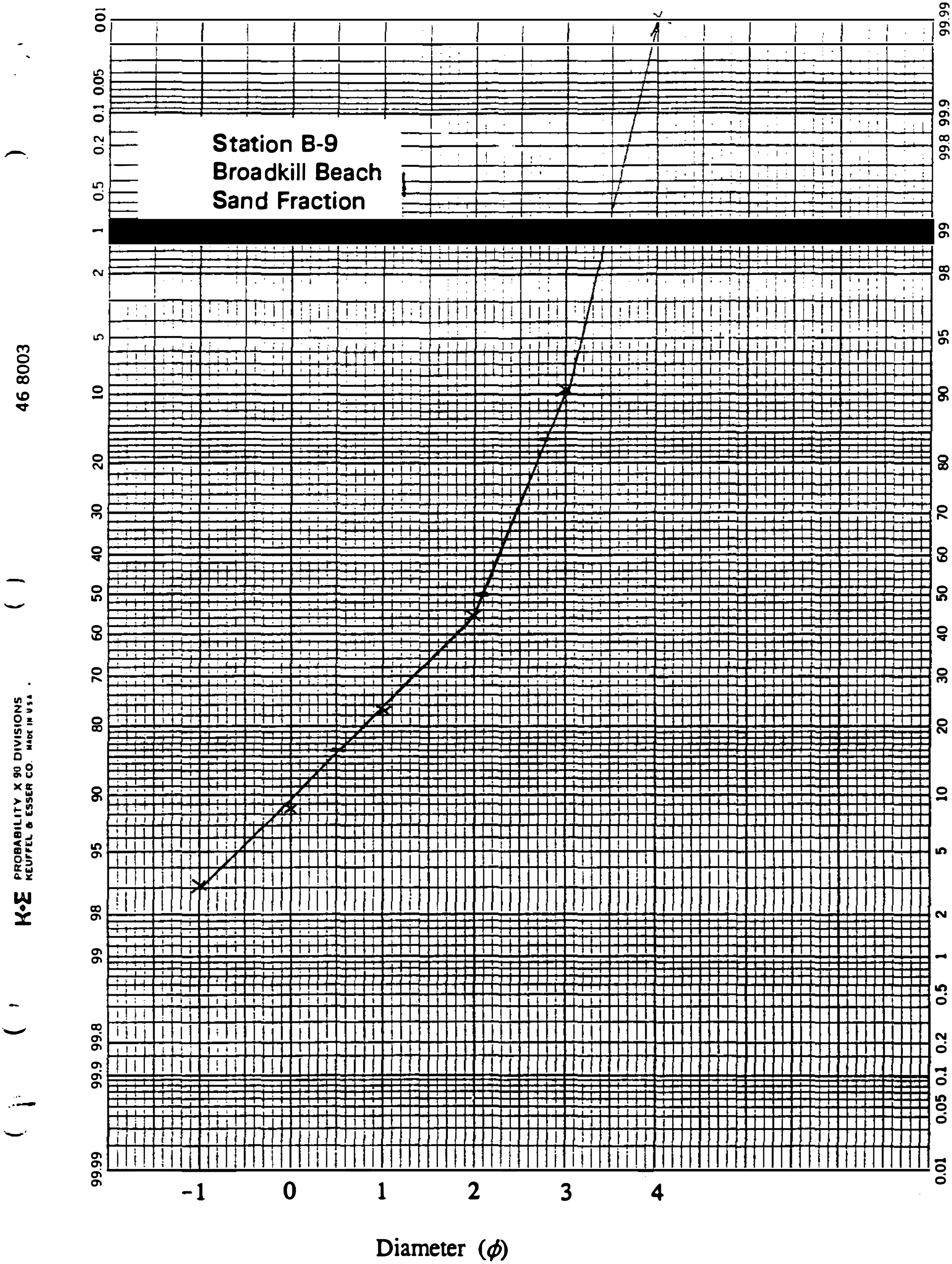



K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station B-7
Broadkill Beach
Sand Fraction
Diameter (φ)

K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

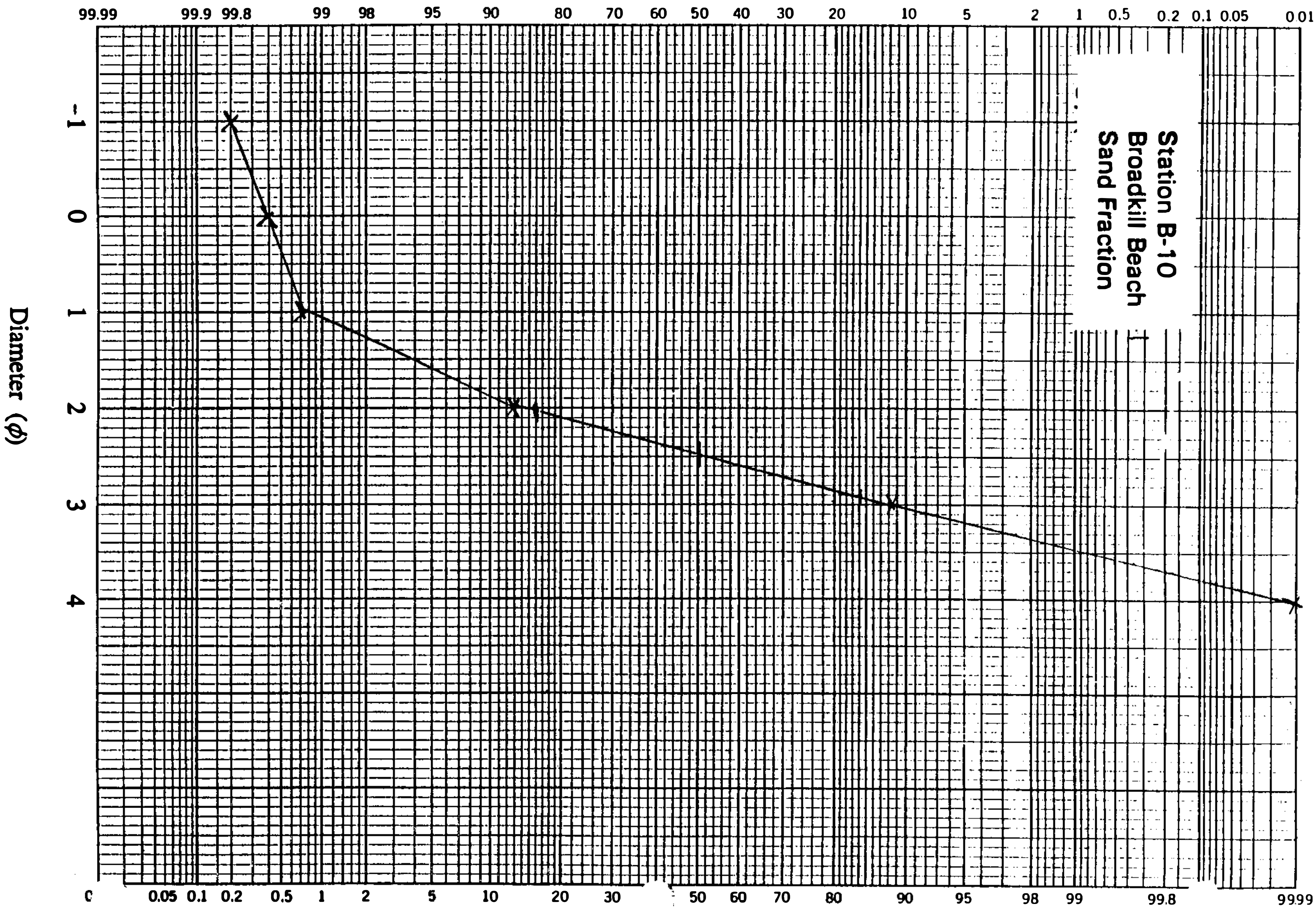
46 8003

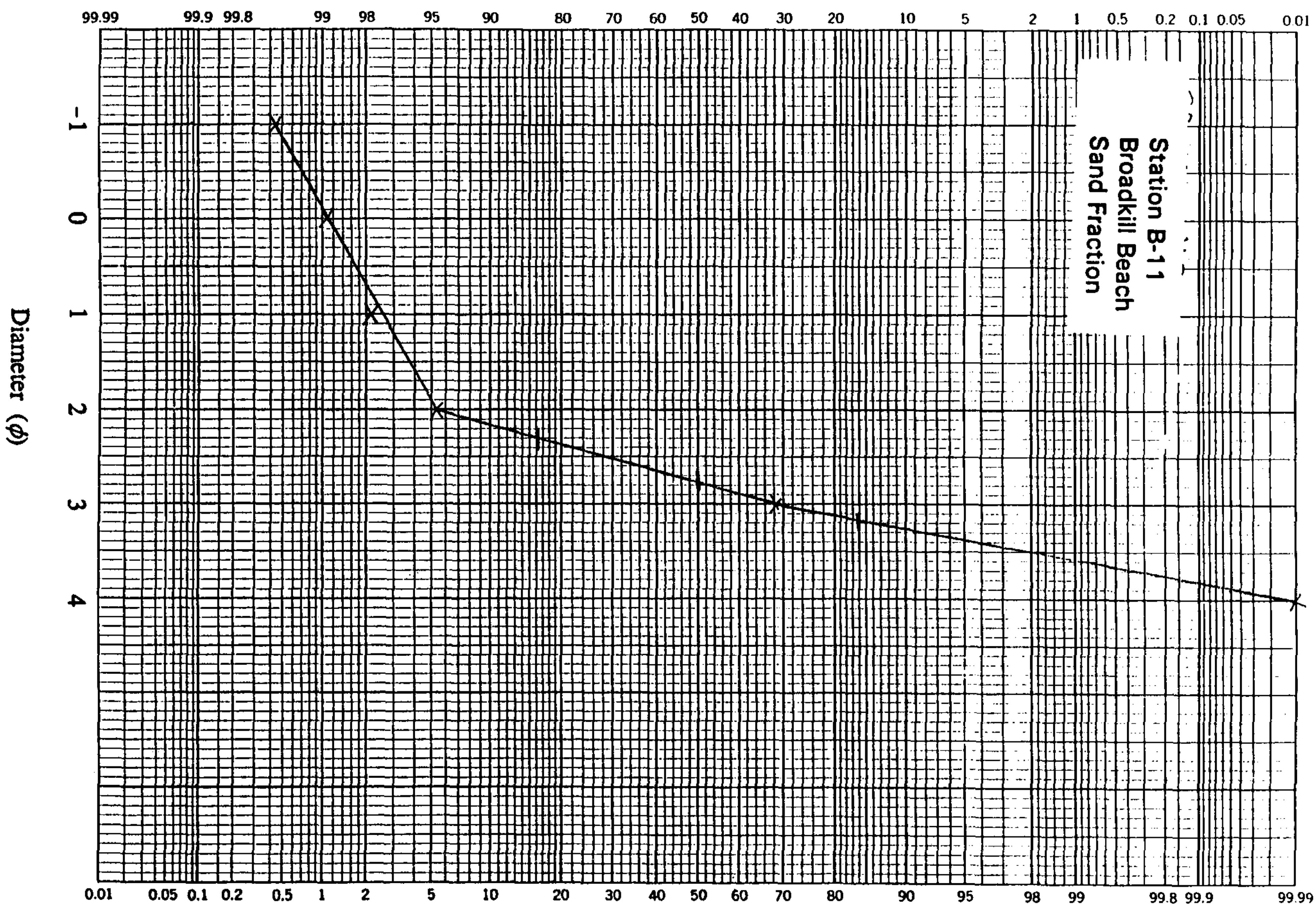


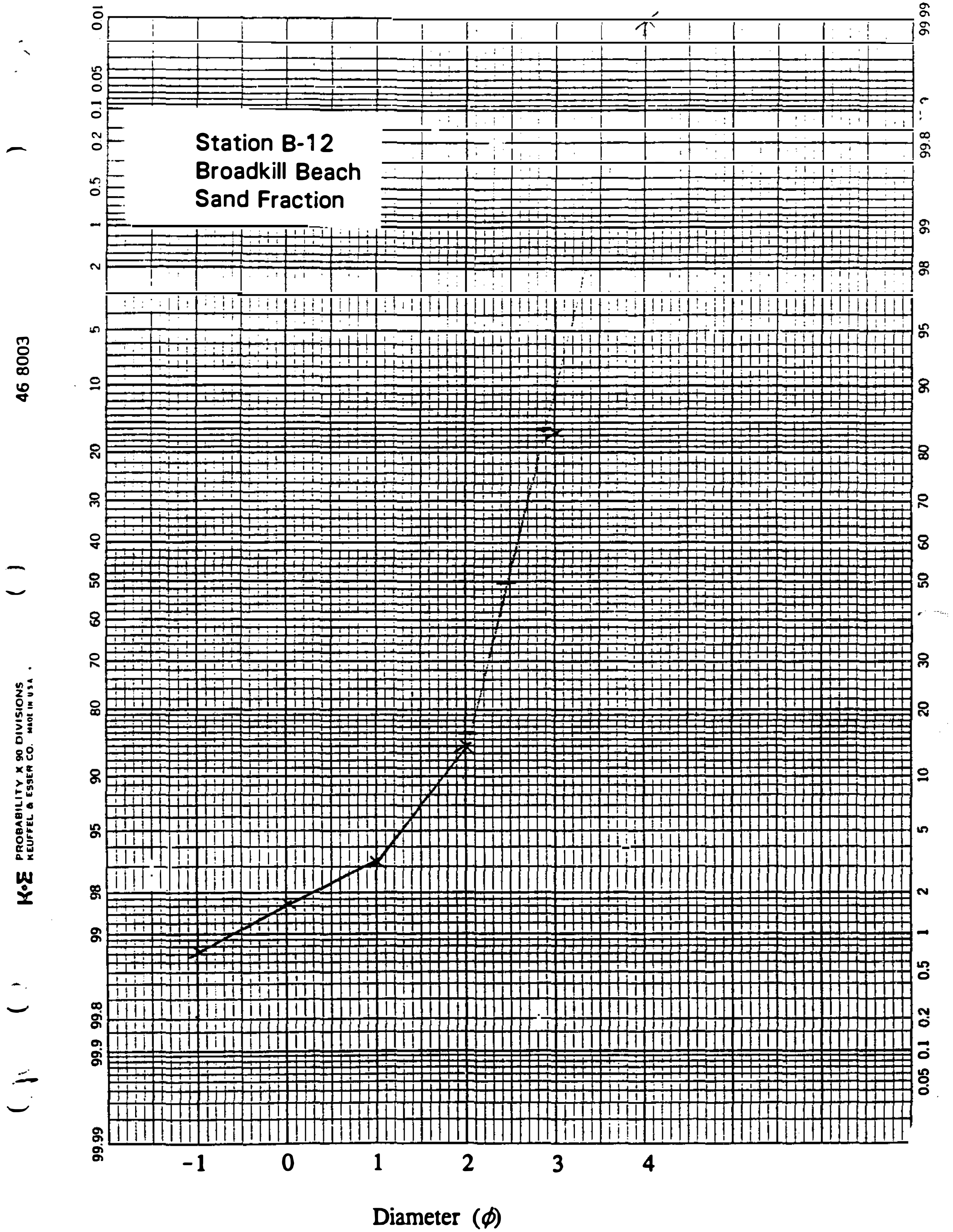

K•Σ PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station B-9
Broadkill Beach
Sand Fraction
-1
0
1
2
3
4
Diameter (ϕ)

K·Σ PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

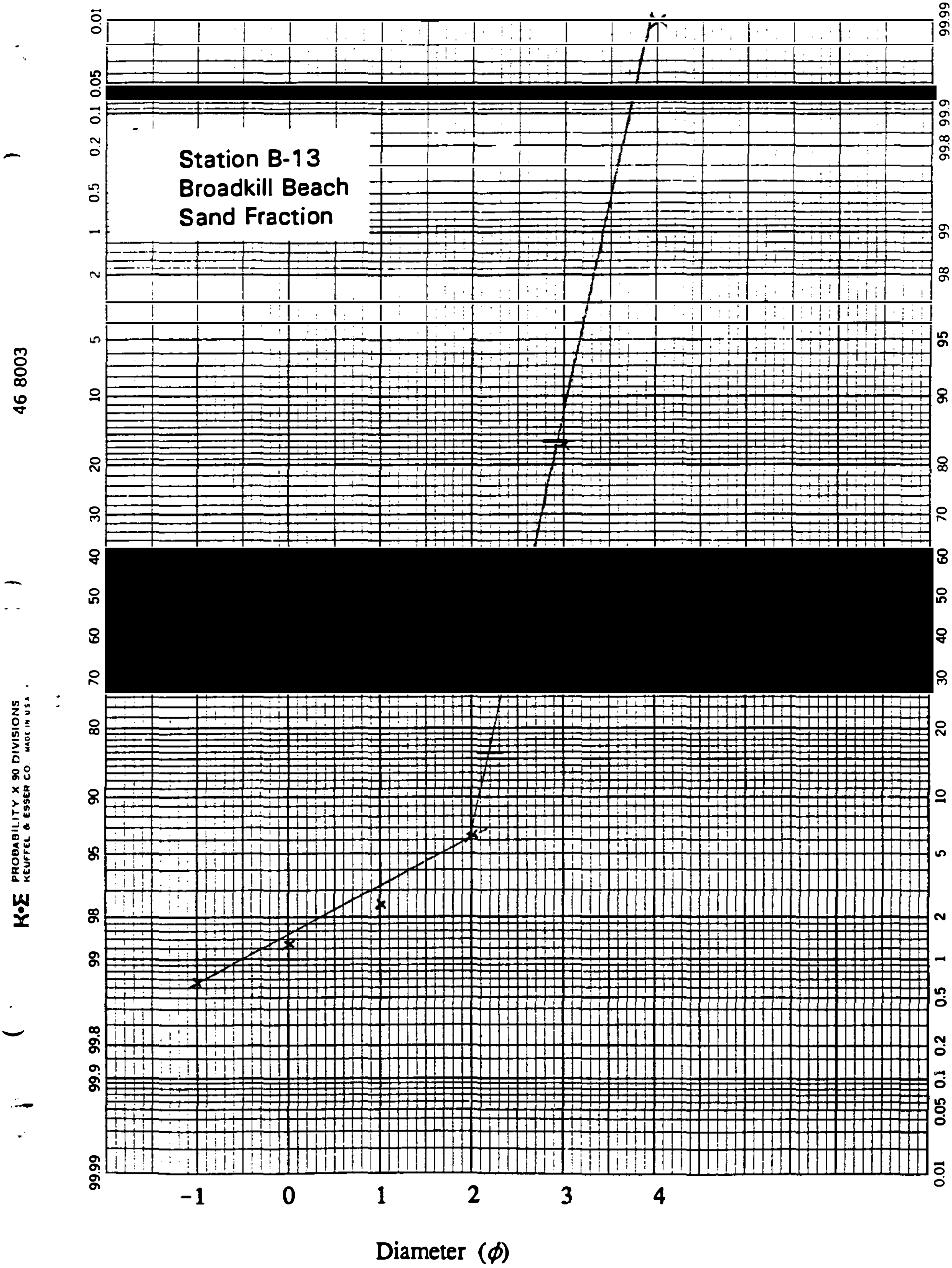
46 8003



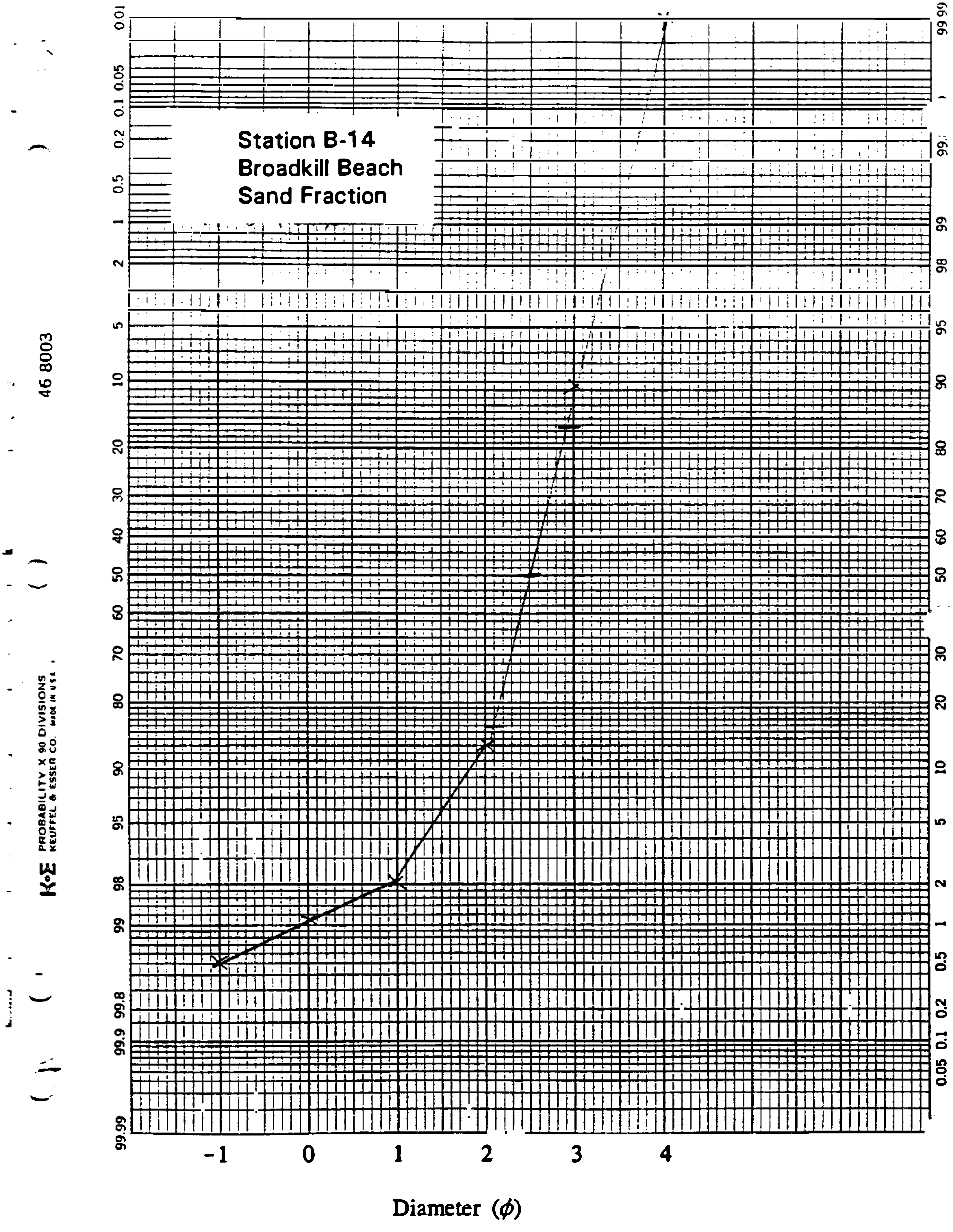

Station B-11
Broadkill Beach
Sand Fraction
Diameter (φ)
-1
0
1
2
3
4
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99

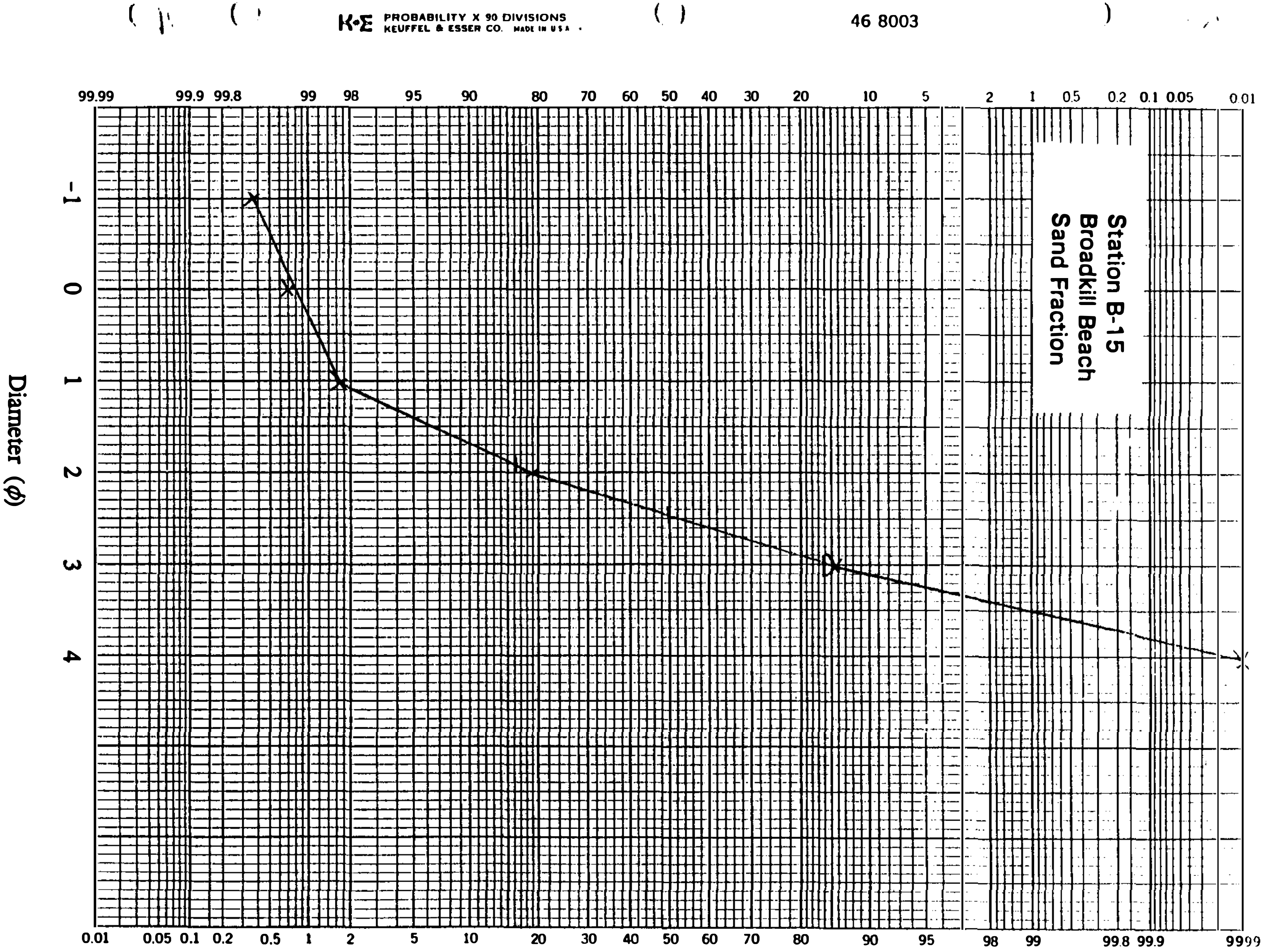


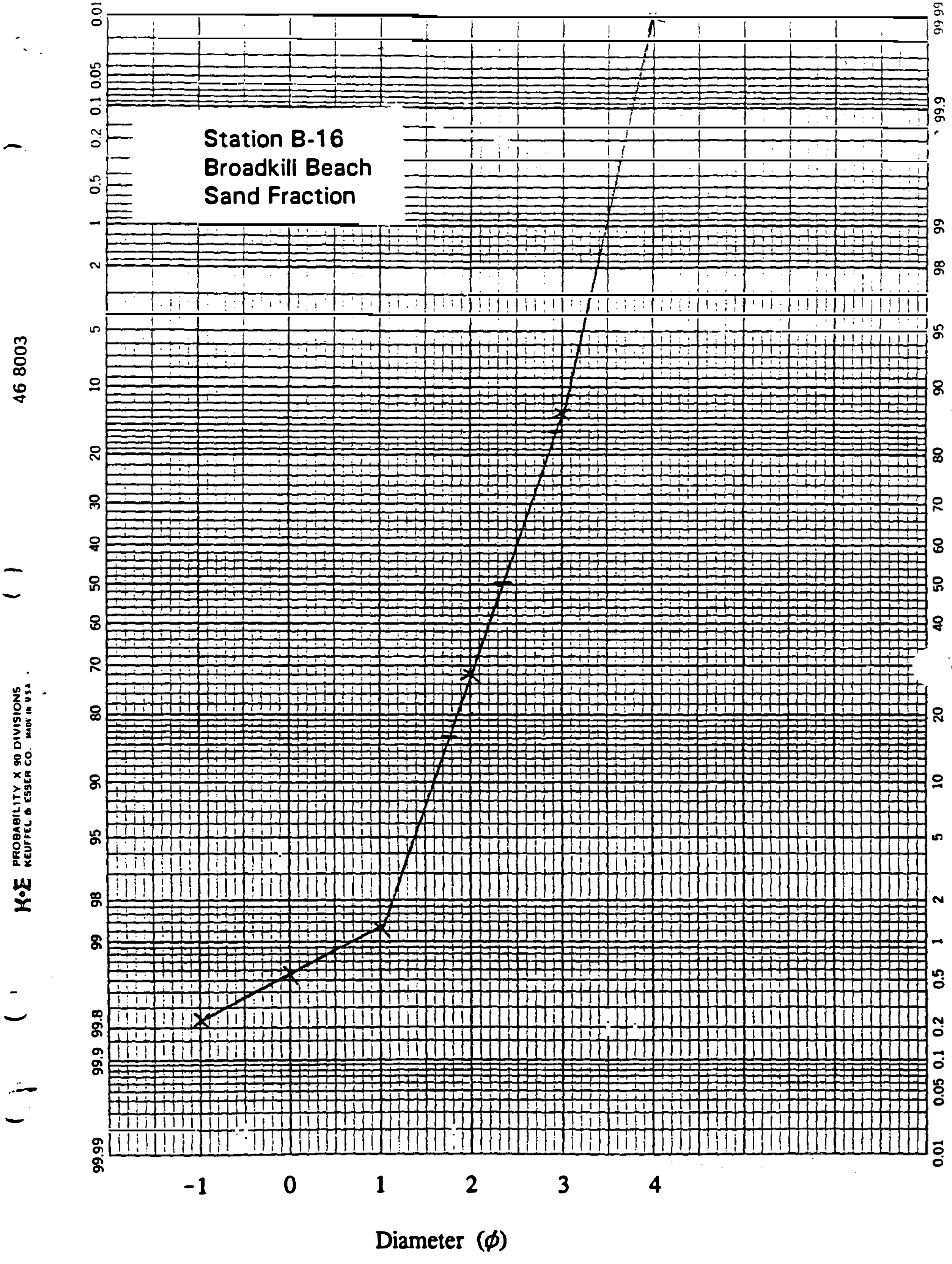
Station B-12
Broadkill Beach
Sand Fraction
-1
0
1
2
3
4
Diameter (ϕ)
46 8003
K·E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

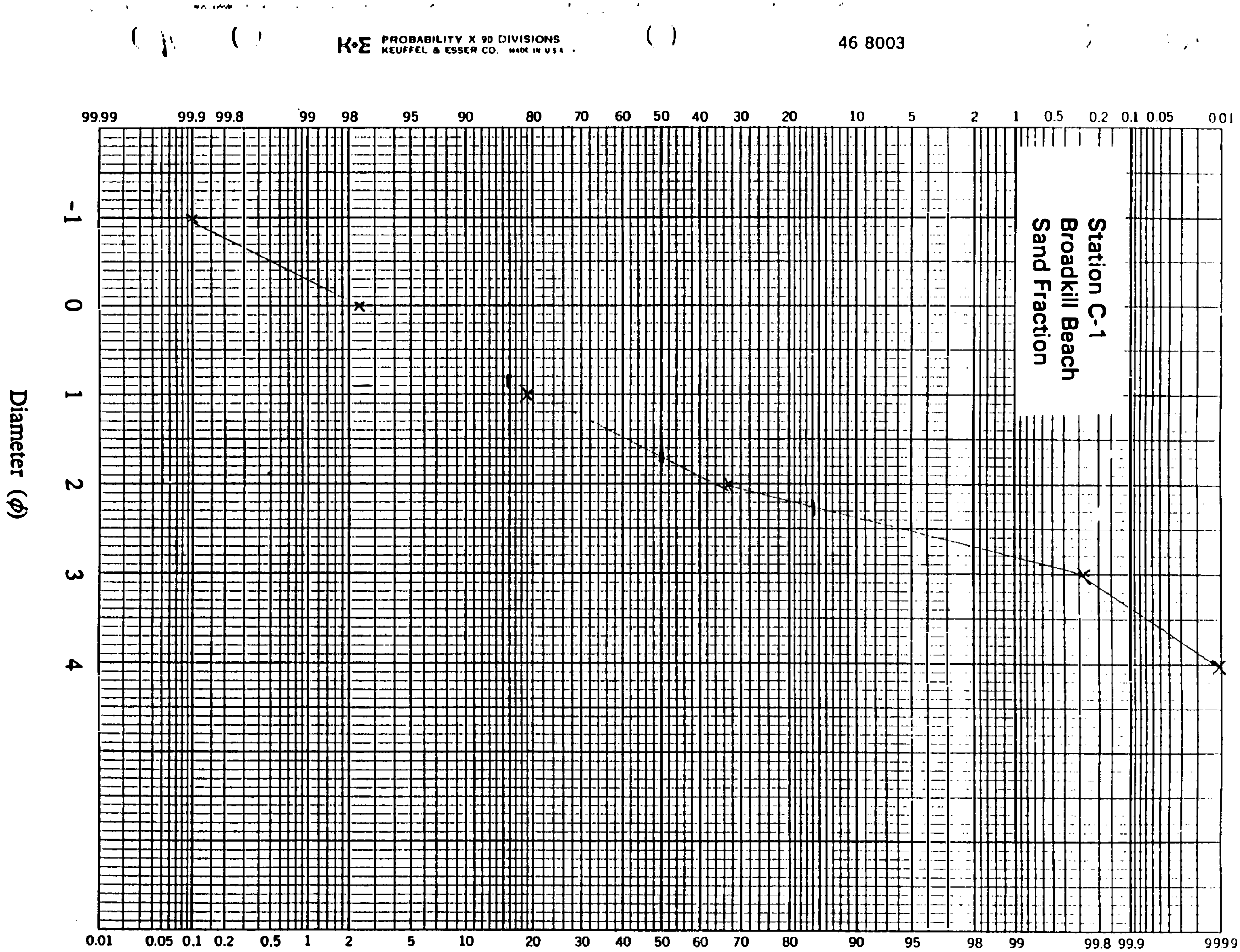


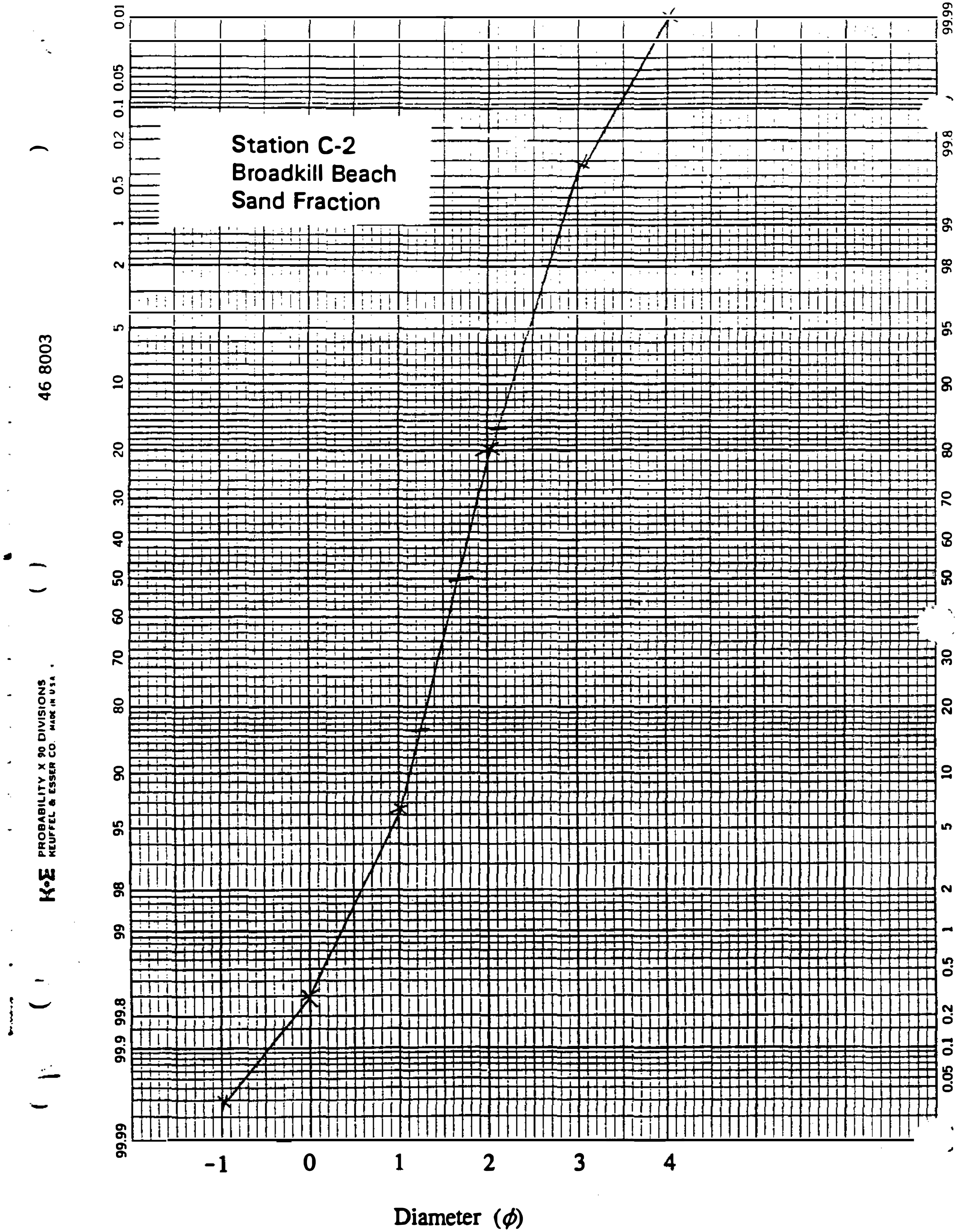
K•Σ PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station B-13
Broadkill Beach
Sand Fraction
Diameter (ϕ)


Station B-14
Broadkill Beach
Sand Fraction
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
-1
0
1
2
3
4
Diameter (ϕ)
46 8003
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

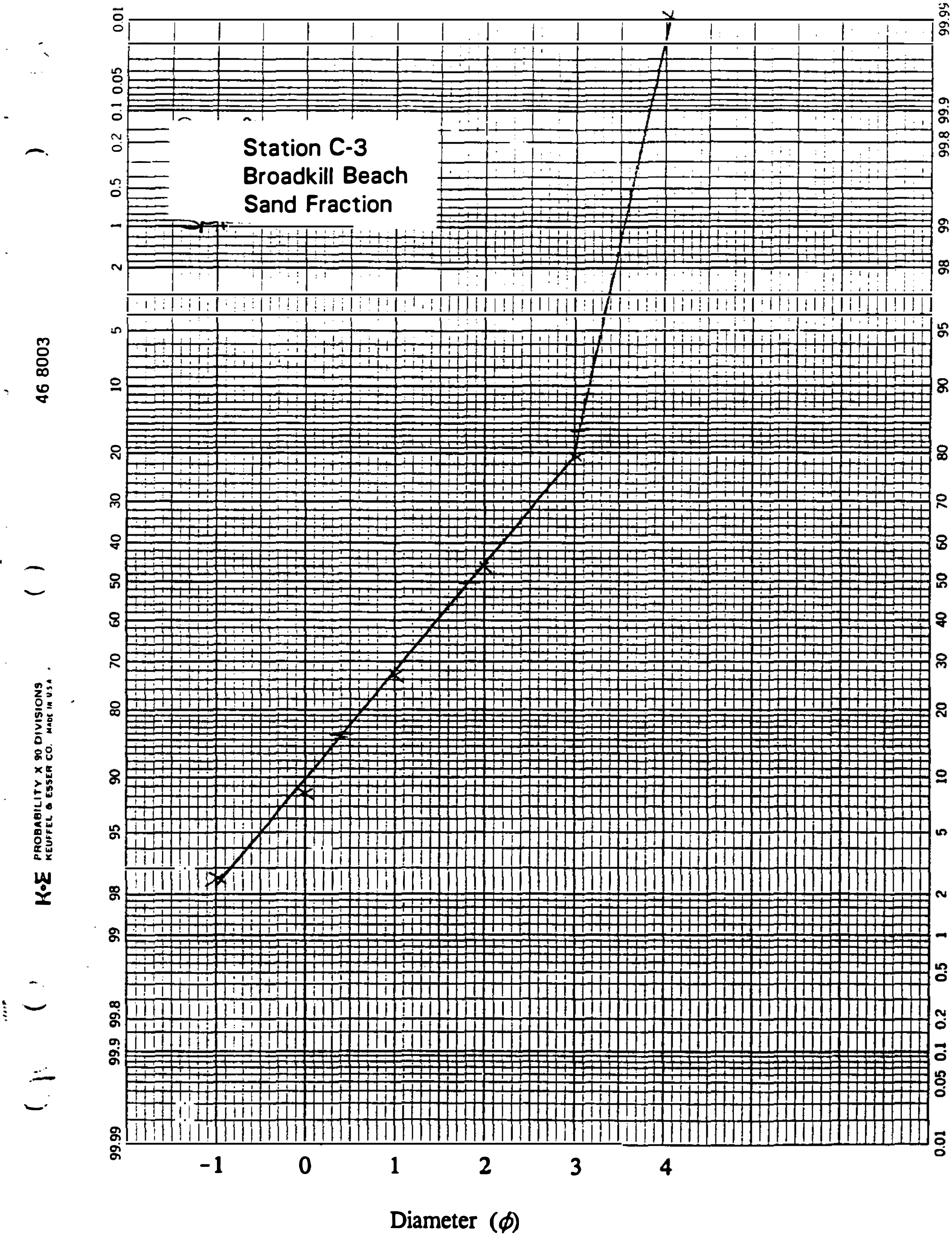

K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station B-15
Broadkill Beach
Sand Fraction
Diameter (ϕ)
-1
0
1
2
3
4
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01

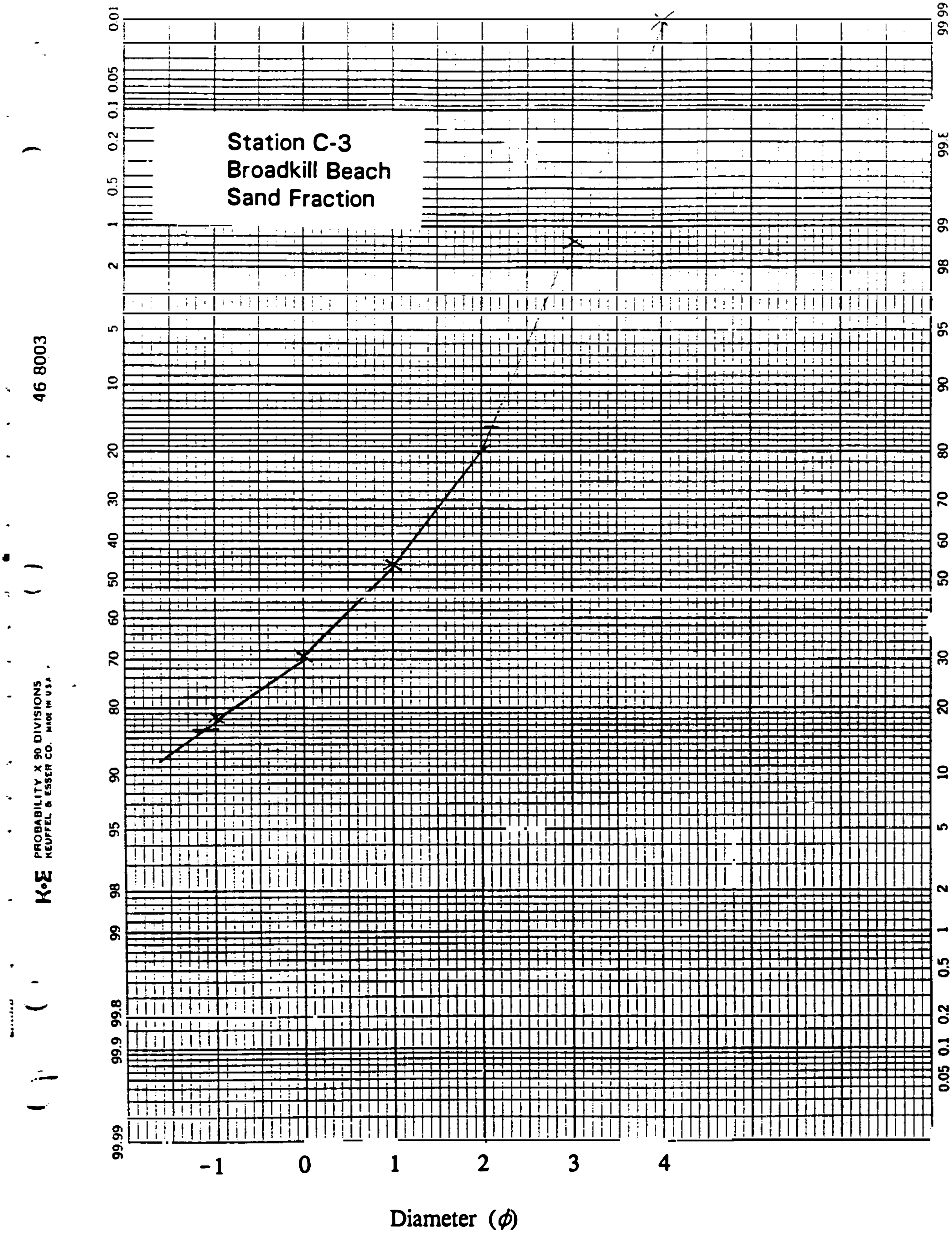

Station B-16
Broadkill Beach
Sand Fraction
-1
0
1
2
3
4
Diameter (φ)
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
46 8003
K·E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN USA

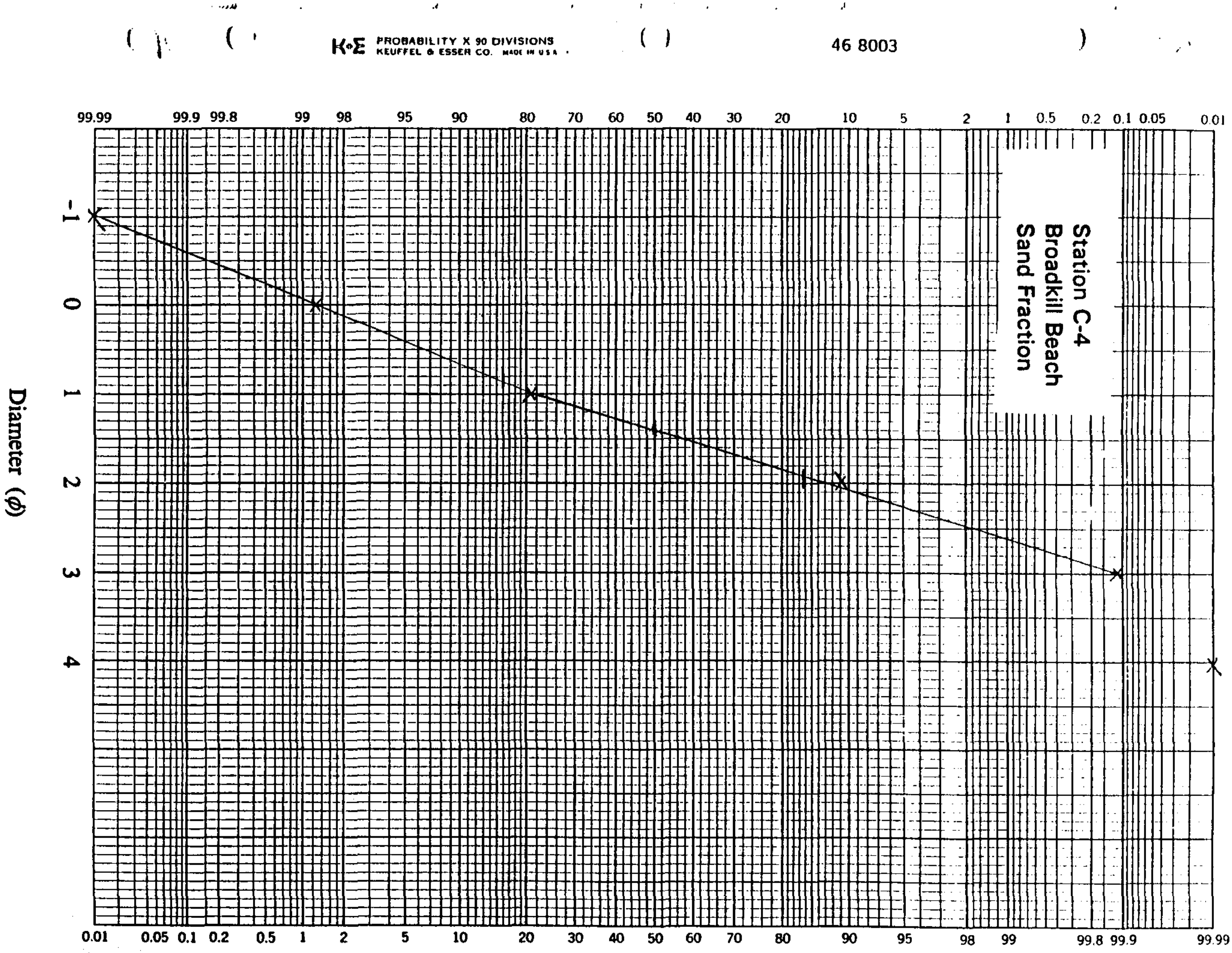

K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station C-1
Broadkill Beach
Sand Fraction
Diameter (ϕ)
-1
0
1
2
3
4
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99

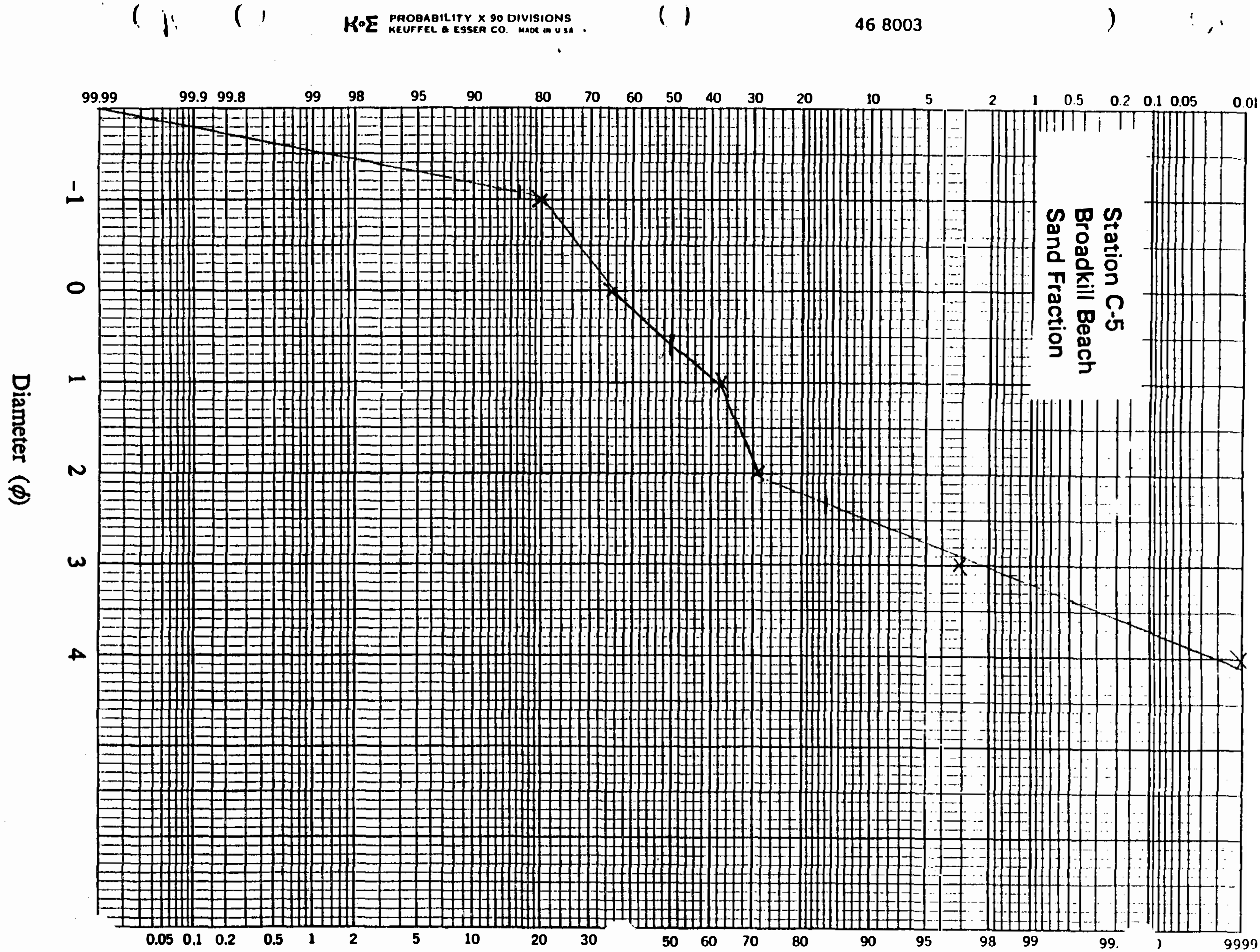


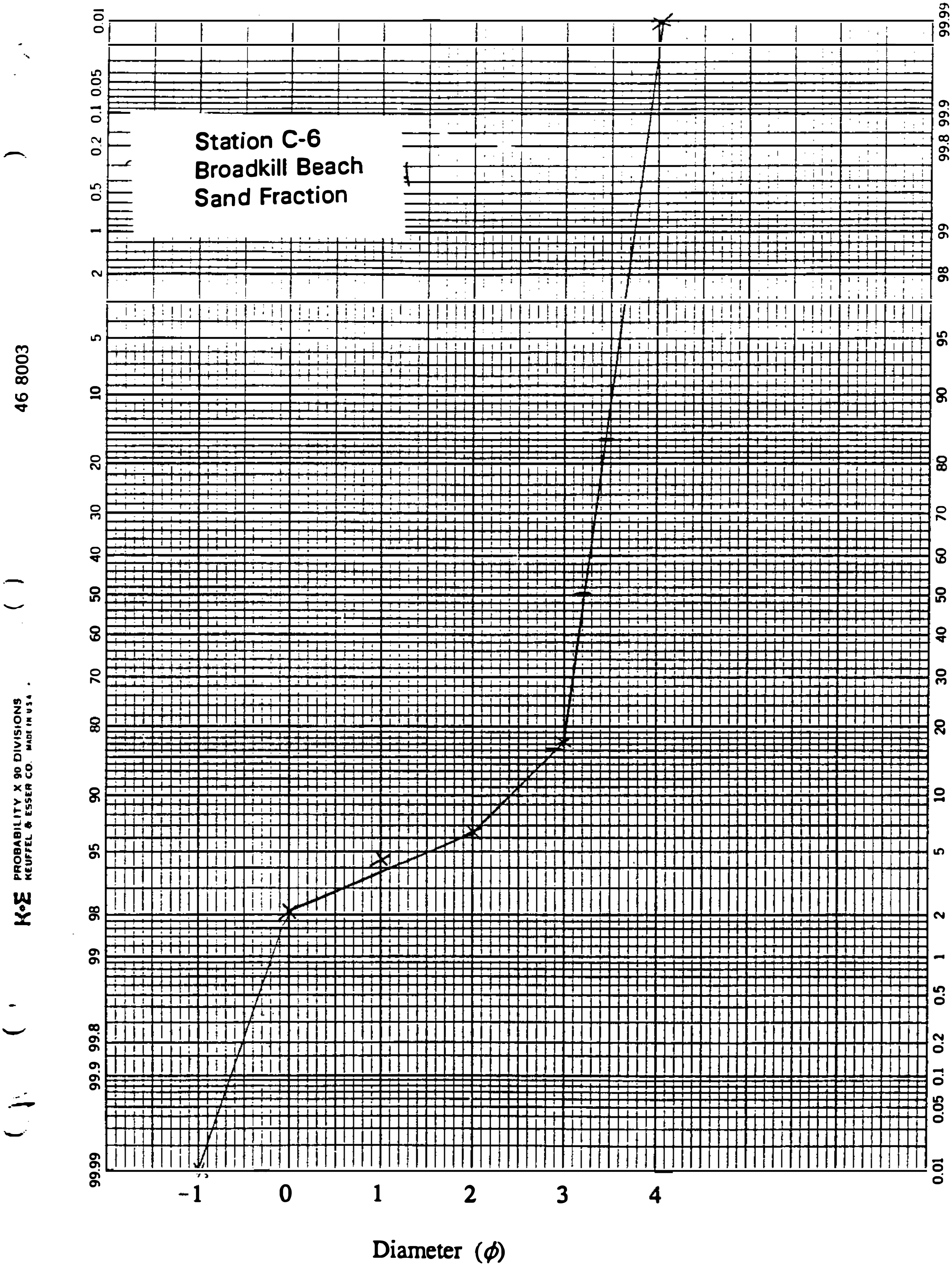
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station C-2
Broadkill Beach
Sand Fraction
Diameter (ϕ)

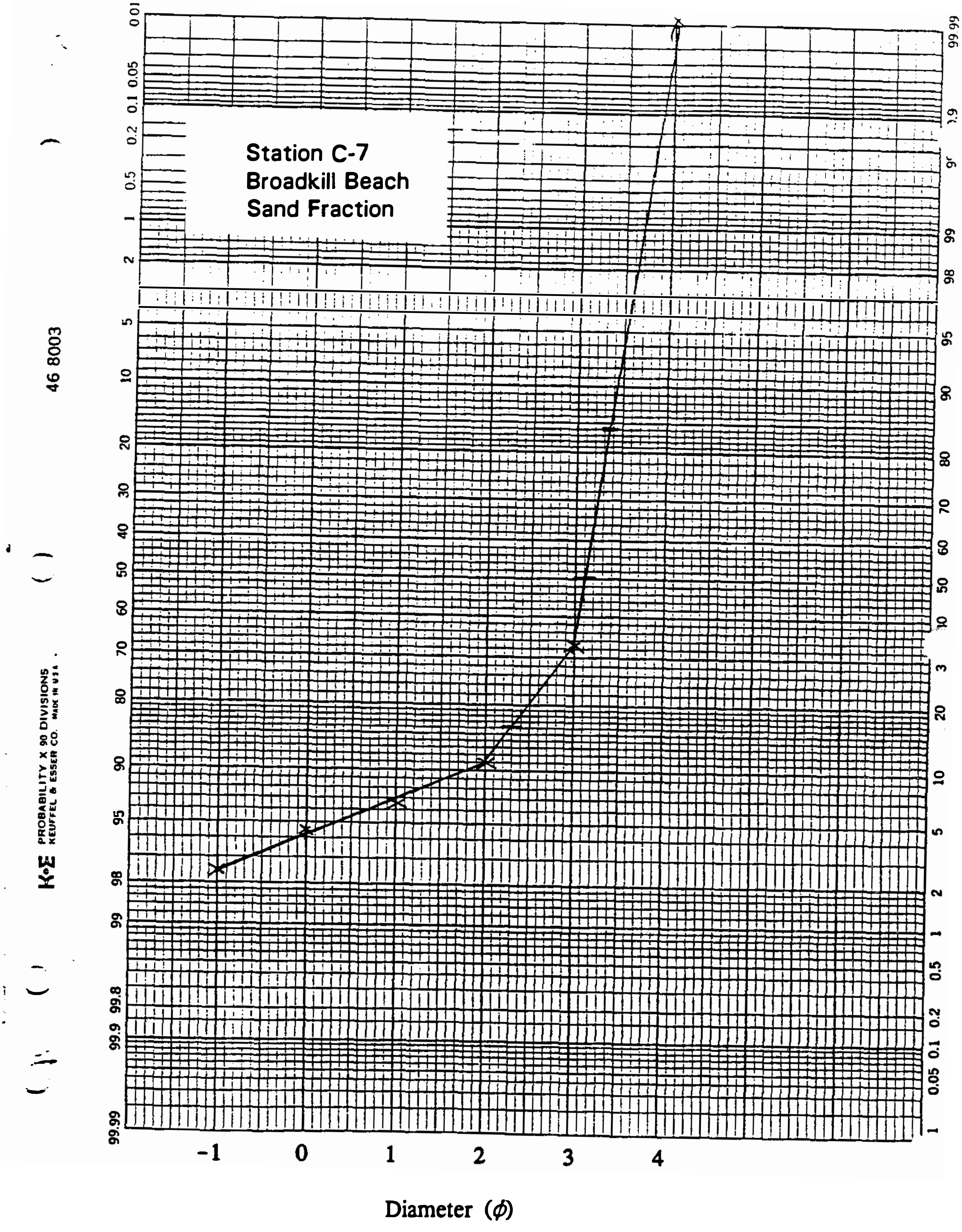

Station C-3
Broadkill Beach
Sand Fraction
-1
0
1
2
3
4
Diameter (φ)
K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003


Station C-3
Broadkill Beach
Sand Fraction
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
-1
0
1
2
3
4
Diameter (ϕ)
46 8003
K&E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

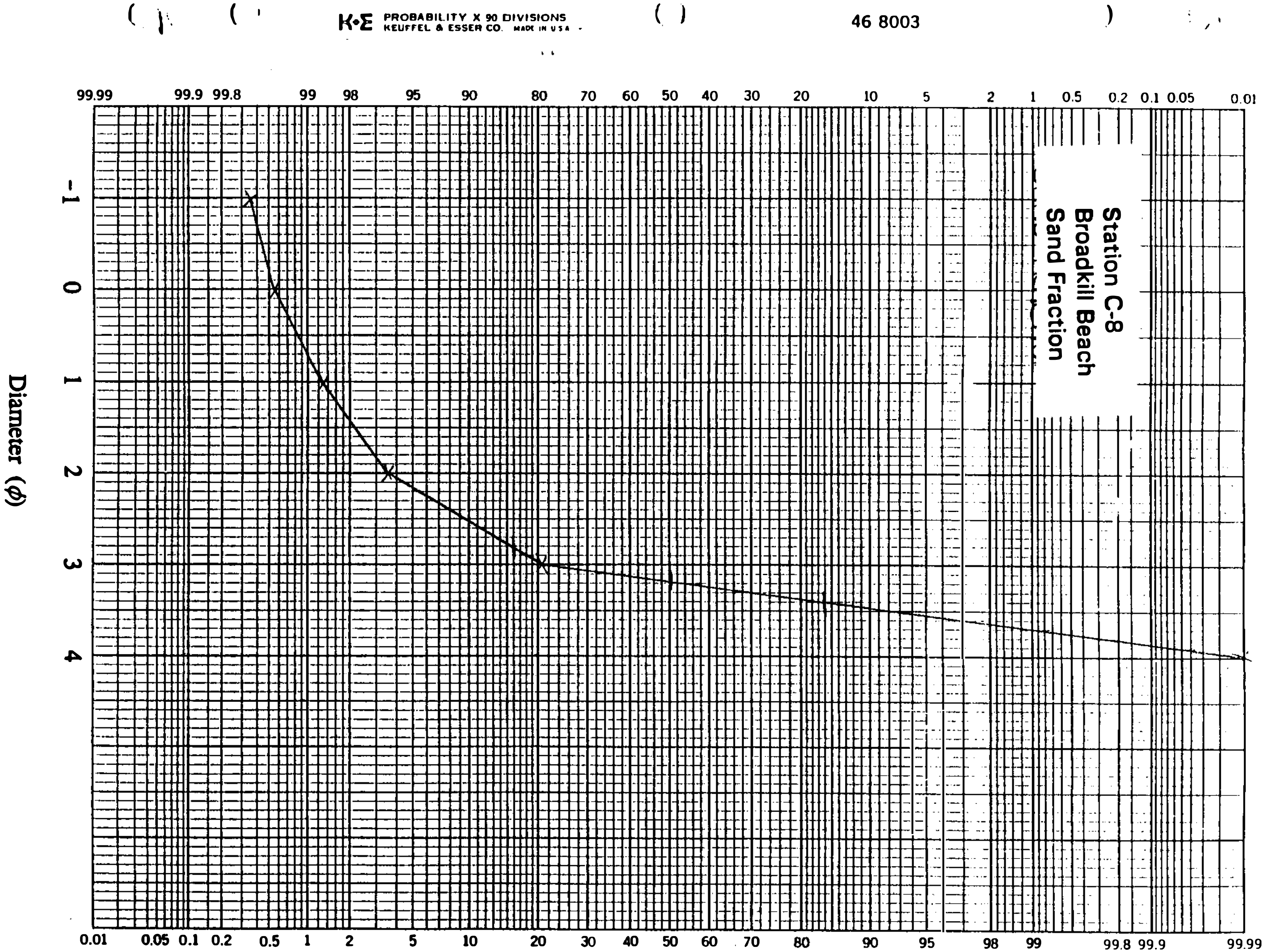

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station C-4
Broadkill Beach
Sand Fraction
Diameter (ϕ)
-1
0
1
2
3
4
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99


K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station C-5
Broadkill Beach
Sand Fraction
Diameter (ϕ)
-1
0
1
2
3
4


Station C-6
Broadkill Beach
Sand Fraction
K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Diameter (ϕ)

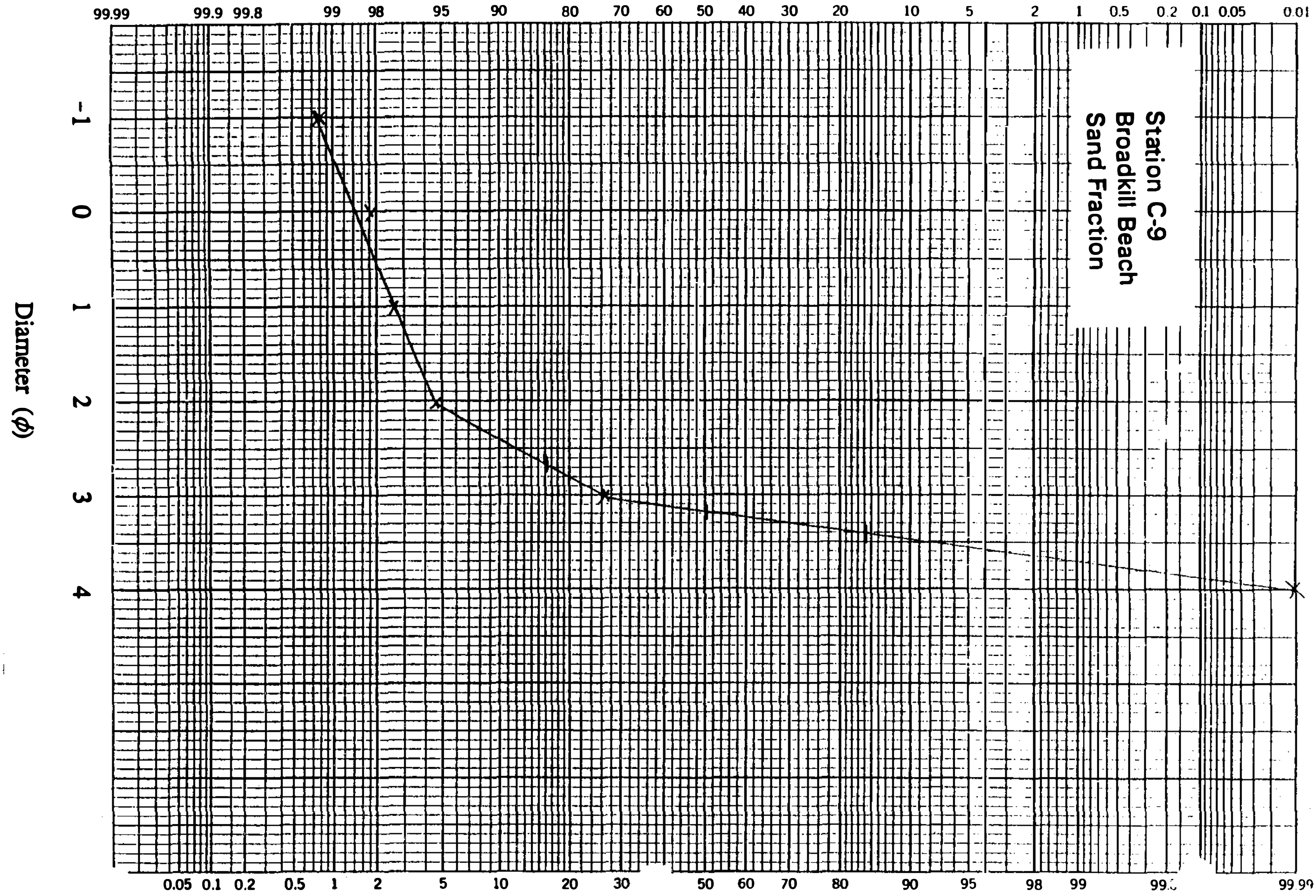


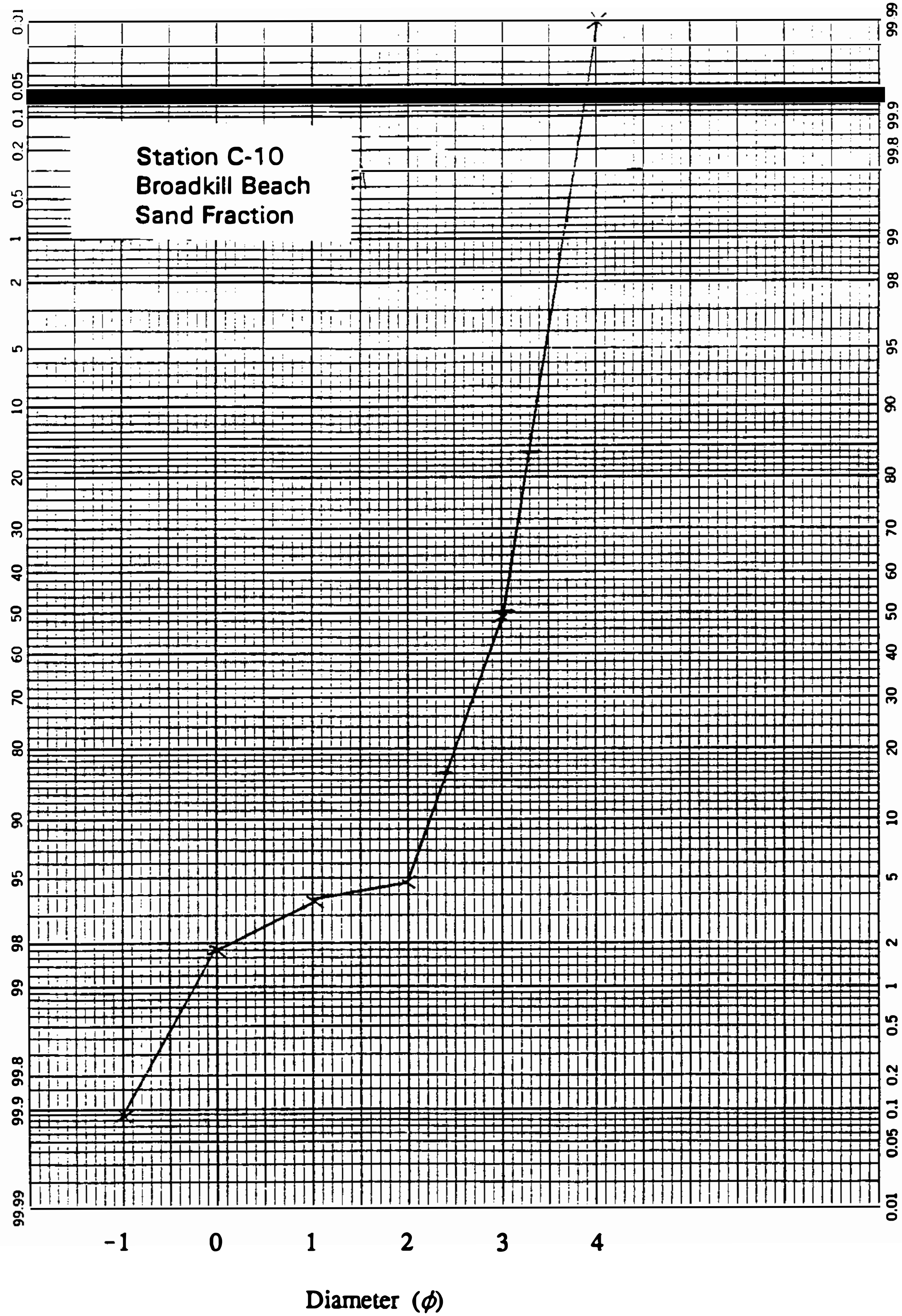
Station C-7
Broadkill Beach
Sand Fraction
46 8003
K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
-1
0
1
2
3
4
Diameter (φ)


K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8003
Station C-8
Broadkill Beach
Sand Fraction
Diameter (φ)
-1
0
1
2
3
4
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99

K•E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8003




Station C-10
Broadkill Beach
Sand Fraction
Diameter (ϕ)

APPENDIX D
MACROFAUNAL DATA

COMPREHENSIVE LIST OF MACROBENTHIC INVERTEBRATES IDENTIFIED FROM SAMPLES COLLECTED OFF BROADKILL BEACH, DELAWARE IN JULY 1-2, 1994

Identifications Performed by Cove Corporation
in August 1994

- P. Cnidaria
    - C. Anthozoa
        - F. Cerianthidae
            - *Ceriantheopsis americanus*
        - Anthozoa
- P. Nemertinea
    - Nemertinea
- P. Platyhelminthes
    - C. Turbellaria
        - Turbellaria
- P. Annelida
    - C. Oligochaeta
        - Oligochaeta
    - C. Polychaeta
        - F. Ampharetidae
            - *Ampharete arctica*
            - *Asabellides oculata*
            - Ampharetidae
        - F. Arabellidae
            - *Drilonereis longa*
            - *Notocirrus spiniferus*
        - F. Capitellidae
            - *Amastigos caperatus*
            - *Heteromastus filiformis*
            - *Mediomastus ambiseta*
            - Capitellidae
        - F. Chaetopteridae
            - *Spiochaetopterus costarum*
        - F. Cirratulidae
            - *Aphelochaeta* sp.
            - *Caulleriella* sp. A
            - *Monticellina* sp.
            - *Tharyx* sp. A
            - Cirratulidae
        - F. Dorvilleidae
            - *Parougia caeca*
        - F. Flabelligeridae
            - *Pherusa affinis*
        - F. Glyceridae
            - *Glycera americana*
            - *Glycera dibranchiata*
            - *Glycera* spp.
        - F. Goniadidae
            - *Glycinde solitaria*
            - Goniadidae
        - F. Hesionidae
            - *Microphthalmus sczelkowii*
            - *Microphthalmus* sp.
            - *Podarkeopsis levifuscina*
        - F. Lumbrineridae
            - *Scoletoma tenuis*

F. Magelonidae
- *Magelona* sp.

F. Maldanidae
- *Clymenella torquata*
- Maldanidae

F. Nephytidae
- *Nephtys bucera*
- *Nephtys incisa*
- *Nephtys picta*
- Nephytidae

F. Nereididae
- *Neanthes arenaceodentata*
- *Neanthes succinea*

F. Onuphidae
- *Diopatra cuprea*

F. Opheliidae
- *Travisia* sp. A
- Opheliidae

F. Orbiniidae
- *Leitoscoloplos* cf. *fragilis*
- *Leitoscoloplos robustus*
- *Leitoscoloplos* spp.
- *Scoloplos rubra*
- *Scoloplos* sp.

F. Oweniidae
- *Owenia fusiformis*

F. Paraonidae
- *Aricidea* (*Acmira*) *catherinae*
- *Aricidea* (*Acmira*) *cerrutii*
- *Aricidea* spp.
- *Cirrophorus* sp. B
- *Levinsenia* sp. A
- *Paradoneis* sp. A
- *Paraonis pygoenigmatica*
- *Paraonis fulgens*
- *Paraonis* spp.
- Paraonidae

F. Pectinariidae
- *Pectinaria gouldii*

F. Phyllodocidae
- *Eumida sanguinea*
- *Hypereteone heteropoda*
- *Paranaitis speciosa*

F. Pilargiidae
- *Ancistrosyllis hartmanae*

F. Polygordiidae
- *Polygordius* sp.

F. Polynoidae
- *Lepidonotus sublevis*

F. Sabellaridae
- *Sabellaria vulgaris*

F. Sabellidae
- Sabellidae

F. Serpulidae
- *Hydroides dianthus*

F. Sigalionidae
- *Sigalion arenicola*

- F. Spionidae
  - *Carazziella hobsonae*
  - *Dispio uncinata*
  - *Polydora cornuta*
  - *Polydora socialis*
  - *Scolelepis squamata*
  - *Scolelepis* sp.
  - *Spio setosa*
  - *Spiophanes bombyx*
  - *Streblospio benedicti*
- F. Syllidae
  - *Brania wellfleetensis*
  - *Parapionosyllis longicirrata*
  - *Proceraea cornuta*
  - *Sphaerosyllis taylori*
  - *Streptosyllis pettiboneae*
  - Syllidae
- F. Terebellidae
  - *Polycirrus* sp.
  - Terebellidae

- P. Mollusca
  - C. Bivalvia
    - F. Arcidae
      - *Anadara ovalis*
    - F. Caritidae
      - *Cyclocardia borealis*
    - F. Lasaeidae
      - *Aligena elevata*
    - F. Lyonsiidae
      - *Lyonsia arenosa*
      - *Lyonsia* sp.
    - F. Mactridae
      - *Mulinia lateralis*
      - *Spisula solidissima*
    - F. Montacutidae
      - *Mysella planulata*
    - F. Mytilidae
      - *Mytilus edulis*
    - F. Nuculanidae
      - *Yoldia limatula*
      - *Yoldia* sp.
    - F. Nuculidae
      - *Nucula annulata*
    - F. Pandoridae
      - *Pandora goudiana*
      - *Pandora* sp.
    - F. Solecurtidae
      - *Tagelus divisus*
    - F. Solenidae
      - *Ensis directus*
    - F. Tellinidae
      - *Tellina agilis*
    - F. Veneridae
      - *Gemma gemma*
    - Bivalvia
  - C. Gastropoda
    - F. Acteonidae
      - *Acteon punctostriatus*

F. Calyptraeidae
Crepidula convexa
Crepidula sp.
F. Columbellidae
Astyris lunata
F. Naticidae
Naticidae
F. Nassariidae
Nassarius trivittatus
F. Melongenidae
Busycon carica
Busycon sp.
F. Pyramidellidae
Odostomis sp.
Turbonilla interrupta
F. Scaphandridae
Acteocina canaliculata
Gastropoda
P. Arthropoda
Subphylum Chelicerata
C. Merostomata
F. Limulidae
Limulus polyphemus
Subphylum Crustacea
C. Malacostraca
O. Amphipoda
F. Ampeliscidae
Ampelisca abdita
Ampelisca verrilli
Ampelisca spp.
F. Aoridae
Unciola dissimilis
Unciola serrata
Unciola spp.
F. Bateidae
Batea catharinensis
F. Caprellidae
Paracaprella tenuis
F. Corophiidae
Corophium tuberculatum
Corophium sp.
F. Gammaridae
Mucrogammarus mucronatus
F. Haustoriidae
Acanthohaustorius millsi
Acanthohaustorius similis
Acanthohaustorius spp.
Protohaustoruius wigleyi
F. Isaeidae
Microprotopus raneyi
F. Ischyroceridae
Cerapus tubularis
Ericthonius brasiliensis
F. Liljeborgiidae
Listriella barnardi
Listriella smithi
Listriella spp.

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F. Phoxocephalidae
Rhepoxynius hudsoni
F. Stenothoidae
Parametopella cypris
O. Cumacea
F. Diastylidae
Oxyurostylis smithi
F. Leuconidae
Leucon americanus
O. Isopoda
F. Anthuridae
Amakusanthura magnifica
Cyathura burbancki
F. Idoteidae
Chiridotea sp.
Edotea triloba
F. Sphaeromatidae
Ancinus depressus
O. Mysidacea
F. Mysidae
Neomysis americana
O. Tanaidacea
F. Nototanaidae
Tanaissus psammophilus
O. Decapoda
InfraO. Anomura
F. Paguridae
Pagurus longicarpus
Pagurus sp.
Thalassinidea
InfraO. Brachyura
F. Pinnotheridae
Pinnixa chaetopterana
Pinnixa sayana
Pinnixa spp.
F. Majidae
Libinia emarginata
F. Xanthidae
Dyspanopeus sayi
InfraO. Caridea
F. Crangonidae
Crangon septemspinosa
P. Echinodermata
C. Holothuroidea
F. Synaptidae
Leptosynapta tenuis
Holothuroidea
C. Ophiuroidea
Ophiuroidea
P. Hemichordata
C. Enteropneusta
F. Harrimaniidae
Saccoglossus kowalevskii
P. Chordata
SubP. Urochordata
C. Ascidiacea
F. Molgulidae
Molgula arenata

F. Styelidae
 Cnemidocarpa mollis
Ascidiacea

STUDY SITE = BROADKILL BEACH, DE
STATION = A-1
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	2	0	2
ANNELIDA			
Spiophanes bombyx	13	0	13
Oligochaeta	10	0	10
Scolelepis (S.) squamata	4	0	4
Brania wellfleetensis	3	0	3
Nephtys bucera	0	2	2
Caulleriella sp. A	2	0	2
Travisia sp. A	2	0	2
Scoloplos sp.	1	0	1
Leitoscoloplos spp.	1	0	1
Levinsenia sp. A	1	0	1
Dispio uncinata	0	1	1
Hypereteone heteropoda	1	0	1
Streptosyllis pettiboneae	1	0	1
GASTROPODA			
Gastropoda	2	0	2
BIVALVIA			
Gemma gemma	676	0	676
Tellina agilis	5	0	5
Spisula solidissima	3	0	3
Pandora gouldiana	1	0	1
Cyclocardia borealis	1	0	1
CRUSTACEA			
Protohaustorius wigleyi	64	0	64
Tanaissus psammophilus	55	0	55
Acanthohaustorius spp.	29	0	29
Acanthohaustorius millsi	18	0	18
Acanthohaustorius similis	17	0	17
Rhepoxynius hudsoni	1	0	1
Amakusanthura magnifica	1	0	1
UROCHORDATA			
Ascidiacea	77	0	77
Molgula arenata	5	0	5
Cnemidocarpa mollis	1	0	1

TOTAL NUMBER OF TAXA	30
TOTAL NUMBER OF INDIVIDUALS	1000
SHANNON-WEINER DIVERSITY	1.392
SIMPSON'S DOMINANCE INDEX	0.472
SPECIES RICHNESS	4.20
EVENNESS	0.41

STUDY SITE = BROADKILL BEACH, DE
STATION = A-2
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	7	0	7
ANNELIDA			
Oligochaeta	197	0	197
Brania wellfleetensis	34	0	34
Parapionosyllis longicirrata	20	0	20
Polygordius sp.	9	0	9
Polydora cornuta	8	0	8
Polycirrus sp.	6	0	6
Amastigos caperatus	2	0	2
Sphaerosyllis taylori	2	0	2
Scolelepis spp.	1	0	1
Leitoscoloplos cf. fragilis	0	1	1
Ampharetidae	1	0	1
Glycera dibranchiata	0	1	1
Aricidea (Acmira) catherinae	1	0	1
Diopatra cuprea	0	1	1
Nephtys picta	1	0	1
Paraonis fulgens	1	0	1
GASTROPODA			
Crepidula spp.	4	0	4
BIVALVIA			
Gemma gemma	358	0	358
Cyclocardia borealis	4	0	4
Lyonsia sp.	2	0	2
Tellina agilis	1	0	1
Anadara ovalis	1	0	1
CRUSTACEA			
Rhepoxynius hudsoni	4	0	4
Amakusanthura magnifica	3	0	3
Ancinus depressus	3	0	3
Edotea triloba	2	0	2
Corophium tuberculatum	2	0	2
Neomysis americana	1	0	1
Ampelisca abdita	1	0	1
Leucon americanus	1	0	1
Parametopella cypris	1	0	1
Listriella barnardi	1	0	1
Erichthonius brasiliensis	1	0	1

UROCHORDATA

Ascidiacea	101	0	101
Molgula arenata	1	0	1

TOTAL NUMBER OF TAXA	**36**
TOTAL NUMBER OF INDIVIDUALS	**785**
SHANNON-WEINER DIVERSITY	**1.719**
SIMPSON'S DOMINANCE INDEX	**0.291**
SPECIES RICHNESS	**5.25**
EVENNESS	**0.48**

STUDY SITE = BROADKILL BEACH, DE
STATION = A-3
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	5	0	5
ANNELIDA			
Oligochaeta	122	0	122
Travisia sp. A	35	0	35
Brania wellfleetensis	22	0	22
Aricidea (Acimira) cerrutii	12	0	12
Streptosyllis pettiboneae	10	0	10
Paradoneis sp. A	10	0	10
Paraonis pygoenigmatica	4	0	4
Notocirrus spiniferus	0	3	3
Caulleriella sp. A	1	1	2
Aphelochaeta sp.	1	0	1
Sphaerosyllis taylori	1	0	1
Opheliidae	1	0	1
Neanthes arenaceodentata	1	0	1
Spiophanes bombyx	1	0	1
Scoloplos rubra	1	0	1
BIVALVIA			
Gemma gemma	6328	0	6328
Cyclocardia borealis	54	0	54
Tellina agilis	2	0	2
Lyonsia sp.	2	0	2
Spisula solidissima	1	0	1
CRUSTACEA			
Protohaustorius wigleyi	8	0	8
Acanthohaustorius millsi	6	0	6
Acanthohaustorius spp.	6	0	6
Ampelisca verrilli	1	0	1
Neomysis americana	1	0	1
Ampelisca abdita	1	0	1
UROCHORDATA			
Ascidiacea	195	0	195

TOTAL NUMBER OF TAXA	28
TOTAL NUMBER OF INDIVIDUALS	6836
SHANNON-WEINER DIVERSITY	0.412
SIMPSON'S DOMINANCE INDEX	0.858
SPECIES RICHNESS	3.06
EVENNESS	0.12

STUDY SITE = BROADKILL BEACH, DE
STATION = A-4
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	5	0	5
ANNELIDA			
Oligochaeta	511	0	511
Parapionosyllis longicirrata	97	0	97
Sabellaria vulgaris	70	0	70
Spiophanes bombyx	66	0	66
Brania wellfleetensis	49	0	49
Polydora cornuta	33	0	33
Mediomastus ambiseta	29	0	29
Caulleriella sp. A	15	0	15
Polygordius sp.	14	0	14
Amastigos caperatus	10	0	10
Glycera dibranchiata	0	8	8
Aricidea (Acmira) catherinae	6	0	6
Glycera spp.	4	0	4
Terebellidae	3	0	3
Aphelochaeta sp.	3	0	3
Cirrophorus sp. B	3	0	3
Eumida sanguinea	2	0	2
Scoloplos rubra	1	0	1
Podarkeopsis levifuscina	1	0	1
Maldanidae	1	0	1
Nephtys picta	0	1	1
Polycirrus sp.	1	0	1
Sphaerosyllis taylori	1	0	1
Spio setosa	1	0	1
Proceraea cornuta	1	0	1
GASTROPODA			
Astyris lunata	5	0	5
Crepidula spp.	3	0	3
Crepidula convexa	2	0	2
BIVALVIA			
Gemma gemma	46	0	46
Tellina agilis	9	0	9
Ensis directus	0	5	5
Spisula solidissima	2	0	2
CRUSTACEA			
Corophium tuberculatum	35	0	35
Amakusanthura magnifica	11	0	11
Ancinus depressus	3	0	3
Ampelisca verrilli	3	0	3

Parametopella cypris	3	0	3
Paracaprella tenuis	3	0	3
Pagurus longicarpus	2	0	2
Unciola spp.	2	0	2
Edotea triloba	2	0	2
Libinia emarginata	1	0	1
Batea catharinensis	1	0	1
Ampelisca abdita	1	0	1
Mucrogammarus mucronatus	1	0	1
Listriella sp.	1	0	1
Dyspanopeus sayi	1	0	1
UROCHORDATA			
Ascidiacea	22	0	22

TOTAL NUMBER OF TAXA	**49**
TOTAL NUMBER OF INDIVIDUALS	**1100**
SHANNON-WEINER DIVERSITY	**2.262**
SIMPSON'S DOMINANCE INDEX	**0.239**
SPECIES RICHNESS	**6.85**
EVENNESS	**0.58**

STUDY SITE = BROADKILL BEACH, DE
STATION = A-5
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	4	0	4
ANNELIDA			
Amastigos caperatus	442	0	442
Oligochaeta	96	0	96
Spio setosa	51	0	51
Brania wellfleetensis	42	0	42
Parapionosyllis longicirrata	25	0	25
Polydora cornuta	19	0	19
Aricidea (Acmira) catherinae	13	0	13
Spiophanes bombyx	13	0	13
Sabellidae	11	0	11
Maldanidae	6	0	6
Sabellaria vulgaris	6	0	6
Caulleriella sp. A	5	0	5
Glycera dibranchiata	0	3	3
Ampharete arctica	2	0	2
Leitoscoloplos spp.	2	0	2
Ampharetidae	2	0	2
Heteromastus filiformis	1	0	1
Clymenella torquata	1	0	1
Glycera spp.	1	0	1
Leitoscoloplos robustus	0	1	1
GASTROPODA			
Crepidula spp.	7	0	7
Odostomia sp.	5	0	5
Astyris lunata	1	0	1
Busycon spp.	1	0	1
BIVALVIA			
Tellina agilis	158	0	158
Nucula annulata	23	0	23
Gemma gemma	7	0	7
Ensis directus	0	2	2
Spisula solidissima	1	0	1
Bivalvia	1	0	1
CRUSTACEA			
Ampelisca verrilli	10	0	10
Neomysis americana	4	0	4
Ampelisca abdita	4	0	4
Corophium tuberculatum	3	0	3
Unciola dissimilis	2	0	2
Unciola spp.	2	0	2

Oxyurostylis smithi	1	0	1
Batea catharinensis	1	0	1
Parametopella cypris	1	0	1

TOTAL NUMBER OF TAXA	**40**
TOTAL NUMBER OF INDIVIDUALS	**980**
SHANNON-WEINER DIVERSITY	**2.083**
SIMPSON'S DOMINANCE INDEX	**0.246**
SPECIES RICHNESS	**5.66**
EVENNESS	**0.56**

STUDY SITE = BROADKILL BEACH, DE
STATION = A-6
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	6	0	6
ANNELIDA			
Oligochaeta	315	0	315
Amastigos caperatus	243	0	243
Brania wellfleetensis	63	0	63
Spiophanes bombyx	23	0	23
Polydora cornuta	21	0	21
Parapionosyllis longicirrata	12	0	12
Aricidea (Acmira) catherinae	12	0	12
Mediomastus ambiseta	8	0	8
Spio setosa	8	0	8
Glycera dibranchiata	0	4	4
Sabellaria vulgaris	4	0	4
Microphthalmus sczelkowii	3	0	3
Sphaerosyllis taylori	3	0	3
Maldanidae	3	0	3
Sabellidae	3	0	3
Caulleriella sp. A	3	0	3
Carazziella hobsonae	3	0	3
Polygordius sp.	3	0	3
Leitoscoloplos spp.	0	2	2
Heteromastus filiformis	2	0	2
Streptosyllis pettiboneae	2	0	2
Leitoscoloplos robustus	0	1	1
Capitellidae	1	0	1
Neanthes arenaceodentata	1	0	1
Cirrophorus sp. B	1	0	1
GASTROPODA			
Crepidula spp.	8	0	8
BIVALVIA			
Tellina agilis	35	0	35
Gemma gemma	33	0	33
Ensis directus	2	0	2
Spisula solidissima	2	0	2
Lyonsia sp.	2	0	2
Nucula annulata	1	0	1
CRUSTACEA			
Ampelisca verrilli	25	0	25
Corophium tuberculatum	7	0	7
Unciola spp.	4	0	4
Listriella sp.	3	0	3

Cerapus tubularis	2	0	2
Parametopella cypris	2	0	2
Pinnixa chaetopterana	2	0	2
Crangon septemspinosa	0	2	2
Ampelisca abdita	2	0	2
Listriella barnardi	2	0	2
Unciola dissimilis	2	0	2
Thalassinidea	1	0	1

TOTAL NUMBER OF TAXA	**45**
TOTAL NUMBER OF INDIVIDUALS	**887**
SHANNON-WEINER DIVERSITY	**2.212**
SIMPSON'S DOMINANCE INDEX	**0.212**
SPECIES RICHNESS	**6.48**
EVENNESS	**0.58**

STUDY SITE = BROADKILL BEACH, DE
STATION = A-7
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	2	0	2
ANNELIDA			
Amastigos caperatus	582	0	582
Oligochaeta	409	0	409
Sabellaria vulgaris	72	0	72
Brania wellfleetensis	45	0	45
Parapionosyllis longicirrata	38	0	38
Polydora cornuta	32	0	32
Caulleriella sp. A	26	0	26
Mediomastus ambiseta	7	0	7
Polydora socialis	4	0	4
Spio setosa	4	0	4
Microphthalmus sczelkowii	3	0	3
Glycera dibranchiata	0	3	3
Hydroides dianthus	3	0	3
Aricidea (Acmira) catherinae	2	0	2
Scoloplos rubra	2	0	2
Parougia caeca	2	0	2
Glycera americana	2	0	2
Hypereteone heteropoda	1	0	1
Maldanidae	1	0	1
Scoletoma tenuis	1	0	1
Leitoscoloplos robustus	0	1	1
Heteromastus filiformis	1	0	1
Streptosyllis pettiboneae	1	0	1
Proceraea cornuta	1	0	1
Leitoscoloplos spp.	1	0	1
Neanthes succinea	0	1	1
Nephtys picta	0	1	1
GASTROPODA			
Crepidula spp.	13	0	13
Gastropoda	3	0	3
Astyris lunata	1	0	1
Odostomia sp.	1	0	1
BIVALVIA			
Tellina agilis	67	0	67
Nucula annulata	13	0	13
Gemma gemma	7	0	7
Ensis directus	2	3	5

CRUSTACEA

Corophium tuberculatum	8	0	8
Batea catharinensis	7	0	7
Pagurus spp.	6	0	6
Unciola spp.	6	0	6
Parametopella cypris	5	0	5
Unciola dissimilis	5	0	5
Unciola serrata	3	0	3
Pagurus longicarpus	2	0	2
Ampelisca abdita	2	0	2
Neomysis americana	2	0	2
Oxyurostylis smithi	1	0	1
Ampelisca verrilli	1	0	1
Listriella sp.	1	0	1
Listriella barnardi	1	0	1

TOTAL NUMBER OF TAXA	50
TOTAL NUMBER OF INDIVIDUALS	1408
SHANNON-WEINER DIVERSITY	1.946
SIMPSON'S DOMINANCE INDEX	0.263
SPECIES RICHNESS	6.76
EVENNESS	0.50

STUDY SITE = BROADKILL BEACH, DE
STATION = A-8
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
PLATYHELMINTHES			
Turbellaria	1	0	1
NEMERTINEA			
Nemertinea	6	0	6
ANNELIDA			
Oligochaeta	440	0	440
Brania wellfleetensis	31	0	31
Parapionosyllis longicirrata	25	0	25
Spiophanes bombyx	21	0	21
Paradoneis sp. A	9	0	9
Polygordius sp.	4	0	4
Sphaerosyllis taylori	3	0	3
Polycirrus sp.	3	0	3
Amastigos caperatus	3	0	3
Neanthes arenaceodentata	2	0	2
Scoletoma tenuis	2	0	2
Nephtys bucera	0	2	2
Notocirrus spiniferus	1	0	1
Cirratulidae	1	0	1
Streptosyllis pettiboneae	1	0	1
Sabellaria vulgaris	1	0	1
Aricidea (Acimira) cerrutii	1	0	1
Polydora cornuta	1	0	1
BIVALVIA			
Gemma gemma	354	0	354
Cyclocardia borealis	3	0	3
Tellina agilis	2	0	2
Lyonsia sp.	1	0	1
Mysella planulata	1	0	1
CRUSTACEA			
Tanaissus psammophilus	6	0	6
Protohaustorius wigleyi	5	0	5
Listriella barnardi	4	0	4
Pinnixa chaetopterana	3	0	3
Acanthohaustorius similis	1	0	1
Acanthohaustorius spp.	1	0	1
Rhepoxynius hudsoni	1	0	1
Pagurus spp.	1	0	1
Amakusanthura magnifica	1	0	1
Ancinus depressus	1	0	1

HEMICHORDATA			
Saccoglossus kowalevskii	2	0	2
UROCHORDATA			
Ascidiacea	45	0	45

TOTAL NUMBER OF TAXA	**37**
TOTAL NUMBER OF INDIVIDUALS	**990**
SHANNON-WEINER DIVERSITY	**1.583**
SIMPSON'S DOMINANCE INDEX	**0.330**
SPECIES RICHNESS	**5.22**
EVENNESS	**0.44**

STUDY SITE = BROADKILL BEACH, DE
STATION = A-9
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	3	1	4
ANNELIDA			
Oligochaeta	74	0	74
Spiophanes bombyx	13	0	13
Polygordius sp.	9	0	9
Sphaerosyllis taylori	5	0	5
Streptosyllis pettiboneae	3	0	3
Paraonis fulgens	2	0	2
Brania wellfleetensis	2	0	2
Nephtys picta	1	1	2
Nephtys bucera	0	1	1
Travisia sp. A	1	0	1
Cirrophorus sp. B	1	0	1
Scolelepis (S.) squamata	1	0	1
Maldanidae	1	0	1
Leitoscoloplos spp.	0	1	1
Paraonidae	1	0	1
Magelona sp.	1	0	1
BIVALVIA			
Gemma gemma	1179	0	1179
Tellina agilis	13	0	13
Spisula solidissima	4	0	4
Cyclocardia borealis	2	0	2
Lyonsia sp.	1	0	1
Ensis directus	0	1	1
CRUSTACEA			
Protohaustorius wigleyi	21	0	21
Acanthohaustorius spp.	12	0	12
Tanaissus psammophilus	6	0	6
Rhepoxynius hudsoni	4	0	4
Acanthohaustorius similis	3	0	3
Pinnixa chaetopterana	3	0	3
Acanthohaustorius millsi	2	0	2
Ampelisca verrilli	1	0	1
Pagurus spp.	1	0	1
Ampelisca abdita	1	0	1
ECHINODERMATA			
Leptosynapta tenuis	0	1	1
Ophiuroidea	0	present	0

HEMICHORDATA			
Saccoglossus kowalevskii	1	0	1
UROCHORDATA			
Ascidiacea	231	0	231
Molgula arenata	1	0	1
TOTAL NUMBER OF TAXA	37		
TOTAL NUMBER OF INDIVIDUALS	1610		
SHANNON-WEINER DIVERSITY	1.082		
SIMPSON'S DOMINANCE INDEX	0.559		
SPECIES RICHNESS	4.88		
EVENNESS	0.30		

STUDY SITE = BROADKILL BEACH, DE
STATION = A-10
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Anthozoa	1	0	1
ANNELIDA			
Oligochaeta	34	0	34
Streptosyllis pettiboneae	4	0	4
Sigalion arenicola	1	3	4
Polygordius sp.	3	0	3
Brania wellfleetensis	2	0	2
Parapionosyllis longicirrata	2	0	2
Caulleriella sp. A	2	0	2
Dispio uncinata	0	2	2
Spiophanes bombyx	1	0	1
Paraonis spp.	1	0	1
Cirrophorus sp. B	1	0	1
Magelona sp.	1	0	1
Sabellaria vulgaris	1	0	1
Sphaerosyllis taylori	1	0	1
Amastigos caperatus	1	0	1
Paradoneis sp. A	1	0	1
Maldanidae	1	0	1
Paraonis fulgens	1	0	1
GASTROPODA			
Busycon spp.	1	0	1
BIVALVIA			
Gemma gemma	5592	0	5592
Tellina agilis	15	0	15
Cyclocardia borealis	12	0	12
Spisula solidissima	3	0	3
CRUSTACEA			
Protohaustorius wigleyi	51	0	51
Acanthohaustorius spp.	26	0	26
Tanaissus psammophilus	16	0	16
Acanthohaustorius similis	13	0	13
Acanthohaustorius millsi	11	0	11
Rhepoxynius hudsoni	5	0	5
Neomysis americana	2	0	2
Pagurus longicarpus	1	0	1
Amakusanthura magnifica	1	0	1

UROCHORDATA

Ascidiacea	523	0	523
Molgula arenata	3	0	3

TOTAL NUMBER OF TAXA	**35**
TOTAL NUMBER OF INDIVIDUALS	**6339**
SHANNON-WEINER DIVERSITY	**0.529**
SIMPSON'S DOMINANCE INDEX	**0.785**
SPECIES RICHNESS	**3.88**
EVENNESS	**0.15**

STUDY SITE = BROADKILL BEACH, DE
STATION = A-11
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	2	1	3
ANNELIDA			
Brania wellfleetensis	11	0	11
Oligochaeta	11	0	11
Caulleriella sp. A	7	0	7
Scolelepis (S.) squamata	4	0	4
Spio setosa	0	2	2
Streptosyllis pettiboneae	2	0	2
Nephtys bucera	0	1	1
Drilonereis longa	0	1	1
Travisia sp. A	1	0	1
BIVALVIA			
Gemma gemma	4085	0	4085
Spisula solidissima	7	0	7
Tellina agilis	3	0	3
Cyclocardia borealis	2	0	2
CRUSTACEA			
Protohaustorius wigleyi	112	0	112
Tanaissus psammophilus	53	0	53
Acanthohaustorius spp.	32	0	32
Acanthohaustorius millsi	25	0	25
Acanthohaustorius similis	4	0	4
Oxyurostylis smithi	1	0	1
Crangon septemspinosa	1	0	1
Chiridotea sp.	1	0	1
Ampelisca verrilli	1	0	1
UROCHORDATA			
Ascidiacea	57	0	57
Molgula arenata	2	0	2

TOTAL NUMBER OF TAXA	**25**
TOTAL NUMBER OF INDIVIDUALS	**4429**
SHANNON-WEINER DIVERSITY	**0.441**
SIMPSON'S DOMINANCE INDEX	**0.852**
SPECIES RICHNESS	**2.86**
EVENNESS	**0.14**

STUDY SITE = BROADKILL BEACH, DE
STATION = A-12
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	3	0	3
ANNELIDA			
Oligochaeta	1514	0	1514
Parapionosyllis longicirrata	52	0	52
Brania wellfleetensis	46	0	46
Amastigos caperatus	38	0	38
Mediomastus ambiseta	10	0	10
Caulleriella sp. A	9	0	9
Aricidea (Acmira) catherinae	8	0	8
Sphaerosyllis taylori	6	0	6
Polycirrus sp.	4	0	4
Glycera dibranchiata	0	3	3
Microphthalmus sczelkowii	2	0	2
Lepidonotus sublevis	1	0	1
Polydora cornuta	1	0	1
Scoloplos rubra	1	0	1
Streptosyllis pettiboneae	1	0	1
Spiophanes bombyx	1	0	1
GASTROPODA			
Astyris lunata	1	0	1
Acteocina canaliculata	1	0	1
BIVALVIA			
Gemma gemma	267	0	267
Tellina agilis	25	0	25
Cyclocardia borealis	4	0	4
Spisula solidissima	3	0	3
Lyonsia spp.	2	0	2
CRUSTACEA			
Pinnixa spp.	4	0	4
Listriella barnardi	3	0	3
Ampelisca verrilli	2	0	2
Pagurus longicarpus	1	0	1
Ampelisca abdita	1	0	1
Pagurus spp.	1	0	1
UROCHORDATA			
Ascidiacea	81	0	81

TOTAL NUMBER OF TAXA	31
TOTAL NUMBER OF INDIVIDUALS	2096
SHANNON-WEINER DIVERSITY	1.141
SIMPSON'S DOMINANCE INDEX	0.541
SPECIES RICHNESS	3.92
EVENNESS	0.33

STUDY SITE = BROADKILL BEACH, DE
STATION = A-13
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	2	0	2
ANNELIDA			
Oligochaeta	479	0	479
Amastigos caperatus	127	0	127
Parapionosyllis longicirrata	54	0	54
Brania wellfleetensis	37	0	37
Aricidea (Acmira) catherinae	17	0	17
Polydora cornuta	12	0	12
Caulleriella sp. A	8	0	8
Glycera dibranchiata	0	7	7
Maldanidae	6	0	6
Spiophanes bombyx	6	0	6
Nephtys picta	0	5	5
Spio setosa	4	0	4
Streptosyllis pettiboneae	4	0	4
Polycirrus sp.	4	0	4
Clymenella torquata	3	0	3
Cirrophorus sp. B	3	0	3
Sabellaria vulgaris	2	0	2
Mediomastus ambiseta	2	0	2
Glycera spp.	2	0	2
Sphaerosyllis taylori	2	0	2
Streblospio benedicti	1	0	1
Leitoscoloplos robustus	0	1	1
Heteromastus filiformis	1	0	1
Ancistrosyllis hartmanae	1	0	1
Scoloplos rubra	0	1	1
Nephtyidae	1	0	1
Microphthalmus spp.	1	0	1
GASTROPODA			
Crepidula spp.	2	0	2
Busycon spp.	1	0	1
Acteocina canaliculata	1	0	1
Odostomia sp.	1	0	1
BIVALVIA			
Gemma gemma	48	0	48
Tellina agilis	34	0	34
Lyonsia spp.	4	0	4
Spisula solidissima	4	0	4
Lyonsia arenosa	2	0	2
Ensis directus	2	0	2
Aligena elevata	1	0	1

CRUSTACEA			
Ampelisca verrilli	17	0	17
Ampelisca abdita	10	0	10
Neomysis americana	5	0	5
Listriella barnardi	4	0	4
Oxyurostylis smithi	2	0	2
Listriella smithi	1	0	1
Edotea triloba	1	0	1
Pagurus spp.	1	0	1
Ancinus depressus	1	0	1
UROCHORDATA			
Ascidiacea	14	0	14

TOTAL NUMBER OF TAXA	**49**
TOTAL NUMBER OF INDIVIDUALS	**949**
SHANNON-WEINER DIVERSITY	**2.079**
SIMPSON'S DOMINANCE INDEX	**0.283**
SPECIES RICHNESS	**7.00**
EVENNESS	**0.53**

STUDY SITE = BROADKILL BEACH, DE
STATION = A-14
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	8	0	8
ANNELIDA			
Oligochaeta	67	0	67
Amastigos caperatus	24	0	24
Brania wellfleetensis	13	0	13
Caulleriella sp. A	9	0	9
Parapionosyllis longicirrata	3	0	3
Nephtys picta	0	2	2
Polycirrus sp.	2	0	2
Cirrophorus sp. B	2	0	2
Leitoscoloplos robustus	0	1	1
Spiophanes bombyx	1	0	1
Polydora cornuta	1	0	1
Polygordius sp.	1	0	1
Glycera dibranchiata	0	1	1
BIVALVIA			
Gemma gemma	87	0	87
Tellina agilis	83	0	83
Spisula solidissima	2	0	2
Cyclocardia borealis	1	0	1
CRUSTACEA			
Pinnixa spp.	4	0	4
Ampelisca verrilli	4	0	4
Rhepoxynius hudsoni	3	0	3
Amakusanthura magnifica	2	0	2
Pinnixa sayana	2	0	2
Corophium spp.	1	0	1
Edotea triloba	1	0	1
Neomysis americana	1	0	1
UROCHORDATA			
Ascidiacea	24	0	24

TOTAL NUMBER OF TAXA	**27**
TOTAL NUMBER OF INDIVIDUALS	**350**
SHANNON-WEINER DIVERSITY	**2.186**
SIMPSON'S DOMINANCE INDEX	**0.167**
SPECIES RICHNESS	**4.44**
EVENNESS	**0.66**

STUDY SITE = BROADKILL BEACH, DE
STATION = B-1
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Anthozoa	1	0	1
NEMERTINEA			
Nemertinea	1	0	1
ANNELIDA			
Amastigos caperatus	65	0	65
Oligochaeta	2	0	2
Spio setosa	1	0	1
Leitoscoloplos spp.	1	0	1
Glycera dibranchiata	0	1	1
Glycinde solitaria	1	0	1
GASTROPODA			
Acteocina canaliculata	20	0	20
Odostomia sp.	10	0	10
Busycon spp.	1	0	1
BIVALVIA			
Tellina agilis	53	0	53
Mulinia lateralis	2	0	2
Gemma gemma	1	0	1
Lyonsia arenosa	1	0	1
Ensis directus	1	0	1
Spisula solidissima	1	0	1
CRUSTACEA			
Neomysis americana	16	0	16
Ampelisca verrilli	2	0	2
Leucon americanus	1	0	1
Edotea triloba	1	0	1
Ampelisca abdita	1	0	1

TOTAL NUMBER OF TAXA	22
TOTAL NUMBER OF INDIVIDUALS	184
SHANNON-WEINER DIVERSITY	1.882
SIMPSON'S DOMINANCE INDEX	0.231
SPECIES RICHNESS	4.03
EVENNESS	0.61

STUDY SITE = BROADKILL BEACH, DE
STATION = B-2
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	6	0	6
ANNELIDA			
Oligochaeta	21	0	21
Amastigos caperatus	10	0	10
Glycera americana	2	1	3
Leitoscoloplos spp.	2	0	2
Glycera spp.	2	0	2
Tharyx sp. A	1	0	1
GASTROPODA			
Acteocina canaliculata	16	0	16
Odostomia sp.	11	0	11
BIVALVIA			
Tellina agilis	210	0	210
Ensis directus	2	8	10
Nucula annulata	5	0	5
Lyonsia arenosa	3	0	3
Gemma gemma	3	0	3
Tagelus divisus	1	0	1
CRUSTACEA			
Ampelisca verrilli	50	0	50
Neomysis americana	29	0	29
Edotea triloba	2	0	2
Ampelisca abdita	2	0	2
Mucrogammarus mucronatus	1	0	1
Microprotopus raneyi	1	0	1

TOTAL NUMBER OF TAXA	**21**
TOTAL NUMBER OF INDIVIDUALS	**389**
SHANNON-WEINER DIVERSITY	**1.771**
SIMPSON'S DOMINANCE INDEX	**0.321**
SPECIES RICHNESS	**3.35**
EVENNESS	**0.58**

STUDY SITE = BROADKILL BEACH, DE
STATION = B-3
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Anthozoa	2	0	2
ANNELIDA			
Amastigos caperatus	144	0	144
Oligochaeta	114	0	114
Brania wellfleetensis	43	0	43
Caulleriella sp. A	12	0	12
Mediomastus ambiseta	6	0	6
Nephtys picta	2	3	5
Aricidea (Acmira) catherinae	4	0	4
Parapionosyllis longicirrata	4	0	4
Spiophanes bombyx	4	0	4
Polycirrus sp.	4	0	4
Microphthalmus spp.	1	0	1
Leitoscoloplos spp.	1	0	1
Nephtyidae	1	0	1
Drilonereis longa	0	1	1
Syllidae	1	0	1
Scoloplos rubra	0	1	1
GASTROPODA			
Odostomia sp.	5	0	5
Turbonilla interrupta	1	0	1
Busycon carica	0	1	1
BIVALVIA			
Tellina agilis	103	0	103
Gemma gemma	2	0	2
Ensis directus	1	0	1
CRUSTACEA			
Rhepoxynius hudsoni	13	0	13
Neomysis americana	3	0	3
Ampelisca abdita	2	0	2
Ancinus depressus	2	0	2
Pinnixa spp.	1	0	1

TOTAL NUMBER OF TAXA	28
TOTAL NUMBER OF INDIVIDUALS	482
SHANNON-WEINER DIVERSITY	1.996
SIMPSON'S DOMINANCE INDEX	0.201
SPECIES RICHNESS	4.37
EVENNESS	0.60

STUDY SITE = BROADKILL BEACH, DE
STATION = B-4
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
ANNELIDA			
Oligochaeta	224	0	224
Brania wellfleetensis	99	0	99
Amastigos caperatus	19	0	19
Scoloplos rubra	0	6	6
Capitellidae	2	0	2
Glycera dibranchiata	0	2	2
Aricidea (Acmira) catherinae	2	0	2
Parapionosyllis longicirrata	1	0	1
Glycinde solitaria	1	0	1
Mediomastus ambiseta	1	0	1
Polydora cornuta	1	0	1
Leitoscoloplos spp.	1	0	1
Pectinaria gouldii	0	1	1
Spio setosa	1	0	1
GASTROPODA			
Crepidula spp.	5	0	5
BIVALVIA			
Tellina agilis	52	0	52
Gemma gemma	7	0	7
Nucula annulata	6	0	6
Mulinia lateralis	4	0	4
Mytilus edulis	2	0	2
CRUSTACEA			
Ampelisca verrilli	4	0	4
Edotea triloba	3	0	3

TOTAL NUMBER OF TAXA	22
TOTAL NUMBER OF INDIVIDUALS	444
SHANNON-WEINER DIVERSITY	1.610
SIMPSON'S DOMINANCE INDEX	0.321
SPECIES RICHNESS	3.44
EVENNESS	0.52

STUDY SITE = BROADKILL BEACH, DE
STATION = B-5
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	7	0	7
ANNELIDA			
Oligochaeta	63	0	63
Leitoscoloplos spp.	13	0	13
Glycinde solitaria	4	0	4
Glycera americana	0	3	3
Microphthalmus sczelkowii	1	0	1
GASTROPODA			
Acteocina canaliculata	290	0	290
Turbonilla interrupta	7	0	7
Odostomia sp.	3	0	3
Naticidae	1	0	1
Acteon punctostriatus	1	0	1
BIVALVIA			
Nucula annulata	174	0	174
Tellina agilis	24	0	24
Mulinia lateralis	19	0	19
Yoldia limatula	18	0	18
Yoldia sp.	5	0	5
CRUSTACEA			
Ampelisca verrilli	6	0	6
Ampelisca spp.	3	0	3
Neomysis americana	3	0	3
Ampelisca abdita	1	0	1
Edotea triloba	1	0	1
Leucon americanus	1	0	1

TOTAL NUMBER OF TAXA	22
TOTAL NUMBER OF INDIVIDUALS	648
SHANNON-WEINER DIVERSITY	1.713
SIMPSON'S DOMINANCE INDEX	0.286
SPECIES RICHNESS	3.24
EVENNESS	0.55

STUDY SITE = BROADKILL BEACH, DE
STATION = B-6
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	8	0	8
ANNELIDA			
Amastigos caperatus	93	0	93
Glycera dibranchiata	1	1	2
Nephtys picta	1	1	2
Spiochaetopterus costarum	0	1	1
Scoloplos rubra	0	1	1
GASTROPODA			
Acteocina canaliculata	12	0	12
Odostomia sp.	8	0	8
Turbonilla interrupta	1	0	1
BIVALVIA			
Tellina agilis	64	0	64
Mulinia lateralis	2	0	2
Ensis directus	0	2	2
Mytilus edulis	1	0	1
CRUSTACEA			
Pinnixa chaetopterana	16	0	16
Ampelisca verrilli	11	0	11
Crangon septemspinosa	3	0	3
Neomysis americana	3	0	3
ECHINODERMATA			
Holothuroidea	0	1	1

TOTAL NUMBER OF TAXA	18
TOTAL NUMBER OF INDIVIDUALS	231
SHANNON-WEINER DIVERSITY	1.833
SIMPSON'S DOMINANCE INDEX	0.252
SPECIES RICHNESS	3.12
EVENNESS	0.63

STUDY SITE = BROADKILL BEACH, DE
STATION = B-7
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
ANNELIDA			
Oligochaeta	274	0	274
Mediomastus ambiseta	4	0	4
Leitoscoloplos robustus	0	1	1
Caulleriella sp. A	1	0	1
Scoloplos sp.	0	1	1
Monticellina sp.	1	0	1
Heteromastus filiformis	0	1	1
GASTROPODA			
Acteocina canaliculata	3	0	3
BIVALVIA			
Nucula annulata	43	0	43
Tellina agilis	12	0	12
Mulinia lateralis	4	0	4
Gemma gemma	2	0	2
Mytilus edulis	1	0	1
Bivalvia	1	0	1
CRUSTACEA			
Leucon americanus	46	0	46
Neomysis americana	3	0	3
Cerapus tubularis	3	0	3
Edotea triloba	3	0	3
Crangon septemspinosa	0	1	1

TOTAL NUMBER OF TAXA	19
TOTAL NUMBER OF INDIVIDUALS	405
SHANNON-WEINER DIVERSITY	1.235
SIMPSON'S DOMINANCE INDEX	0.483
SPECIES RICHNESS	3.00
EVENNESS	0.42

STUDY SITE = BROADKILL BEACH, DE
STATION = B-8
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	3	0	3
ANNELIDA			
Oligochaeta	192	0	192
Amastigos caperatus	7	0	7
Leitoscoloplos spp.	4	0	4
Glycera americana	1	0	1
Spiochaetopterus costarum	1	0	1
Maldanidae	0	1	1
Pectinaria gouldii	1	0	1
GASTROPODA			
Acteocina canaliculata	138	0	138
Turbonilla interrupta	11	0	11
Odostomia sp.	3	0	3
Acteon punctostriatus	2	0	2
BIVALVIA			
Nucula annulata	129	0	129
Mulinia lateralis	16	0	16
Yoldia limatula	14	1	15
Tellina agilis	6	0	6
Yoldia sp.	3	0	3
Mytilus edulis	1	0	1
CRUSTACEA			
Leucon americanus	5	0	5
Cerapus tubularis	2	0	2
Ampelisca verrilli	2	0	2
Edotea triloba	2	0	2

TOTAL NUMBER OF TAXA	**22**
TOTAL NUMBER OF INDIVIDUALS	**545**
SHANNON-WEINER DIVERSITY	**1.748**
SIMPSON'S DOMINANCE INDEX	**0.247**
SPECIES RICHNESS	**3.33**
EVENNESS	**0.57**

STUDY SITE = BROADKILL BEACH, DE
STATION = B-9
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	5	0	5
ANNELIDA			
Oligochaeta	52	0	52
Scoloplos rubra	3	6	9
Pectinaria gouldii	7	0	7
Leitoscoloplos spp.	5	0	5
Heteromastus filiformis	1	0	1
GASTROPODA			
Turbonilla interrupta	4	0	4
Acteocina canaliculata	4	0	4
BIVALVIA			
Tellina agilis	106	0	106
Nucula annulata	105	0	105
Mulinia lateralis	6	0	6
Gemma gemma	3	0	3
Ensis directus	0	1	1
Yoldia limatula	1	0	1
Mytilus edulis	1	0	1
CRUSTACEA			
Leucon americanus	16	0	16
Ampelisca abdita	4	0	4
Edotea triloba	2	0	2
Ampelisca verrilli	1	0	1
Crangon septemspinosa	1	0	1

TOTAL NUMBER OF TAXA	**20**
TOTAL NUMBER OF INDIVIDUALS	**334**
SHANNON-WEINER DIVERSITY	**1.876**
SIMPSON'S DOMINANCE INDEX	**0.229**
SPECIES RICHNESS	**3.27**
EVENNESS	**0.63**

STUDY SITE = BROADKILL BEACH, DE
STATION = B-10
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	15	0	15
ANNELIDA			
Amastigos caperatus	74	0	74
Mediomastus ambiseta	43	0	43
Leitoscoloplos spp.	7	0	7
Polydora cornuta	4	0	4
Oligochaeta	4	0	4
Glycinde solitaria	3	0	3
Spio setosa	2	0	2
Spiophanes bombyx	2	0	2
Ampharetidae	1	0	1
Tharyx sp. A	1	0	1
Nephtys picta	0	1	1
Proceraea cornuta	1	0	1
GASTROPODA			
Odostomia sp.	21	0	21
Acteocina canaliculata	13	0	13
Nassarius trivittatus	2	0	2
Turbonilla interrupta	1	0	1
BIVALVIA			
Tellina agilis	245	0	245
Mulinia lateralis	3	0	3
Ensis directus	0	2	2
Mytilus edulis	1	0	1
Yoldia limatula	1	0	1
Nucula annulata	1	0	1
Tagelus divisus	1	0	1
Lyonsia arenosa	1	0	1
CRUSTACEA			
Ampelisca verrilli	47	0	47
Ampelisca abdita	9	0	9
Neomysis americana	8	0	8
Edotea triloba	6	0	6
TOTAL NUMBER OF TAXA	29		
TOTAL NUMBER OF INDIVIDUALS	520		
SHANNON-WEINER DIVERSITY	1.964		
SIMPSON'S DOMINANCE INDEX	0.261		
SPECIES RICHNESS	4.48		
EVENNESS	0.58		

STUDY SITE = BROADKILL BEACH, DE
STATION = B-11
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Ceriantheopsis americanus	1	0	1
NEMERTINEA			
Nemertinea	17	0	17
ANNELIDA			
Oligochaeta	61	0	61
Leitoscoloplos spp.	25	0	25
Amastigos caperatus	7	0	7
Leitoscoloplos robustus	0	4	4
Mediomastus ambiseta	3	0	3
Spiochaetopterus costarum	2	0	2
Asabellides oculata	2	0	2
Tharyx sp. A	1	0	1
Maldanidae	1	0	1
Paranaitis speciosa	1	0	1
Glycera americana	0	1	1
Heteromastus filiformis	1	0	1
Polydora cornuta	1	0	1
Spio setosa	1	0	1
Pherusa affinis	1	0	1
GASTROPODA			
Acteocina canaliculata	36	0	36
Odostomia sp.	28	0	28
Turbonilla interrupta	3	0	3
Gastropoda	2	0	2
BIVALVIA			
Tellina agilis	131	0	131
Nucula annulata	57	0	57
Yoldia limatula	10	0	10
Lyonsia arenosa	1	0	1
Ensis directus	0	1	1
Gemma gemma	1	0	1
Mulinia lateralis	1	0	1
CRUSTACEA			
Ampelisca verrilli	74	0	74
Neomysis americana	6	0	6
Edotea triloba	5	0	5
Ampelisca abdita	5	0	5

Oxyurostylis smithi	1	0	1
Crangon septemspinosa	1	0	1

TOTAL NUMBER OF TAXA	**34**
TOTAL NUMBER OF INDIVIDUALS	**493**
SHANNON-WEINER DIVERSITY	**2.409**
SIMPSON'S DOMINANCE INDEX	**0.135**
SPECIES RICHNESS	**5.32**
EVENNESS	**0.68**

STUDY SITE = BROADKILL BEACH, DE
STATION = B-12
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Anthozoa	3	0	3
NEMERTINEA			
Nemertinea	18	0	18
ANNELIDA			
Oligochaeta	14	0	14
Leitoscoloplos spp.	4	0	4
Spiochaetopterus costarum	1	1	2
Glycera americana	2	0	2
Magelona sp.	1	0	1
Glycera dibranchiata	0	1	1
Glycinde solitaria	1	0	1
Microphthalmus spp.	1	0	1
Spio setosa	1	0	1
Leitoscoloplos robustus	0	1	1
Nephtyidae	1	0	1
Asabellides oculata	1	0	1
GASTROPODA			
Acteocina canaliculata	49	0	49
Turbonilla interrupta	4	0	4
Odostomia sp.	2	0	2
Crepidula spp.	1	0	1
BIVALVIA			
Tellina agilis	114	0	114
Nucula annulata	9	0	9
Ensis directus	0	4	4
Mulinia lateralis	2	0	2
Yoldia limatula	2	0	2
Lyonsia arenosa	1	0	1
Spisula solidissima	1	0	1
CRUSTACEA			
Neomysis americana	18	0	18
Ampelisca verrilli	17	0	17
Edotea triloba	2	0	2
Ampelisca abdita	2	0	2
Crangon septemspinosa	1	0	1
Cerapus tubularis	1	0	1

TOTAL NUMBER OF TAXA	31
TOTAL NUMBER OF INDIVIDUALS	281
SHANNON-WEINER DIVERSITY	2.189
SIMPSON'S DOMINANCE INDEX	0.212
SPECIES RICHNESS	5.32
EVENNESS	0.64

STUDY SITE = BROADKILL BEACH, DE
STATION = B-13
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	5	0	5
ANNELIDA			
Amastigos caperatus	65	0	65
Nephtys picta	0	4	4
Capitellidae	3	0	3
Glycera americana	1	1	2
Spio setosa	2	0	2
Glycera spp.	1	0	1
Scoloplos rubra	1	0	1
Leitoscoloplos spp.	1	0	1
Oligochaeta	1	0	1
GASTROPODA			
Acteocina canaliculata	43	0	43
Odostomia sp.	12	0	12
Busycon carica	2	0	2
Turbonilla interrupta	1	0	1
BIVALVIA			
Tellina agilis	118	0	118
Nucula annulata	4	0	4
Mulinia lateralis	3	0	3
Yoldia limatula	2	0	2
Gemma gemma	1	0	1
CRUSTACEA			
Ampelisca verrilli	15	0	15
Neomysis americana	5	0	5
Crangon septemspinosa	1	1	2

TOTAL NUMBER OF TAXA	22
TOTAL NUMBER OF INDIVIDUALS	293
SHANNON-WEINER DIVERSITY	1.901
SIMPSON'S DOMINANCE INDEX	0.239
SPECIES RICHNESS	3.70
EVENNESS	0.62

STUDY SITE = BROADKILL BEACH, DE
STATION = B-14
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	6	0	6
ANNELIDA			
Amastigos caperatus	38	0	38
Nephtys picta	0	7	7
Capitellidae	2	0	2
Tharyx sp. A	2	0	2
Spio setosa	2	0	2
Leitoscoloplos spp.	2	0	2
Oligochaeta	2	0	2
Glycera dibranchiata	0	1	1
Leitoscoloplos robustus	0	1	1
Glycinde solitaria	1	0	1
GASTROPODA			
Acteocina canaliculata	37	0	37
Odostomia sp.	13	0	13
Busycon carica	0	1	1
BIVALVIA			
Tellina agilis	84	0	84
Nucula annulata	2	0	2
Mulinia lateralis	1	0	1
Gemma gemma	1	0	1
Ensis directus	0	1	1
CRUSTACEA			
Neomysis americana	10	0	10
Ampelisca verrilli	7	0	7
Crangon septemspinosa	1	0	1

TOTAL NUMBER OF TAXA	**22**
TOTAL NUMBER OF INDIVIDUALS	**222**
SHANNON-WEINER DIVERSITY	**2.039**
SIMPSON'S DOMINANCE INDEX	**0.209**
SPECIES RICHNESS	**3.89**
EVENNESS	**0.66**

STUDY SITE = BROADKILL BEACH, DE
STATION = B-15
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	15	0	15
ANNELIDA			
Oligochaeta	9	0	9
Polydora cornuta	6	0	6
Leitoscoloplos spp.	4	0	4
Amastigos caperatus	3	0	3
Glycera dibranchiata	0	2	2
Microphthalmus sczelkowii	2	0	2
Pectinaria gouldii	2	0	2
Aricidea (Acmira) catherinae	2	0	2
Glycinde solitaria	1	0	1
Asabellides oculata	0	1	1
Podarkeopsis levifuscina	1	0	1
Glycera americana	0	1	1
GASTROPODA			
Acteocina canaliculata	49	0	49
Odostomia sp.	14	0	14
Crepidula spp.	2	0	2
Turbonilla interrupta	1	0	1
BIVALVIA			
Tellina agilis	80	0	80
Nucula annulata	13	0	13
Mulinia lateralis	6	0	6
Gemma gemma	4	0	4
Mytilus edulis	1	1	2
Pandora gouldiana	1	0	1
Tagelus divisus	1	0	1
CRUSTACEA			
Ampelisca verrilli	56	0	56
Neomysis americana	17	0	17
Corophium tuberculatum	5	0	5
Cerapus tubularis	5	0	5
Ampelisca abdita	3	0	3
Crangon septemspinosa	1	0	1
Edotea triloba	1	0	1
Microprotopus raneyi	1	0	1
Pinnixa spp.	1	0	1
Pinnixa chaetopterana	1	0	1

TOTAL NUMBER OF TAXA	34
TOTAL NUMBER OF INDIVIDUALS	313
SHANNON-WEINER DIVERSITY	2.522
SIMPSON'S DOMINANCE INDEX	0.134
SPECIES RICHNESS	5.74
EVENNESS	0.72

STUDY SITE = BROADKILL BEACH, DE
STATION = B-16
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	9	0	9
ANNELIDA			
Amastigos caperatus	16	0	16
Aricidea (Acmira) catherinae	4	0	4
Polycirrus sp.	4	0	4
Spio setosa	2	0	2
Monticellina sp.	2	0	2
Glycera dibranchiata	0	1	1
Magelona sp.	1	0	1
Glycinde solitaria	1	0	1
Oligochaeta	1	0	1
Microphthalmus sczelkowii	1	0	1
Glycera americana	0	1	1
Leitoscoloplos spp.	1	0	1
GASTROPODA			
Acteocina canaliculata	13	0	13
Odostomia sp.	9	0	9
BIVALVIA			
Tellina agilis	81	0	81
Gemma gemma	6	0	6
Ensis directus	0	3	3
Nucula annulata	2	0	2
Spisula solidissima	1	0	1
Mulinia lateralis	1	0	1
Mytilus edulis	1	0	1
CRUSTACEA			
Ampelisca verrilli	18	0	18
Neomysis americana	15	0	15
Leucon americanus	1	0	1
Ampelisca abdita	1	0	1
Pinnixa chaetopterana	1	0	1

TOTAL NUMBER OF TAXA	27
TOTAL NUMBER OF INDIVIDUALS	197
SHANNON-WEINER DIVERSITY	2.262
SIMPSON'S DOMINANCE INDEX	0.201
SPECIES RICHNESS	4.92
EVENNESS	0.69

STUDY SITE = BROADKILL BEACH, DE
STATION = C-1
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	12	0	12
ANNELIDA			
Oligochaeta	121	0	121
Brania wellfleetensis	25	0	25
Streptosyllis pettiboneae	12	0	12
Caulleriella sp. A	5	2	7
Polygordius sp.	5	0	5
Sabellaria vulgaris	3	0	3
Sphaerosyllis taylori	3	0	3
Amastigos caperatus	2	0	2
Maldanidae	2	0	2
Parapionosyllis longicirrata	2	0	2
Levinsenia sp. A	2	0	2
Spiophanes bombyx	2	0	2
Glycera dibranchiata	0	1	1
Dispio uncinata	0	1	1
Scoloplos rubra	0	1	1
Cirrophorus sp. B	1	0	1
GASTROPODA			
Gastropoda	3	0	3
Acteocina canaliculata	1	0	1
BIVALVIA			
Gemma gemma	2051	0	2051
Tellina agilis	6	0	6
Cyclocardia borealis	6	0	6
Spisula solidissima	4	0	4
Pandora sp.	1	0	1
Pandora gouldiana	1	0	1
CRUSTACEA			
Protohaustorius wigleyi	44	0	44
Tanaissus psammophilus	43	0	43
Acanthohaustorius spp.	37	0	37
Acanthohaustorius similis	16	0	16
Acanthohaustorius millsi	15	0	15
Rhepoxynius hudsoni	3	0	3
Ampelisca abdita	2	0	2
Amakusanthura magnifica	2	0	2
Pinnixa chaetopterana	2	0	2
Cyathura burbancki	1	0	1
Neomysis americana	1	0	1
HEMICHORDATA			

Saccoglossus kowalevskii	1	0	1
UROCHORDATA			
Ascidiacea	593	0	593
Molgula arenata	6	0	6

TOTAL NUMBER OF TAXA	**39**
TOTAL NUMBER OF INDIVIDUALS	**3041**
SHANNON-WEINER DIVERSITY	**1.187**
SIMPSON'S DOMINANCE INDEX	**0.495**
SPECIES RICHNESS	**4.74**
EVENNESS	**0.32**

STUDY SITE = BROADKILL BEACH, DE
STATION = C-2
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
PLATYHELMINTHES			
Turbellaria	3	0	3
NEMERTINEA			
Nemertinea	8	0	8
ANNELIDA			
Spiophanes bombyx	37	0	37
Oligochaeta	32	0	32
Sabellaria vulgaris	4	0	4
Dispio uncinata	0	3	3
Paraonis fulgens	3	0	3
Glycera dibranchiata	0	3	3
Streptosyllis pettiboneae	2	0	2
Sphaerosyllis taylori	1	0	1
Amastigos caperatus	1	0	1
Carazziella hobsonae	1	0	1
Brania wellfleetensis	1	0	1
Travisia sp. A	1	0	1
Polygordius sp.	1	0	1
BIVALVIA			
Gemma gemma	3173	0	3173
Tellina agilis	31	0	31
Cyclocardia borealis	3	0	3
Spisula solidissima	2	0	2
Ensis directus	0	1	1
Lyonsia spp.	1	0	1
CRUSTACEA			
Acanthohaustorius spp.	86	0	86
Protohaustorius wigleyi	68	0	68
Acanthohaustorius similis	50	0	50
Rhepoxynius hudsoni	37	0	37
Tanaissus psammophilus	6	0	6
Pinnixa chaetopterana	1	0	1
Ancinus depressus	1	0	1
Oxyurostylis smithi	1	0	1
Amakusanthura magnifica	1	0	1
Parametopella cypris	1	0	1
UROCHORDATA			
Ascidiacea	67	0	67
Molgula arenata	5	0	5

MEROSTOMATA			
Limulus polyphemus	0	1	1

TOTAL NUMBER OF TAXA	**34**
TOTAL NUMBER OF INDIVIDUALS	**3637**
SHANNON-WEINER DIVERSITY	**0.700**
SIMPSON'S DOMINANCE INDEX	**0.763**
SPECIES RICHNESS	**4.02**
EVENNESS	**0.20**

STUDY SITE = BROADKILL BEACH, DE
STATION = C-3
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Anthozoa	1	0	1
NEMERTINEA			
Nemertinea	8	0	8
ANNELIDA			
Oligochaeta	8	0	8
Amastigos caperatus	4	0	4
Spio setosa	4	0	4
Leitoscoloplos spp.	2	0	2
Glycera dibranchiata	0	1	1
Microphthalmus sczelkowii	1	0	1
Goniadidae	1	0	1
Glycera americana	0	1	1
Paranaitis speciosa	1	0	1
Sabellaria vulgaris	1	0	1
Scoloplos rubra	0	1	1
GASTROPODA			
Acteocina canaliculata	6	0	6
Turbonilla interrupta	1	0	1
BIVALVIA			
Nucula annulata	37	0	37
Tellina agilis	19	0	19
Gemma gemma	4	0	4
Lyonsia spp.	1	0	1
Mulinia lateralis	1	0	1
CRUSTACEA			
Neomysis americana	8	0	8
Ampelisca verrilli	4	0	4
Protohaustorius wigleyi	2	0	2
Edotea triloba	1	0	1
Acanthohaustorius millsi	1	0	1
Ampelisca abdita	1	0	1
Leucon americanus	1	0	1

TOTAL NUMBER OF TAXA	27
TOTAL NUMBER OF INDIVIDUALS	121
SHANNON-WEINER DIVERSITY	2.522
SIMPSON'S DOMINANCE INDEX	0.140
SPECIES RICHNESS	5.42
EVENNESS	0.77

STUDY SITE = BROADKILL BEACH, DE
STATION = C-4
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	5	0	5
ANNELIDA			
Oligochaeta	31	0	31
Brania wellfleetensis	15	0	15
Spiophanes bombyx	10	0	10
Nephtys picta	0	2	2
Amastigos caperatus	2	0	2
Nephtys bucera	0	2	2
Streptosyllis pettiboneae	1	0	1
Sphaerosyllis taylori	1	0	1
Polygordius sp.	1	0	1
Leitoscoloplos robustus	0	1	1
Magelona sp.	1	0	1
Paraonidae	1	0	1
Scolelepis (S.) squamata	1	0	1
Parapionosyllis longicirrata	1	0	1
BIVALVIA			
Gemma gemma	404	0	404
Tellina agilis	44	0	44
Lyonsia spp.	3	0	3
Spisula solidissima	3	0	3
CRUSTACEA			
Protohaustorius wigleyi	40	0	40
Acanthohaustorius similis	15	0	15
Rhepoxynius hudsoni	8	0	8
Pinnixa chaetopterana	3	0	3
Amakusanthura magnifica	1	0	1
UROCHORDATA			
Ascidiacea	66	0	66
Molgula arenata	3	0	3

TOTAL NUMBER OF TAXA	**26**
TOTAL NUMBER OF INDIVIDUALS	**665**
SHANNON-WEINER DIVERSITY	**1.586**
SIMPSON'S DOMINANCE INDEX	**0.391**
SPECIES RICHNESS	**3.85**
EVENNESS	**0.49**

STUDY SITE = BROADKILL BEACH, DE
STATION = C-5
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	6	0	6
ANNELIDA			
Oligochaeta	11	0	11
Leitoscoloplos robustus	0	2	2
Amastigos caperatus	2	0	2
Leitoscoloplos spp.	2	0	2
Glycera dibranchiata	0	1	1
Streptosyllis pettiboneae	1	0	1
Scoloplos rubra	0	1	1
Capitellidae	1	0	1
Microphthalmus sczelkowii	1	0	1
Glycinde solitaria	1	0	1
GASTROPODA			
Crepidula convexa	2	0	2
Busycon carica	2	0	2
Crepidula spp.	1	0	1
Acteocina canaliculata	1	0	1
BIVALVIA			
Tellina agilis	37	0	37
Nucula annulata	10	0	10
Gemma gemma	5	0	5
Ensis directus	2	3	5
Mulinia lateralis	2	0	2
CRUSTACEA			
Ampelisca abdita	8	0	8
Neomysis americana	6	0	6
Leucon americanus	4	0	4
Crangon septemspinosa	3	0	3
Cerapus tubularis	3	0	3
Pagurus longicarpus	1	0	1
Acanthohaustorius similis	1	0	1

TOTAL NUMBER OF TAXA	27
TOTAL NUMBER OF INDIVIDUALS	120
SHANNON-WEINER DIVERSITY	2.640
SIMPSON'S DOMINANCE INDEX	0.128
SPECIES RICHNESS	5.43
EVENNESS	0.80

STUDY SITE = BROADKILL BEACH, DE
STATION = C-6
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	16	0	16
ANNELIDA			
Oligochaeta	95	0	95
Leitoscoloplos spp.	19	0	19
Glycera americana	0	2	2
Glycinde solitaria	2	0	2
Nephtys incisa	0	2	2
Asabellides oculata	1	0	1
Pherusa affinis	0	1	1
Pectinaria gouldii	1	0	1
GASTROPODA			
Acteocina canaliculata	213	0	213
Turbonilla interrupta	26	0	26
Odostomia sp.	16	0	16
Acteon punctostriatus	14	0	14
Nassarius trivittatus	1	0	1
BIVALVIA			
Nucula annulata	129	0	129
Tellina agilis	65	0	65
Mulinia lateralis	16	0	16
Yoldia limatula	3	0	3
Mytilus edulis	1	0	1
Ensis directus	0	1	1
Yoldia sp.	1	0	1
CRUSTACEA			
Edotea triloba	60	0	60
Cerapus tubularis	19	0	19
Ampelisca abdita	4	0	4
Ampelisca verrilli	3	0	3
Neomysis americana	2	0	2

TOTAL NUMBER OF TAXA	26
TOTAL NUMBER OF INDIVIDUALS	713
SHANNON-WEINER DIVERSITY	2.218
SIMPSON'S DOMINANCE INDEX	0.160
SPECIES RICHNESS	3.81
EVENNESS	0.68

STUDY SITE = BROADKILL BEACH, DE
STATION = C-7
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Ceriantheopsis americanus	2	0	2
NEMERTINEA			
Nemertinea	10	0	10
ANNELIDA			
Oligochaeta	127	0	127
Glycera americana	1	2	3
Leitoscoloplos spp.	2	0	2
Heteromastus filiformis	1	0	1
Leitoscoloplos robustus	0	1	1
GASTROPODA			
Acteocina canaliculata	136	0	136
Odostomia sp.	6	0	6
Turbonilla interrupta	6	0	6
Acteon punctostriatus	5	0	5
BIVALVIA			
Nucula annulata	224	0	224
Mulinia lateralis	79	0	79
Tellina agilis	11	0	11
Yoldia limatula	6	0	6
Yoldia sp.	4	0	4
Mytilus edulis	1	0	1
CRUSTACEA			
Ampelisca verrilli	5	0	5
Edotea triloba	5	0	5
Ampelisca abdita	2	0	2
Leucon americanus	1	0	1
Neomysis americana	1	0	1
Cerapus tubularis	1	0	1

TOTAL NUMBER OF TAXA	23
TOTAL NUMBER OF INDIVIDUALS	639
SHANNON-WEINER DIVERSITY	1.828
SIMPSON'S DOMINANCE INDEX	0.224
SPECIES RICHNESS	3.41
EVENNESS	0.58

STUDY SITE = BROADKILL BEACH, DE
STATION = C-8
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m² YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Ceriantheopsis americanus	3	0	3
NEMERTINEA			
Nemertinea	8	0	8
ANNELIDA			
Oligochaeta	78	0	78
Leitoscoloplos spp.	15	0	15
Glycera americana	0	3	3
Asabellides oculata	1	0	1
Glycinde solitaria	1	0	1
GASTROPODA			
Acteocina canaliculata	164	0	164
Turbonilla interrupta	16	0	16
Odostomia sp.	8	0	8
Acteon punctostriatus	5	0	5
Nassarius trivittatus	1	0	1
BIVALVIA			
Nucula annulata	120	0	120
Tellina agilis	52	0	52
Mulinia lateralis	42	0	42
Yoldia limatula	19	0	19
Yoldia sp.	5	0	5
Mytilus edulis	1	0	1
CRUSTACEA			
Cerapus tubularis	7	0	7
Edotea triloba	5	0	5
Neomysis americana	4	0	4
Ampelisca abdita	3	0	3
Leucon americanus	2	0	2
Ampelisca verrilli	1	0	1

TOTAL NUMBER OF TAXA	24
TOTAL NUMBER OF INDIVIDUALS	564
SHANNON-WEINER DIVERSITY	2.183
SIMPSON'S DOMINANCE INDEX	0.167
SPECIES RICHNESS	3.63
EVENNESS	0.69

STUDY SITE = BROADKILL BEACH, DE
STATION = C-9
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = 0.1m^2 YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
CNIDARIA			
Anthozoa	2	0	2
NEMERTINEA			
Nemertinea	7	2	9
ANNELIDA			
Oligochaeta	77	0	77
Leitoscoloplos spp.	16	1	17
Glycera americana	2	6	8
Spiochaetopterus costarum	1	2	3
Glycinde solitaria	2	0	2
Microphthalmus sczelkowii	2	0	2
Brania wellfleetensis	1	0	1
GASTROPODA			
Acteocina canaliculata	314	0	314
Turbonilla interrupta	17	0	17
Odostomia sp.	7	0	7
Acteon punctostriatus	3	0	3
Gastropoda	1	0	1
BIVALVIA			
Nucula annulata	128	0	128
Tellina agilis	68	0	68
Mulinia lateralis	29	0	29
Yoldia limatula	19	0	19
Mytilus edulis	2	0	2
Yoldia sp.	2	0	2
CRUSTACEA			
Edotea triloba	3	0	3
Neomysis americana	2	0	2
Ampelisca verrilli	2	0	2
Pinnixa spp.	1	0	1

TOTAL NUMBER OF TAXA	24
TOTAL NUMBER OF INDIVIDUALS	719
SHANNON-WEINER DIVERSITY	1.895
SIMPSON'S DOMINANCE INDEX	0.247
SPECIES RICHNESS	3.50
EVENNESS	0.60

STUDY SITE = BROADKILL BEACH, DE
STATION = C-10
COLLECTION DATE = JULY 1994
SIEVE SIZE = 0.5mm
COLLECTION GEAR = $0.1m^2$ YOUNG MODIFIED VAN VEEN

TAXA	<2cm	≥2cm	SUM
NEMERTINEA			
Nemertinea	8	0	8
ANNELIDA			
Oligochaeta	16	0	16
Leitoscoloplos spp.	5	0	5
Glycera americana	1	4	5
Leitoscoloplos robustus	1	3	4
Owenia fusiformis	1	2	3
Asabellides oculata	2	1	3
Polydora cornuta	2	0	2
Spiophanes bombyx	2	0	2
Aricidea spp.	0	1	1
GASTROPODA			
Acteocina canaliculata	132	0	132
Turbonilla interrupta	11	0	11
Odostomia sp.	8	0	8
Nassarius trivittatus	2	0	2
Busycon spp.	2	0	2
BIVALVIA			
Tellina agilis	115	0	115
Nucula annulata	45	0	45
Yoldia limatula	12	0	12
Mulinia lateralis	9	0	9
Ensis directus	0	1	1
CRUSTACEA			
Ampelisca verrilli	122	0	122
Cerapus tubularis	73	0	73
Edotea triloba	35	0	35
Ampelisca abdita	10	0	10
Neomysis americana	4	0	4
Corophium tuberculatum	2	0	2
Oxyurostylis smithi	1	0	1

TOTAL NUMBER OF TAXA	27
TOTAL NUMBER OF INDIVIDUALS	633
SHANNON-WEINER DIVERSITY	2.339
SIMPSON'S DOMINANCE INDEX	0.137
SPECIES RICHNESS	4.03
EVENNESS	0.71

APPENDIX E
LIST OF SUBCONTRACTORS

Survey Vessel

T G & B
639 Boxberry Hill Rd.
Falmouth, MA 02536

Sediment Grain-Size Analysis

GeoPlan Associates, Inc.
30 Mann Street
Hingham, MA 02043

Sediment TOC Analysis

Global Geochemistry Corporation
6919 Eton Avenue
Canoga Park, CA 91303

Macrofaunal Analysis

Cove Corporation
10200 Breeden Road
Lusby, MD 20657

APPENDIX F
SCOPE OF WORK

SCIENTIFIC SERVICES PROGRAM
Short Term Analysis Service (STAS)
Statement of Work

STATEMENT OF WORK
TCN: 94-246

1. Title: Delaware Bay Coastline - Broadkill Beach Interim Feasibility Study, Sussex County, Delaware: Benthic Animal Assessment of Potential Borrow Source.

2. General: The benthic animal assessment for the Broadkill Beach area is part of a broader study covering approximately 60 miles of shoreline along the Delaware Bay between Salem River to Cape May in New Jersey and the Chesapeake and Delaware Canal to Cape Henlopen in Delaware.

The purpose of this study is to investigate shore protection and hurricane damage problems and to consider potential solutions. The feasibility study is being conducted through a series of three staggered interim studies. The first interim study and the investigation area for this Statement of Work is the Broadkill Beach, Delaware Study. Specifically, the Broadkill Beach study area is located in Sussex County on a 3 mile stretch of shoreline of the lower Delaware Bay. Broadkill Beach consists of about 200 homes, predominately summer resort cottages, and has experienced substantial recent growth, as evidenced by the number of newly constructed homes. Similar to other areas in this region, portions of the beach are very narrow at high tide. Five timber groins were constructed by the state between 1950 and 1954, and two rubble mound groins in 1964, near the north end of the town to reduce erosion.

A critical component of this feasibility study is the evaluation and selection of an offshore sand borrow source for beach nourishment. Several issues have been identified during the Reconnaissance Study that need to be addressed such as the disruption of commercially/recreationally and ecologically important benthic communities within the borrow source, and the generation of baseline benthic data for this area in order to determine potential impacts to these benthic habitats.

Due to the dynamic nature of benthic biological communities and the relatively long time-frame of the interim studies, only the borrow source for the first interim feasibility study and its immediate vicinity will be investigated under this statement of work. The potential borrow source area identified for this interim study is located immediately offshore of Broadkill Beach (see Figure 1).

The Philadelphia District Environmental Resources Branch does not have the necessary in-house capability to perform the tasks specified in the Statement of Work, and no other known government laboratory or center has the capability to perform the work.

3. Objectives: The purpose of the benthic study is to evaluate the benthic macroinvertebrate community within the proposed

borrow area, and to offer a comparison with the benthic communities outside of the proposed borrow areas. The contractor should establish a baseline for the benthic macroinvertebrate assemblages within the proposed borrow area and in two distinct control areas immediately outside of the proposed borrow area. The contractor will also identify the presence of any commercial and/or recreational benthic macroinvertebrates within the proposed borrow area.

4. **Specific Tasks:** The contract must provide a demonstrated capability to provide all facilities, equipment, supplies, and personnel necessary to perform the benthic assessment study with qualitative and quantitative interpretation and report generation described in the tasks below. The work is to be performed by the contractor independent of government direction, supervision, and control. This request represents non-personal services and is not in violation of the personal services policy set forth in Paragraph 37.104 of the Federal Acquisition Regulation.

Benthic sampling stations shall be distributed throughout the proposed borrow area offshore of Broadkill Beach. Several sampling stations will be located outside of these proposed borrow areas and will act as "control" areas. Field sampling shall be conducted between the period 1 June through 15 July 1994. Each sample shall contain enough grabs to cover an area of at least 0.1 m^2 of the bottom. Particle size distribution analyses shall be conducted at each sample station. Samples shall be obtained by using a benthic grab, dredge, or similar device and preserved with formalin and rose bengal stain. The samples shall be sorted into the major taxonomic groups (Phylum Annelida, Mollusca, etc.). Each major taxonomic group shall be analyzed for organism abundance, biomass density, and size distribution. Taxonomic identifications shall be conducted on each sample to the lowest taxonomic unit possible (genus or species). Benthic community structure and diversity, commercial species and opportunistic species information, and benthic community similarity/dissimilarity shall be analyzed on each sample. This information shall be presented in a type-written scientific report including sections describing the objective, methodologies, results, discussion, and conclusions. The results and analyses shall include but not be limited to graphical, tabular, and chart presentations of the data and findings. The conclusions section shall evaluate the potential recovery of the benthic community based on the species found. Original data sheets shall be provided in the appendices of the report.

<u>Specific Tasks to Be Performed</u>:

Task I: SAMPLING

A. Sample Station Locations

1. Suitable sand borrow source is located immediately offshore of Broadkill Beach. The borrow area is

defined in Delaware State Plane coordinates (National Geodetic Survey) and longitude/latitude coordinates and will be provided at a later date. The area being considered is estimated to be approximately 340 acres. The borrow area will be divided into thirty (30) equal cells of approximately 11.3 acres each. The thirty cells shall contain 1 randomly selected sample station within each.

2. Ten "control" samples shall be taken outside the boundary of the borrow area but within an area exhibiting similar depth and substrate characteristics. The contractor will consult with the government point of contact to identify 10 control sample sites outside of previously disturbed areas.

3. Each sample shall have one (1) sub-core sample utilized for sediment grain size analysis.

4. Each sample station location shall be predetermined and plotted on a U.S.C.G. or NOAA Navigation Map. This map shall be presented in the report. LORAN or GPS navigation systems shall be utilized on the boat for accurate verification of sample locations. The system utilized must be identified in the report.

B. Field Records

1. The following information shall be recorded at the time of each sample collection:

- time and date
- time of latest high or low tide at closest tide station
- physical and chemical factors such as depth and dissolved oxygen. All stations shall have depth measurements.

2. The following information shall be recorded once per sampling day:

- chemical factors such as temperature, ph and salinity of the water column directly above the benthic community.

3. The following information shall be recorded inside and on each sample jar on separate labels:

- station number
- sample number
- date

C. Sample Collection

1. A benthic grab device such as a Smith-McIntyre grab, Peterson Dredge, Van-Veen Dredge or similar device shall be used for sampling the benthic community. The appropriate number of grabs shall be conducted to attain a sample area equivalent to 0.1 square meter.

*Note: the number of individual grabs to attain a sampling area of 0.1 square meters is equal to one sample.

2. All samples shall be gently rinsed and washed through a 0.5 mm sieve (a 1.0 mm sieve may be used to remove larger animals and debris prior to using the 0.5 mm sieve.) Large debris shall be picked and removed from the sample. Samples shall be labeled, placed in separate jars and preserved in a 50% formalin solution containing rose bengal stain. The sediment samples shall be placed in its entirety and unpreserved in a sample container or plastic bag for laboratory particle size analysis.

3. Physical and chemical factors shall be measured and recorded concurrently with the biological sampling at the designated stations. These factors shall include depth, temperature, pH, dissolved oxygen, and salinity.

**All sampling devices and equipment shall be obtained by the contractor. A list of suggested equipment is provided in Appendix A.

TASK II: LABORATORY ANALYSIS

A. Species Identification

1. Samples shall be washed with water and placed in water during laboratory analysis. Animals shall be picked from the detritus. Animals from each sample shall be sorted into their respective major taxonomic groups (Phyla).

2. All intact macrofaunal species and body fragments identifiable to species level will be removed from each sample for processing. Dead bivalves (hinged shells and intact single valves) of commercial value will also be removed from the sample debris.

3. Organisms from each major taxonomic group shall be counted separately. Record the number of individuals within each taxonomic unit for each sample.

4. The animals in each taxonomic unit shall be estimated for approximate length (greater than or equal to; or less than 2 cm in length). If individuals are fragmented, record based on the approximate length of the whole animal.

5. Biomass determinations shall be completed on each sample within the same day to avoid sample degradation.

6. Store final samples in 70% ethanol, with one vial or jar per sample. The contractor shall retain samples for a period of 3 months after the final report is issued. A reference collection of each taxonomic unit shall be provided to the Philadelphia District Corps of Engineers after this period.

The remaining samples shall become property of the contractor and utilized at the discretion of the contractor.

TASK III: A publishable report shall be prepared presenting the data, analysis, and discussions of the benthic sampling study.

A. Data Presentation

1. The following information shall be presented in the report: size distribution of organisms, taxonomic distribution, wet weight biomass of major taxonomic groups, and sediment grain size analysis at each station. Additional information regarding recreational/commercial species and opportunistic species shall be presented.

2. All data shall be presented in, but not be limited to, graphical and tabular forms. Data tables per station will be presented in Appendices and include the following:

- taxa
- number of individuals per taxon by size group (<2 cm and $\geq$ 2 cm) and total count
- total number of taxa per station
- total number of individuals per station
- Shannon-Weiner Diversity
- Simpson's Dominance Index
- Species Richness
- Evenness

Data tables summarizing environmental parameters shall include the following:

- sediment as defined by mean grain size, standard deviation, sorting descriptive, and percent composition by sediment classification
- salinity (ppt)
- pH
- water temperature (C)
- DO (mg/L)

B. Statistical Analysis

1. Statistical analysis shall include but not be limited to abundance and/or densities (i.e. biomass/unit area, numbers of organisms/unit area etc.), and benthic community structure and diversity (i.e. Shannon-Weiner Diversity Index, Simpson's Dominance Index, and Bray-Curtis Similarity Measure and Cluster Analysis).

2. Sediment data will be analyzed for mean grain size and standard deviation using formulas provided in the Shore

Protection Manual (U.S. Army Corps of Engineers, 1984) for the graphic mean (cumulative grain size distribution). Grain size distribution of sediments should also be described qualitatively as well sorted or poorly sorted (Folk, 1974) depending on how close all particle sizes are to the typical size (mean).

3. Statistical data shall be presented in graphical or tabular form to provide easy comparisons between stations.

C. Report Text

The Corps will provide, upon contractor's request, readily available district project information.

1. The report shall include written discussions of, but not be limited to, the following sections:

- purpose/objective of the study
- methodology
- results
- discussion
- conclusions

The discussion and/or conclusions sections shall include information resulting from a survey of appropriate literature/reports to address 1) grain size compatibility with the beach nourishment site, 2) the potential for impacts to threatened and endangered species as well as marine mammals, 3)the potential for impacts to nearby sessile epifaunal communities by resuspension, 4) and the potential for impacts to commercial or sport fisheries.

D. Appendices

1. All figures, tables, maps, and charts shall be presented in the appendices, as appropriate.

2. Appendices shall include original (dated) data sheets.

3. Appendices shall also include a copy of the names of all subcontractors utilized and their addresses.

E. Miscellaneous

1. If the report has been written by someone other than the contract principal investigator, the cover and title page of the publishable report shall bear the inscription: Prepared Under the Supervision of (Name), Principal Investigator. The principal investigator is required to sign the original document. In addition, the principal investigator must at least prepare a forward describing the overall research context of the report, the significance of the work and any other related

background circumstances relating to the manner in which the work was undertaken.

2. The TITLE PAGE of the report shall include the date (month and year) the report was submitted, the project name, the author organization and/or client, and contract number.

3. A TABLE OF CONTENTS, including a list of all Figures and Tables shall be presented in the report.

4. PAGE SIZE AND FORMAT. The report shall be produced on 8 1/2 x 11" paper, single-spaced, with double spacing between paragraphs. Figures shall be 8 1/2 x 11" or folded 11 x 17" format sheet size. All text pages (including appendices) shall be consecutively numbered. Text print quality must be at least letter quality.

5. All references shall be properly cited in a bibliography at the end of the report text.

5. <u>Reporting Requirements</u>:

A. Field sampling shall commence on or after 1 June 1994, and shall be completed no later than 15 July 1994.

B. The Contractor shall provide 3 copies of the draft report to the Philadelphia District U.S. Army Corps of Engineers, 100 Pen Square East, Philadelphia, Pennsylvania 19107-3390. POC: Barbara Conlin, Environmental Resources Branch (215-656-6557) within 50 calendar days from the completion of the sample collection or no later than 3 September 1994.

C. The Corps will provide comments to the contractor within 21 calendar days of receipt of the draft report or no later than 24 September 1994. The contractor is responsible for incorporating any changes to the draft document.

D. The contractor shall provide 5 bound copies and 1 unbound, reproducible original copy of the final report to the Philadelphia District Corps of Engineers within 21 calendar days of receipt of the review comments on the draft report or no later than 15 October 1994.

E. All tasks described under this scope shall be completed by 15 October 1994.

6. **Qualification Requirements:** The contractor must have a demonstrated ability to develop and perform biological field sampling in a marine system at statistically representative locations using benthic grab sampling equipment and to provide statistical analytical review and discussion of the results. It is the reponsibility of the contractor (or subcontractors) to furnish any facilities (equipment, laboratory support, etc) needed to perform the effort.

7. Place, Period of Performance, and Travel:

a. The desired inclusive performance period will be from EDODO through 15 October 1994.

b. The contractor should conduct all field work within 7 calendar days, weather permitting, laboratory analysis and interpretation within 45 calendar days and report preparation within 23 calendar days.

Approximately 37 working days for a research group are required for this study.

8. Restrictions: No known or potential conflict of interest exists.

9. Security Clearance: No security clearance is required.

10. Contracting Officer's Technical Representative: Project Biologist: Barbara Conlin, Environmental Resources Branch, (215) 656-6557, (215) 656-6543 (fax). Philadelphia District Corps of Engineers, Wanamaker Building, 100 Penn Square East, Philadelphia, Pennsylvania 19107-3390. ATTN: CENAP-PL-E

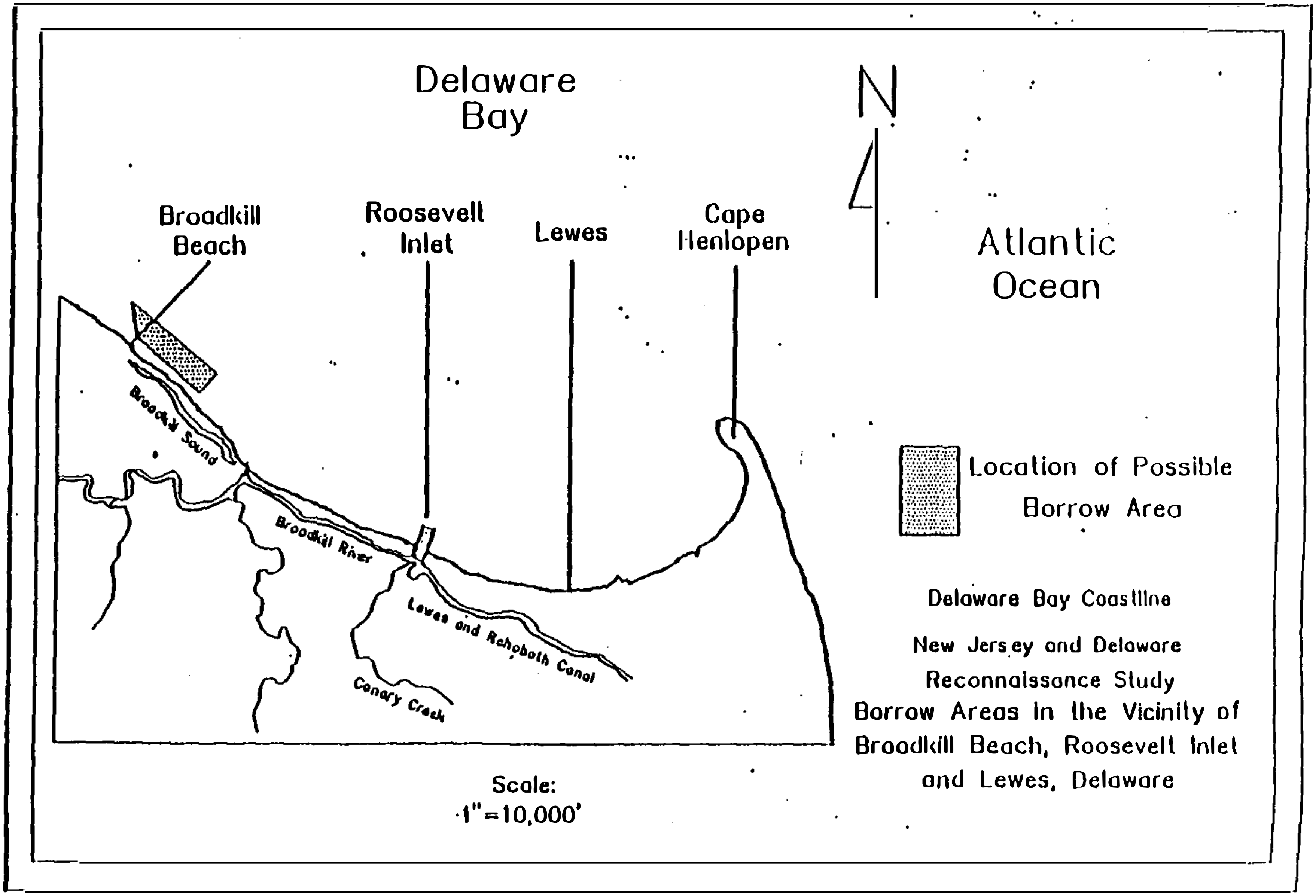
Delaware Bay
Broadkill Beach
Roosevelt Inlet
Lewes
Cape Henlopen
N
Atlantic Ocean
Broadkill Sound
Broadkill River
Lewes and Rehoboth Canal
Canary Creek
Location of Possible Borrow Area
Delaware Bay Coastline
New Jersey and Delaware Reconnaissance Study
Borrow Areas in the Vicinity of Broadkill Beach, Roosevelt Inlet and Lewes, Delaware
Scale: 1"=10,000'

Figure 1

APPENDIX A: SUGGESTED EQUIPMENT LIST (may be modified as necessary)

A. Sampling Devices

-Smith-McIntyre grab
-1/10 square meter Petersen grab
-1/10 square meter Van-Veen hydraulic dredge

B. 0.5 mm (500 micron) sieve (circular with 12" or greater sides)

C. 1.0 mm (1000 micron) sieve (circular with 12" or greater sides)

D. Wash bottles with squirt nozzles and water pitchers or beakers for sample washdown

E. Forceps and eyedropper

F. Plastic sample jars (pint or quart jars with lids)

G. Labels, grease pencil, waterproof paper, pen or pencil

H. 50% solution of buffered and stained (rose bengal) formalin for sample preservation: 1 quart = approx. 10 samples

I. One 3-4 foot diameter wash tub (optional)

J. Funnel

K. White tray for sample sorting

L. Spatulas or small scoops

M. Small twist tie plastic bags for sediment samples

N. Munsell color chart

O. Boat equipped with suitable surveying/positioning equipment. This equipment is subject to Corps approval.

CULTURAL INVESTIGATION

HUNTER RESEARCH

DRAFT

A PHASE 1 SUBMERGED AND SHORELINE CULTURAL RESOURCES INVESTIGATION BROADKILL BEACH BROADKILL HUNDRED, SUSSEX COUNTY DELAWARE

CONTRACT DACW61-94-R-0012
DELIVERY ORDER #2

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA DISTRICT

Prepared by:
Dolan Research, Inc.
4425 Osage Avenue
Philadelphia, PA 19104
and
Hunter Research, Inc.
714 South Clinton Avenue
Trenton, NJ 08611

Submitted to:

U.S. Army Corps of Engineers
Philadelphia District
The Wanamaker Building
100 Penn Square East
Philadelphia, PA 19107-3390

Prepared under the supervision of:

J. Lee Cox, Jr. (Dolan Research, Inc.)

Richard Hunter (Hunter Research, Inc.)
Principal Investigators

November 1994

MANAGEMENT SUMMARY

This report describes the results of a Phase 1 submerged and shoreline cultural resources investigation of two proposed sand borrow areas and a 2.5-mile segment of the Broadkill Beach tidal zone and shoreline in Broadkill Hundred, Sussex County, Delaware. This study was performed in connection with a program of beach nourishment and shoreline erosion control planned by the Philadelphia District of the U.S. Army Corps of Engineers. Investigative tasks included: background and documentary research; terrestrial pedestrian survey of the shoreline at low tide; underwater archaeological survey using magnetic, acoustic and bathymetric remote sensing equipment; analysis and evaluation of assembled research and field data; and preparation of this report. Since the principal potential archaeological impacts of this project will occur within the Delaware Bay, the investigative emphasis was mostly placed on background research. paleoenvironmental analysis and underwater survey activities.

No known prehistoric resources have been identified within the project area, but it should be noted that the level of study precluded a full evaluation of prehistoric archaeological potential. A limited program of core sampling is suggested for the two sand borrow areas as a means of reconstructing the paleoenvironment of formerly exposed terrain that has been inundated over the past ten to 15 millennia. This would provide a more solid basis for assessing prehistoric archaeological potential within the Delaware Bay. No further prehistoric archaeological analysis is recommended for the shoreline, since beach nourishment should serve to protect buried resources in this zone, if indeed they exist.

The potential for historical archaeological terrestrial resources is considered negligible within the Delaware Bay and no evidence for significant resources of this type was observed along the shoreline. No further investigation of historic archaeological terrestrial resources is considered necessary in connection with the proposed project. The project actions will have no foreseeable adverse effects on historic architectural resources, since buildings within the settlement of Broadkill Beach lie inland from the beach itself and outside the likely zone of impact.

Background research indicates extensive historic maritime activity in the Delaware Bay in the Broadkill Beach vicinity. Over 200 hundred shipwrecks or maritime "accidents" have been documented near the mouth of the Bay and there is consequently a high potential for underwater resources within the zone offshore from Broadkill Beach. Remote sensing survey identified one potentially significant underwater resource, a combined magnetic-acoustic anomaly that may relate to a shipwreck, within Borrow Area 2 (Broadkill). If it is not possible to avoid and preserve this resource in place, further underwater archaeological investigation is recommended to establish the nature of the anomaly.

LIST OF FIGURES

LIST OF PLATES AND TABLES

ACKNOWLEDGEMENTS

Various individuals contributed to the completion of this project. Special thanks are extended to the staff of the Philadelphia District of the U.S Army Corps of Engineers, and in particular Michael Swanda, Archaeologist, Environmental Resources Branch, for providing project-related materials, information and advice.

Thanks are due to the staff of the State of Delaware State Historic Preservation Office, notably Faye L. Stocum and Gwen Coffin Davis, who assisted us in using this agency's site maps and files. Thanks are also extended to the staffs of the Delaware Historical Society, the Delaware State Museum and the Wilmington Public Library for their assistance in identifying relevant archival materials and historic maps.

Background research for this survey was performed by Lee Cox of Dolan Research and Michael Tomkins and William Liebeknecht of Hunter Research. The underwater field survey, which comprised the bulk of the field effort, was performed by Lee Cox, Wes Hall, Ralph Wilbanks and James Reedy of Dolan Research. The terrestrial shoreline field survey was conducted by Lee Cox of Dolan Research with assistance from Michael Tomkins of Hunter Research. The underwater portions of the project report were prepared by Lee Cox of Dolan Research. The prehistoric, terrestrial and general sections of the project report were prepared by Michael Tomkins, Brooke Blades and Richard Hunter of Hunter Research. Final editing and final report assembly were carried out by Hunter Research.

Lee Cox, M.A., Dolan Research, Inc.
Richard Hunter, M.A., S.O.P.A, Hunter Research, Inc.
Principal Investigators

CHAPTER 1

INTRODUCTION

A. Project Background and Scope-of-Work

The following technical report describes a Phase I Submerged and Shoreline Cultural Resources Investigation performed for two offshore sand borrow areas and a 2.5-mile segment of the tidal zone in the vicinity of Broadkill Beach. Broadkill Hundred, Sussex County, Delaware (Figures 1.1 and 1.2). This work was performed for the Philadelphia District of the U.S. Army Corps of Engineers (USACOE) by Hunter Research, Inc. and Dolan Research, Inc. in connection with plans for beach nourishment along the Delaware Bay shorelines of Delaware and New Jersey. Beach renourishment, in this instance, is being considered by the USACOE as a suitable solution to erosion problems along this section of the Sussex County shoreline.

The cultural resources investigations reported on here represent part of a program of ongoing environmental studies that the USACOE is carrying out in cooperation with the Delaware Department of Natural Resources and Environmental Control and the New Jersey Department of Environmental Protection and Energy. The work was carried out as Delivery Order No. 2 under Contract DACW61-94-R-0012 between Hunter Research, Inc. and the U.S. Army Corps of Engineers (Philadelphia District). Dolan Research, Inc. operated as a subconsultant to Hunter Research, Inc., supplying underwater archaeological survey services.

The cultural resources investigations involved two principal work elements:

1). an underwater archaeological survey designed to locate targets associated with submerged historic and archaeological sites within the two proposed sand borrow areas; and

2). a terrestrial survey along a 2.5 mile-section of the tidal zone and shoreline of Broadkill Beach.

Tasks performed included: background and documentary research (for both the underwater and terrestrial surveys); acoustic, magnetic and bathymetric remote sensing with follow-up target analysis (underwater survey only); a pedestrian survey, carried out at low tide (terrestrial survey only); analysis of assembled research and field data; and preparation of this report. The purpose of these investigations has been twofold: to determine the presence or absence of submerged or shoreline cultural resources that are potentially eligible for inclusion in the National Register of Historic Places in areas which might be affected by proposed sand borrow activities; and to assess likely project impacts and make recommendations as to the need for further cultural resources studies, if potentially significant resources may be adversely affected by the proposed project actions.

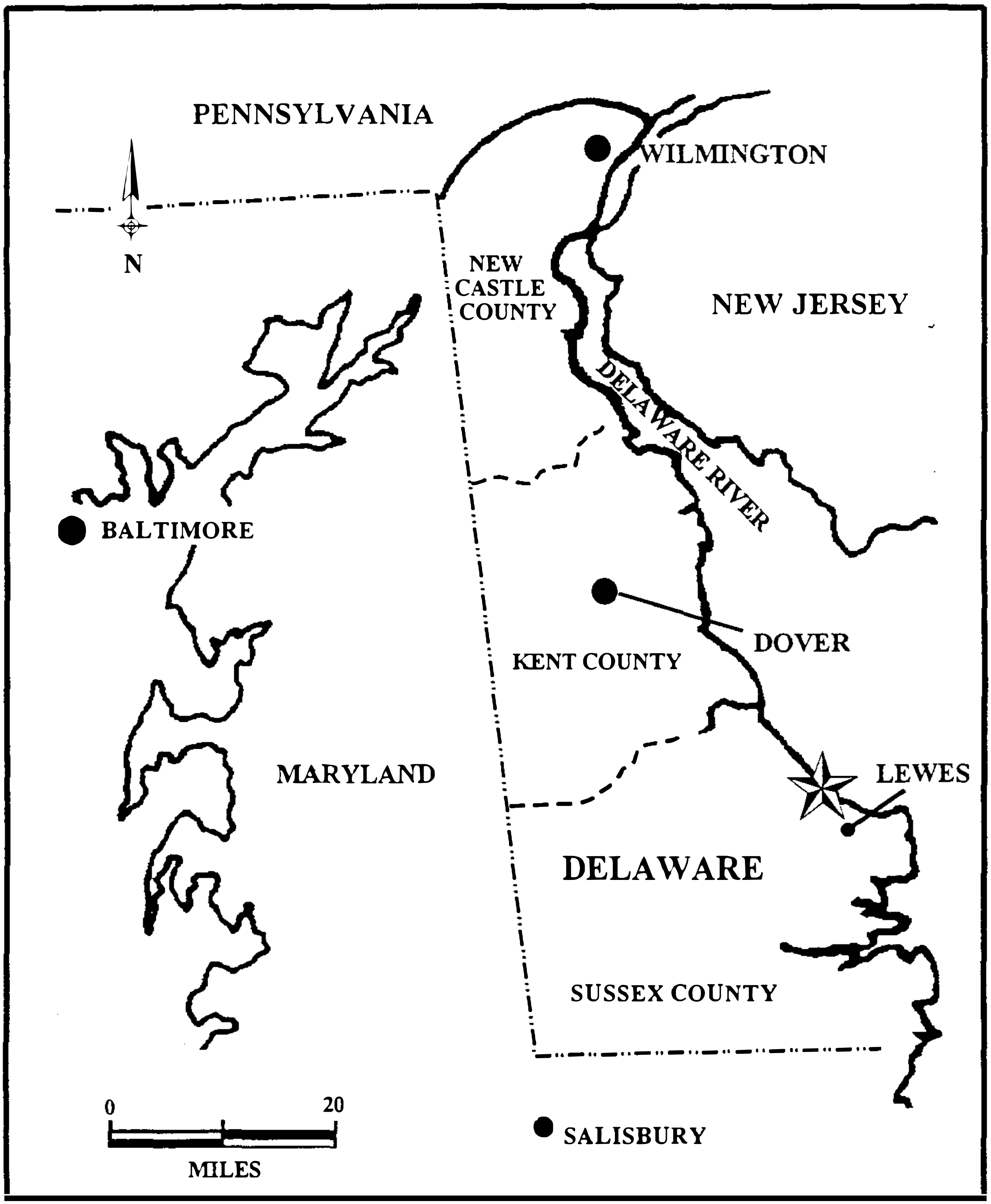

Figure 1.1. Location of Project Area (starred).

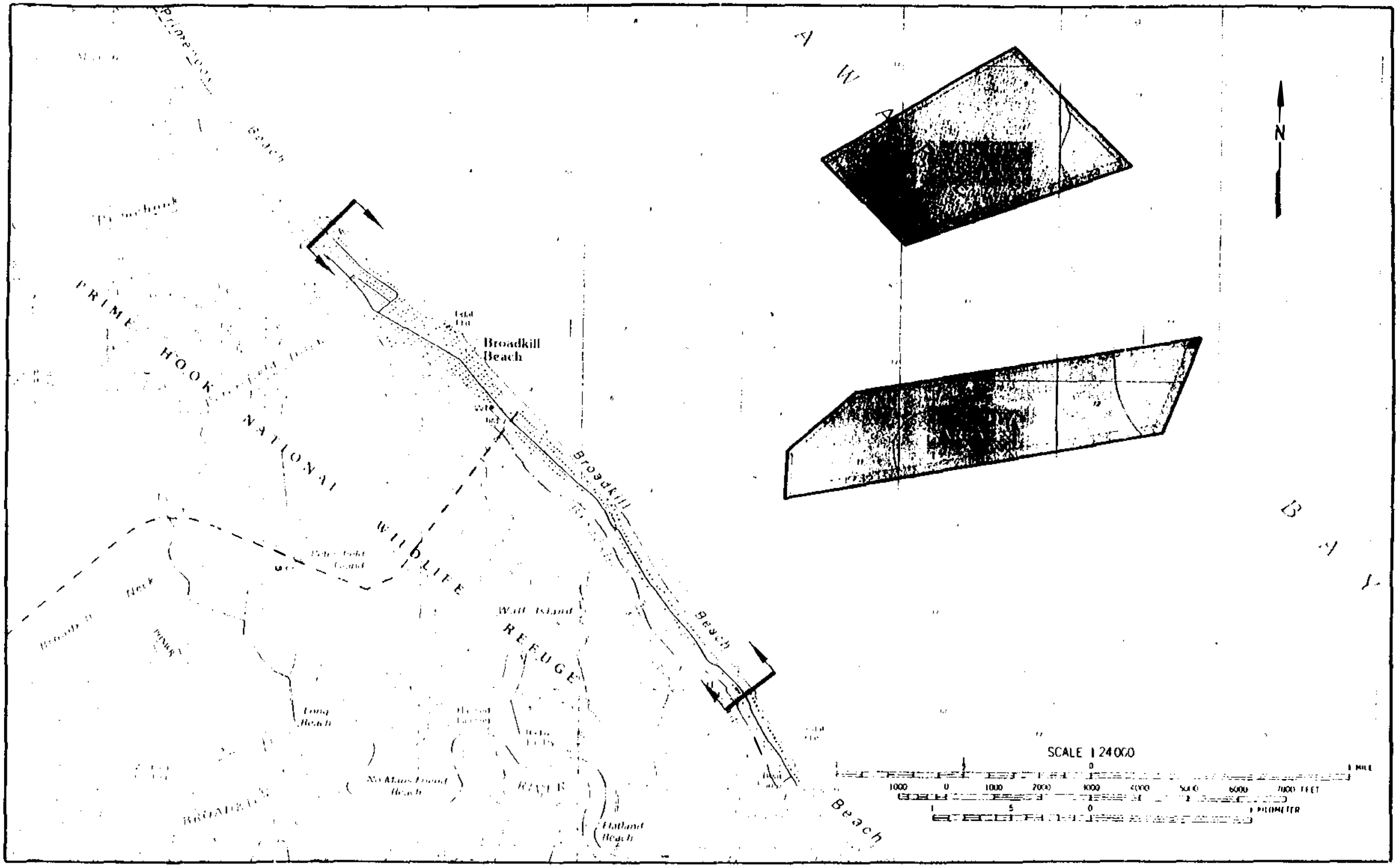

Figure 1.2. Detailed Location of Project Area. The Terrestrial Survey Area is indicated by arrows and the Potential Sand Borrow Areas are shaded. Source: USGS 7.5' Topographic Series, Lewes quadrangle (1984, revised 1991).

These investigations were conducted in accordance with the instructions and intents of various applicable Federal and State legislation and guidelines governing the evaluation of project impacts on archaeological resources, notably: Section 101(b)(4) of the National Environmental Policy Act of 1969; Section 1(3) and 2(b) of Executive Order 11593; Section 106 of the National Historic Preservation Act; 23 CFR 771, as amended October 30, 1980; the guidelines developed by the Advisory Council on Historic Preservation published November 26, 1980; the amended Procedures for the Protection of Historic and Cultural Properties as set forth in 36 CFR Part 800 (October 1, 1986); and Executive Order 215.

B. Criteria of Evaluation

The information generated by these investigations was considered in terms of the criteria for evaluation outlined by the U.S. Department of the Interior, National Register Program:

The quality of significance in American history, architecture, archaeology and culture is present in districts, sites, buildings, structures and objects that possess integrity of location, design, setting, materials, workmanship, feeling and association, and:

> A. that are associated with events that have made a significant contribution to the broad patterns of our history; or
>
> B. that are associated with the lives of persons significant in our past; or
>
> C. that embody the distinctive characteristics of a type, period or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
>
> D. that have yielded, or may be likely to yield information important in prehistory or history.

National Register of Historic Places Bulletin 20 clarifies the National Register review process with regard to shipwrecks and other submerged cultural resources. Shipwrecks must meet at least one of the above criteria and retain integrity of location, design, settings, materials, workmanship, feelings and association. Determining the significance of a historic vessel depends on establishing whether the vessel is:

1. the sole, best, or a good representative of a specific vessel type; or

2. is associated with a significant designer or builder; or

3. was involved in important maritime trade, naval recreational, government, or commercial activities.

Properties which qualify for the National Register, must have significance in one or more "Areas of Significance" that are listed in National Register Bulletin 16A. Although 29 specific categories are listed, only some are relevant to the submerged cultural resources in the Lower Delaware Bay and Delaware River. Architecture, commerce, engineering, industry, invention, maritime history and transportation are potentially applicable data categories for the type of submerged cultural resources which may be expected in the Broadkill Beach study area.

Ordinarily, cemeteries, birthplaces or graves of historical figures, properties owned by religious institutions or used for religious purposes, structures that have been moved from their original locations, reconstructed historic buildings, properties primarily commemorative in nature, and properties that have achieved significance within the past 50 years shall not be considered eligible for the National Register. However, such properties will qualify if they are integral parts of districts that do meet the criteria or if they fall within the following categories:

A. a religious property deriving primary significance from architectural or artistic distinction or historical importance; or

B. a building or structure removed from its original location but which is significant primarily for architectural value, or which is the surviving structure most importantly associated with a historic person or event; or

C. a birthplace or grave of a historical figure of outstanding importance if there is no other appropriate site or building directly associated with his productive life; or

D. a cemetery which derives its primary significance from graves of persons of transcendent importance, from age, from distinctive design features, or from association with historic events; or

E. a reconstructed building when accurately executed in a suitable environment and presented in a dignified manner as part of a restoration master plan, and when no other building or structure with the same association has survived; or

F. a property primarily commemorative in intent of design, age, tradition, or symbolic value has invested it with its own historic significance; or

G. a property achieving significance within the past 50 years if it is of exceptional importance.

C. Definition of Terms

The following definitions are from the Department of the Interior. National Register of Historic Places 36 CFR 63 (Federal Register. Vol. 42. No. 183. Wed. Sept. 21. 1977. pp. 47666-67):

1. A "site" is the location of a significant event. or prehistoric or historic occupation or activity or a building or structure whether standing, ruined, or vanished where the location itself maintains historical or archaeological value regardless of the value of any existing structures.

2. A "building" is a structure created to shelter and form of human activity such as a house, barn, church, hotel or similar structure. "Buildings" may refer to a historically related complex, such as a courthouse and jail or a house and barn.

3. A "structure" is a work make up of interdependent and interrelated parts in a definite pattern or organization. Constructed by man, it is often an engineering project large in scale.

4. An "object" is a material thing of functional, aesthetic, cultural, historical, or scientific value that may be, by nature or design, movable yet related to a specific setting or environment.

D. Previous Research and Principal Information Sources

Previous cultural resources investigations have not addressed the cultural prehistory of the presently submerged portions of the Delaware Bay along the State of Delaware shoreline in any detailed manner owing to the inaccessibility of permanently inundated terrain. Furthermore, no previous archaeological studies have been carried out within the tidal zone along Broadkill Beach and no previously documented evidence has been found for prehistoric sites along this section of the Delaware Bay shoreline. The only detailed cultural resources study to have addressed terrestrial prehistoric resources in the Broadkill Beach vicinity was a Phase I survey of the Prime Hook National Wildlife Refuge carried out in the early 1980s. This study identified three prehistoric sites, all located a half mile or more inland from the present-day shoreline (MAAR, Inc. 1981). While the prehistoric archaeology of the Broadkill Beach vicinity has been little studied and produced scant information of relevance to the current investigation, there has been extensive paleoenvironmental research conducted for the Delaware Bay and adjoining Atlantic coastline that has some bearing on the potential for prehistoric resources in the offshore and tidal zone (e.g., Kraft 1971; Belknap and Kraft 1977; Kraft 1977; Kraft and John 1978; Kraft et al. 1979; Belknap and Kraft 1981; Kraft et al. 1983). This research is summarized below in Chapter 3.

Despite the relative scarcity of prehistoric archaeological research in the study area vicinity. more than a dozen underwater surveys have been directed over the past decade towards historic period submerged and shoreline cultural resources in the Delaware Bay and Lower Delaware River drainage. The emphasis of these studies been primarily on historic shipwrecks and. in addition to the extensive survey activity. one shipwreck, the DeBraak, has also been salvaged at the mouth of the Delaware Bay. Most of these underwater investigations included a cursory literature search. A few entailed more detailed archival study. while others involved a combination of historic research and remote sensing. A small number of these investigations included diving to examine targets established by remote sensing.

Of particular relevance to the current investigations is a study performed for the Philadelphia District of USACOE in the late 1970s in connection with the development of a regional dredged material disposal plan for the tidal portions of the Delaware River and shoreline (Gilbert Commonwealth 1979). This study took the form of a cultural resources sensitivity analysis and supplied good general contextual information, but it was mostly non-specific regarding the deposition of resources in the main shipping channel. A similar study conducted for the USACOE in the early 1980s assessed the cultural resources potential of several specific proposed dredging and disposal sites along the Delaware River from Wilmington north to Philadelphia. Researchers concluded that "previously dredged deep channels and anchorages have virtually no potential for containing significant cultural remains" (GAI Consultants Inc. 1983:iv).

In another USACOE-sponsored study in the mid-1980s, an attempt was made to identify the site of the mid-17th-century Swedish trading post, Fort Elfsborg, which was known to lie along the Salem County, New Jersey shoreline of the Lower Delaware Bay (Heite and Heite 1986). This investigation concluded that the most likely location was off Elsinboro Point between the high water mark and the main shipping channel. Also in the mid-1980s, an initial underwater archaeological analysis was conducted in conjunction with planned improvements to the main navigation channel of the Delaware River between Wilmington and the Atlantic Ocean and a proposed construction of a new deepwater port. This study recommended further investigation for submerged cultural resources if the shipping channel between Wilmington and Brown Shoal was to be widened (Dolan Research, Inc. 1986).

Several cultural resources studies, involving both historical research and remote sensing. were conducted in the Delaware Bay in the mid-1980s. In 1982, Historic Sites Research. under contract to the Philadelphia District of USACOE, carried out a Phase II level cultural resources survey for a proposed offshore borrow area off Cape May. New Jersey. Nine magnetic anomalies were noted. three of which were deemed to be potentially significant enough to avoid in any future activities (Historic Sites Research 1982). In 1985, Tidewater Atlantic Research performed an offshore cultural resources survey for the section of the Delaware Bay between Pickering Beach and Broadkill Beach, Delaware for the Delaware Division of Soil and Water

Conservation. A magnetometer survey was conducted in four areas, all located west (i.e., on the Delaware side) of the main shipping channel -- Pickering Beach, Bowers Beach, Broadkill Beach and Kitts Hummock resulting in the detection of 11 anomalies (four off Broadkill Beach, three off Pickering Beach, three off Kitts Hummock and one off Bowers Beach). Seven of these anomalies were considered potentially significant and avoidance was recommended (Tidewater Atlantic Research 1985).

Two other offshore studies were performed around the same time by Karell Archaeological Services for the Delaware Division of Soil and Water Conservation. One of these studies was carried out in connection with the Slaughter Beach (South) Beach Nourishment Project, Sussex County Delaware. No anomalies were detected during the remote sensing component of this survey (Koski-Karell 1984a). The second investigation consisted of a background research study and field survey of the Delaware Inner Continental Shelf and included remote sensing work at two offshore locations near Indian River Inlet, both offshore and south of the current study area (Koski-Karell 1984b).

Over the past decade, most offshore and shoreline cultural resources investigations in the Delaware Bay have been carried out by Dolan Research, Inc. In 1984, this firm conducted a broad survey for the Pennsylvania Bureau for Historic Preservation which was designed to assist the state in developing a strategy for managing submerged cultural resources in the Delaware and Susquehanna Rivers. The survey included magnetometer and diving work in selected portions of the Delaware River between Essington, Pennsylvania and Trenton, New Jersey. The remote sensing portion of the survey identified 39 targets in nine different work areas. In addition, 13 derelict vessels, one visible shipwreck and one submerged shipwreck were documented. The submerged wreck, discovered in a dredged portion of the Mantua Creek anchorage, lay in 40 feet of water, and had been severely impacted by past dredging activities. Although highly disarticulated by dredging activity, it was still possible to date the remains on structural evidence to the early 19th century (Dolan Research, Inc. 1984).

In 1987, Dolan Research, Inc. conducted a remote sensing survey of 14 locations in the Delaware River between Artificial Island, Salem County, New Jersey and League Island, Philadelphia in conjunction with the proposed modification of the federally-maintained and administered shipping channel. A total of 66 targets were identified of which six were considered potentially significant and in need of additional archaeological investigation (Dolan Research, Inc. 1988a). Two related studies were also conducted by Dolan Research concurrently with the Delaware River main channel project: one at the mouth of the Maurice River, on the New Jersey side of the Delaware Bay (Dolan Research, Inc. 1988b); the other at the mouth of the Salem River, straddling both sides of the Delaware River (Dolan Research, Inc. 1988c).

More recently, Dolan Research has conducted additional magnetic and acoustic investigations in the Delaware Bay and Lower Delaware River, including: a remote sensing survey at the proposed site of a coal pier adjacent to the New Jersey shoreline, north of Oldmans Creek, where 11 targets, none of which were considered significant, were identified (Dolan Research, Inc. 1992a); another remote sensing survey in conjunction with the planned improvement of the Salem River, where six targets were identified, one of which was considered potentially significant (Dolan Research, Inc. 1992b); and a survey of a 200-foot wide proposed pipeline corridor across the Delaware River, just north of Tinicum Island, in which three remote sensing targets were identified, none of which was considered to be historically significant (included in Hunter Research, Inc. 1992).

In 1993, further underwater archaeological investigations were conducted by Dolan Research for the Philadelphia District of USACOE at various locations along Delaware Bay and River, again in conjunction with the planned improvement of main navigation channel. A total of 48 survey areas were examined as part of this project, comprising 12 locations where channel deepening was proposed, three locations where widening of bends in the channel was planned, and 33 locations where the side slope of the channel was to be altered. The survey included an intensive magnetic, acoustic, seismic and bathymetric remote sensing investigation as well as target analysis to determine the presence or absence of submerged cultural resources which might be affected by the proposed improvements. A total of 154 remote sensing targets were identified in the 48 different survey locations, 11 of which were designated as high probability targets because they possessed signature characteristics suggestive of submerged cultural resources. This program of underwater investigation also included ground truthing of five other targets that had been identified during the earlier 1987 underwater survey carried out by Dolan Research. One of these targets was identified as a late 19th-century side paddlewheel steamboat that is preliminarily considered eligible for listing in the National Register of Historic Places (Dolan Research, Inc. 1994).

The extensive amount of underwater survey work performed to date in the Delaware Bay and Lower Delaware River has focussed primarily and appropriately on the identification and evaluation of submerged cultural resources that might be affected by various project actions such as dredging work, navigation improvements and shoreline erosion control. Only one known historic resource has actually been physically removed from the floor of the Delaware Bay during the period that professional surveys have been undertaken. This project, not designed or executed by professional underwater archaeologists, involved the salvage in 1986 of the DeBraak, a late 18th-century British naval vessel, which sank off Cape Henlopen, Delaware in 1796, approximately three miles from the current study area. The salvage work entailed raising the wrecked vessel from a depth of 70 feet in an area of strong currents. The entire operation produced a rich collection of 18th-century artifacts, consisting of well over 2,000 items, and is important in demonstrating that historically significant material may still survive intact in a dynamic, high-energy environment such as that encountered around the mouth of the bay Shomette 1993).

Historic architectural survey is not a significant work component in the current investigation, since the area of study is primarily offshore and does not contain any standing structures. The tidal zone portion of the study area is also devoid of structures. The shoreline proper is lined with buildings, but except for a 3,000-foot long segment centered on the core of the settlement of Broadkill Beach, these are recently constructed and of no historic interest. The buildings within the heart of Broadkill Beach have been surveyed and recorded on Delaware Historic Preservation Office inventory forms. These mostly consist of seaside cottages dating from the 1930s and 1940s.

A wide variety of information sources have been consulted during the course of this study. Basic information sources routinely examined for all aspects of USACOE cultural resources work in Delaware include the site maps, files, technical reports and planning documents held by the Delaware State Historic Preservation Office and the Delaware State Museum, archival data held by the Delaware State Archives and the Historical Society of Delaware, and materials held by the Philadelphia District office of USACOE. Local and county libraries and historical societies were visited by project personnel during the course of background research.

The paleoenvironment, prehistory and history of the project vicinity are discussed in greater detail in Chapters 3 and 4 below. For filling out the prehistoric context of the project vicinity, the late C.A. Weslager's well-known overview of Delaware prehistory, Delaware's Buried Past (1968) and various recent publications by Jay Custer of the University of Delaware's Center for Archaeological Research (1984, 1986, 1989) have provided a suitable general context. For general historical information on the State of Delaware, a range of sources have been consulted (e.g., Scharf 1888; Conrad 1908; Reed 1947; Tyler 1955; Hoffecker 1977; Munroe 1984), while Harold B. Hancock's History of Sussex County, Delaware (1976) and Dick Carter's History of Sussex County (1976) both supplied more detailed data on Sussex County history. For general contextual and bibliographic information on the agricultural history of Sussex County, the recently completed historic context for the archaeology of agriculture and rural life in the period 1770 through 1940 (De Cunzo and Garcia 1993) is an invaluable research tool, although of tangential relevance to the current study.

Specifically for the underwater aspects of this study and other underwater investigations being conducted concurrently for USACOE, project personnel contacted local archaeologists, watermen, sport and commercial divers, knowledgeable professional and avocational historians, and interested lay persons with knowledge of Delaware maritime history. Primary and secondary sources, maps and atlases pertaining to the maritime history of Delaware were examined at maritime institutions, federal, state and local libraries and historical societies. At the National Archives, a variety of record groups containing information on shipwrecks, ship construction, naval activity, and maritime trade activities were consulted. Site specific research pertaining to individual vessels was conducted at the Philadelphia Maritime Museum, the Historical Society of Pennsylvania, and the Steamship Historical Society in Baltimore. Other national and regional repositories visited in conjunction with the maritime historical research include the Cartographic Branch of National Archives. Library of Congress. the Free Library of Philadelphia, University of Pennsylvania's Van Pelt Library as well as the various Delaware State agencies and USACOE offices noted above.

E. Research Methodology and Research Design

From a methodological standpoint, since this cultural resources investigation focussed chiefly on the potential for submerged resources within the Delaware Bay and shoreline resources within the tidal zone, a strongly cartographic and geographic approach was adopted for the background research. Emphasis was placed initially on mapping known and suspected resources. and analyzing these locations in relation to changes in sea level, shoreline configuration and land use. Cartographic research was supplemented with oral historical research. a review of secondary sources and consideration of paleogeographic issues. Fieldwork relied chiefly on remote sensing (for the underwater survey) and surface inspection and interviewing (for the terrestrial survey). At this level of investigation, this non-intrusive landscape and literature-based approach to the study of cultural resources provides the most effective means of assessing archaeological potential without engaging in a complex and expensive program of subsurface investigation and diving.

The potential for prehistoric resources was assessed with reference to Delaware's statewide management plan for prehistoric resources (Custer 1983). The study area lies within the Delaware Shore Zone. This portion of the state has produced negligible evidence for Paleo-Indian occupation and few clear predictive statements can be made concerning site locations and site functions during this time period (c. 14,000 to 8,500 B.P.). During the Paleo-Indian and succeeding Archaic (c. 8,500 to 5,000 B.P.) periods, sea levels were considerably lower than at present and the Delaware Bay resembled an estuarine lowland. The present-day Delaware Shore Zone would have been dissected by a series of east-flowing tributaries draining into a major river situated within what is now the bay. While it is difficult to reconstruct the topography precisely. and the existing data is limited, the Archaic period settlement pattern for this area is hypothesized to consist of: macro-band base camps on low terraces along major creeks, especially near lower order confluences; micro-band base camps on upper terraces of major creeks and near low order confluences up to 10km from major drainages: and procurement sites in the swamp floodplains of both major and minor creeks. on alluvial fans associated with swamps. bogs and lithic sources (Custer 1983:66).

During the Woodland I period (c. 5.000 B.P. to A.D. 1000), with the tidal zone encroaching further inland. the study area lay within a bay shore environment. Typically. one would expect to find micro-band base camps on the upper terraces of the Delaware near freshwater sources and tidal marshes. and procurement sites in tidal marshes and on swampy low-order floodplains. Mortuary sites characteristic of this period are anticipated in locations central to several micro-band base camps (Custer 1983:98). During the Woodland II period (A.D. 1000 to A.D. 1600), the study area would be similarly characterized as a bay shore environment, but now with macro-band base camps being expected on low terraces along both major and minor drainages in addition to procurement sites in tidal marshes and on swampy floodplains (Custer 1983:122).

Overall, in terms of the types of prehistoric resources anticipated in the Delaware Shore Zone, the Broadkill Beach study area lies within the South Bay section of the Coastal Management Unit and is considered to hold a high probability of yielding fair-to-good quality Woodland I and II period resources of the types outlined above. The area has a low probability of producing all predicted resource types for the Paleo-Indian, Archaic and Contact periods, with the exception of Archaic period procurement sites, for which a moderate probability is projected. Data quality for all three of these latter periods is likely to be poor (Custer 1983:146).

In framing research questions concerning historic resources, the project study area clearly possessed a low potential for all types of historic resources, except shipwrecks, since most of it presently lies underwater and was submerged throughout the historic period. The on-land portions of the study area were tidal wetland for the bulk of the historic period, although present-day Broadkill Neck Road, which terminates at the shoreline, dates from at least the mid-19th century. The area has apparently never contained any agricultural or transportation-related building complexes and has only during the present century been put to residential use. The land was both geographically peripheral and economically marginal to the local farmed properties, which were mostly situated a mile or more inland.

The study area was considered to have a moderate potential for shipwrecks, a potential that could only be effectively examined through systematic documentary research and remote sensing (for detail on the remote sensing methodology, see below, Chapter 5). Documentary data were used to provide a framework for identifying submerged historic archaeological resources which may have been deposited within the two offshore borrow areas or within the tidal zone, and to determine the extent of subsequent activities that may have removed or disturbed such resources. Historic and maritime activities within and along the shore of the Delaware Bay were therefore researched and documented in some detail. Both primary and secondary source materials, including historic maps and charts, were consulted to provide data on local and regional historical developments, while local residents and other experts on Delaware history and archaeology were also contacted.

Background research on the historic period established a generalized context for ultimate evaluation of any historic submerged sites that might be identified. While the emphasis of background research focused on maritime activity in the project vicinity, a broad based historic overview is essential for providing the proper framework for assessing the potential significance of submerged cultural resources. Historic maps, secondary and primary shipwreck lists, primary historical accounts, newspapers, and county and thematic histories were all used to develop a set of expected resources within the project area. Specifically, data from the background research was used to generate a list of shipwrecks and ship losses near the mouth of Delaware Bay.

Shoreline and submerged historic resources were considered with reference to the Delaware Comprehensive Historic Preservation Plan (Ames et al. 1989) and the ongoing state preservation planning process. Of particular relevance to the current study is the recently developed historic context on aids-to-navigation prepared for Delaware (Paul 1989), a survey of all remaining aids (Ames et al. 1991) and an archaeological survey of the Bombay Hook Lighthouse (De Cunzo and Silber 1992). The context of navigational improvement relates to the following themes identified in the Delaware Comprehensive Historic Preservation Plan: Fishing and Oystering; Transportation and Communication; and Architecture, Engineering, and Decorative Arts. Federal improvement of navigation in the Delaware Bay occurred during the third, fourth and fifth chronological periods established in the Delaware Plan (1770-1940). The context of regional shipping activities in and around Delaware Bay relates to the following themes identified in the Delaware Plan: Agriculture; Fishing and Oystering; Retailing and Wholesaling; and Transportation and Communication. Regional shipping patterns in Delaware Bay were an important feature of commerce during all five chronological periods established in the Delaware Plan (1630-1940).

In summary, apart from 20th-century standing buildings, the only historic resources likely to be of potential concern are: on land, agricultural landing complexes (for example, wharves and storage buildings) and shipbuilding, fishing or other marine facilities, and, underwater, shipwrecks (De Cunzo and Catts 1990:119-164; De Cunzo and Garcia 1993:255-256, 333-335). Despite the overall low potential for historic resources, it was noted that the coastal zone was identified in the Delaware Comprehensive Historic Preservation Plan as the top priority geographic zone for both above-ground and below-ground historic resources because it is "the area of longest continuous settlement in the state, it is tied to both the mercantile and industrial periods of the state's economy, and it is coterminous with the state's most fragile environmental resources" (Ames et al. 1989:81-82).

CHAPTER 2

GEOGRAPHICAL SETTING

The study area consists of a 2.5-mile stretch of the Delaware Bay shoreline known as Broadkill Beach and two potential sand borrow areas that are located offshore within the bay to the northeast of the small bayside settlement of Broadkill Beach (Plates 2.1-2.6). Broadkill Beach lies within the Atlantic Coastal Plain physiographic zone on the south side of the Delaware Bay, approximately five miles northwest of Lewes and seven miles west northwest of Cape Henlopen, where the Delaware drainage enters the Atlantic Ocean (Figure 1.1). Overall, the Coastal Plain topography is typically level to gently rolling, with elevations ranging between sea level and 100 feet above sea level, although the area examined during this study lies at or below sea level and is subject to tidal fluctuation. The underlying geology consists of the sands of the Columbian Formation, which were washed down from the Piedmont during the Quaternary period and redeposited over earlier sediments of Cretaceous age. These sands have been extensively reworked in recent millennia producing a largely featureless landscape, which in the Broadkill Beach vicinity is dominated by tidal marsh, patches of "fast" land and winding creeks (Vokes 1957; Jordan 1964; Delaware Geological Survey 1976).

Two east-flowing drainages -- the Broadkill River and Primehook Creek -- lie on the landward side of the barrier formed by Broadkill Beach itself (Figure 1.2). The Broadkill River originates upstream from Milton and empties into the Delaware Bay to the south of the study area, through the Roosevelt Inlet, northwest of Lewes City. Primehook Creek flows through the middle of the Prime Hook National Wildlife Refuge, entering the Delaware Bay near the northern end of the settlement of Broadkill Beach. These two drainages are connected by the Broadkill Sound, located to the southwest of and parallel to Broadkill Beach. While Primehook Creek is very narrow and unsuitable for navigation, the lower section of the Broadkill River has been navigable for most, if not all, of the historical period. The Broadkill River is approximately 300 feet wide near its confluence with Broadkill Sound and averages between 200 and 100 feet in width as one travels upstream to Milton.

Soils in the Broadkill Beach vicinity consist of coastal beach and dune land (Co), which is characterized as non-coherent, loose sand that is worked and reworked by waves, tides and wind. The portion of the beach that is washed by waves and tides is smooth and slopes gently upward away from the water. Irregular dunes and hummocks form above high tide and are constantly changed by wind action. Vegetation only occurs above high tide and consists of sparse stands of American beachgrass, beach goldenrod, and switch grass. The terrain to the west of the project area is predominantly Tidal marsh (Tm). This salty marsh, whose surface level fluctuates with the tide, is commonly underlain by sand to a depth of two or three feet. Vegetation in the wetter areas consists mostly of marsh-hay, cordgrass, neddlerush, Olney's three-square, saltgrass, and saltmarsh bulrush. On knolls just above the high tide line, the vegetation is bigleaf swampweed, groudsel bush, high-tide bush, smooth cordgrass, and switchgrass (Ireland and Matthews 1974).

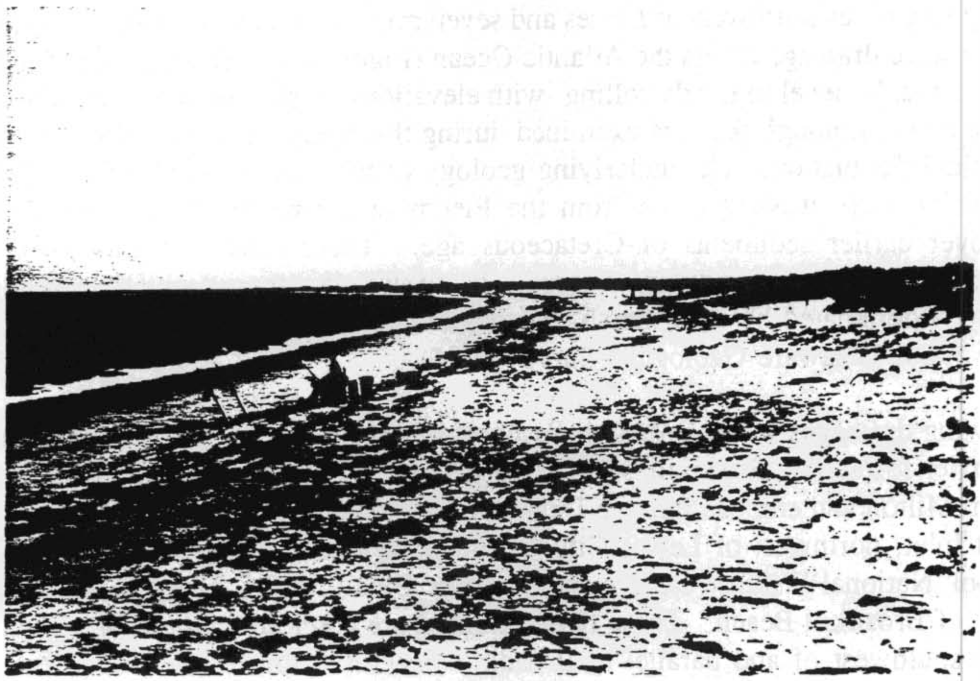

Plate 2.1. Beach Plum Island: general view looking southeast from the southeastern end of Broadkill Beach towards the city of Lewes. The Delaware Bay is located at left of the view (Photographer: William Liebeknecht, September 1994) [HRI neg. 94018/1:7A/8].

Plate 2.2. Broadkill Beach: general view looking northwest from the southeastern end of Broadkill Beach. The Delaware Bay is located at center and right of the view; the settlement of Broadkill Beach at center and left of the view (Photographer: William Liebeknecht, September 1994) [HRI neg. 94018/1:9A/10].

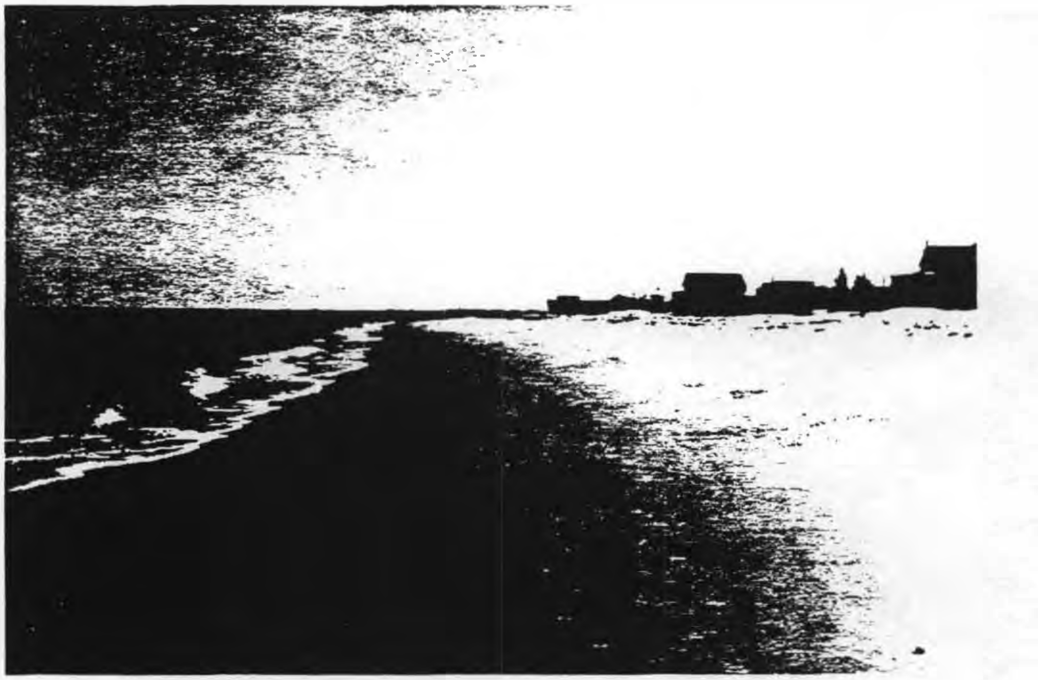

Plate 2.3. Broadkill Beach: general view looking southeast, standing directly across from the terminus of Broadkill Neck Road (Route 16) in the settlement of Broadkill Beach. The Delaware Bay is located at center and left of the view; the settlement of Broadkill Beach can be seen in the background and at right of the view (Photographer: William Liebeknecht, September 1994) [HRI neg. 94018/1:18A/19].

Plate 2.4. Broadkill Beach: general view looking northwest, standing directly across from the terminus of Broadkill Neck Road (Route 16) at the settlement of Broadkill Beach. The Delaware Bay is located at center and right of the view; the settlement of Broadkill Beach can be seen in the background and at left of the view (Photographer: William Liebeknecht, September 1994) [HRI neg. 94018/1:13A/14].

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Plate 2.5. Broadkill Beach: general view looking southeast from the northeastern end of Broadkill Beach. The Delaware Bay is located at center and left of the view; the settlement of Broadkill Beach can be seen in the background and at right of the view (Photographer: William Liebeknecht, September 1994) [HRI neg. 94018/1:19A/20].

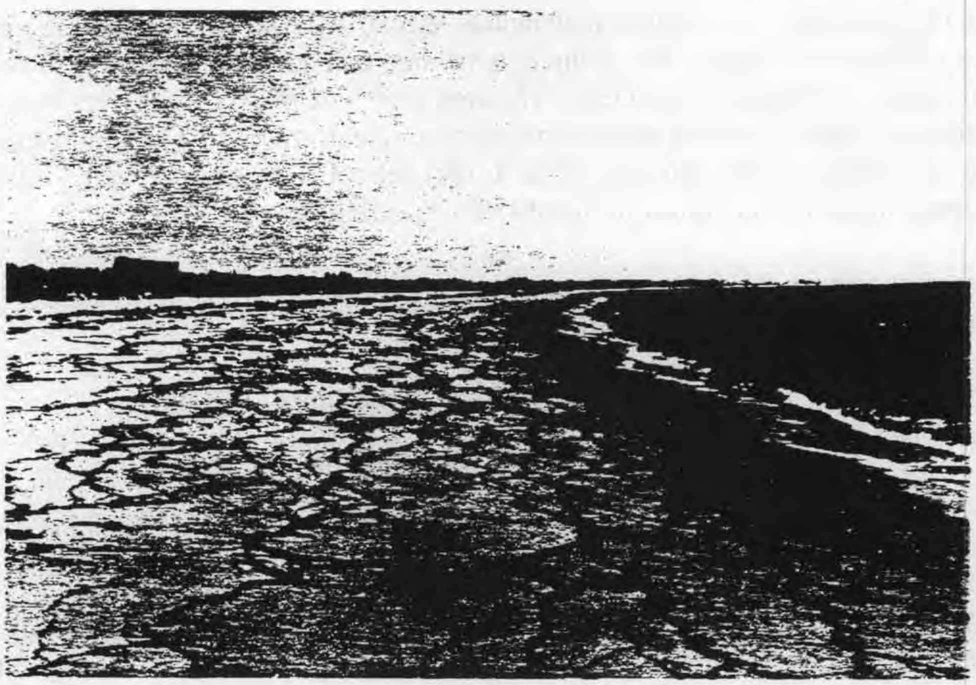


Plate 2.6. Primehook Beach: general view looking northwest from the northeastern end of Broadkill Beach. The Delaware Bay is located at center and right of the view; the settlement of Primehook Beach can be seen in the far background at left of the view (Photographer: William Liebeknecht, September 1994) [HRI neg. 94018/1:23A/24].

CHAPTER 2

GEOGRAPHICAL SETTING

The study area consists of a 2.5-mile stretch of the Delaware Bay shoreline known as Broadkill Beach and two potential sand borrow areas that are located offshore within the bay to the northeast of the small bayside settlement of Broadkill Beach (Plates 2.1-2.6). Broadkill Beach lies within the Atlantic Coastal Plain physiographic zone on the south side of the Delaware Bay, approximately five miles northwest of Lewes and seven miles west northwest of Cape Henlopen, where the Delaware drainage enters the Atlantic Ocean (Figure 1.1). Overall, the Coastal Plain topography is typically level to gently rolling, with elevations ranging between sea level and 100 feet above sea level, although the area examined during this study lies at or below sea level and is subject to tidal fluctuation. The underlying geology consists of the sands of the Columbian Formation, which were washed down from the Piedmont during the Quaternary period and redeposited over earlier sediments of Cretaceous age. These sands have been extensively reworked in recent millennia producing a largely featureless landscape, which in the Broadkill Beach vicinity is dominated by tidal marsh, patches of "fast" land and winding creeks (Vokes 1957; Jordan 1964; Delaware Geological Survey 1976).

Two east-flowing drainages -- the Broadkill River and Primehook Creek -- lie on the landward side of the barrier formed by Broadkill Beach itself (Figure 1.2). The Broadkill River originates upstream from Milton and empties into the Delaware Bay to the south of the study area, through the Roosevelt Inlet, northwest of Lewes City. Primehook Creek flows through the middle of the Prime Hook National Wildlife Refuge, entering the Delaware Bay near the northern end of the settlement of Broadkill Beach. These two drainages are connected by the Broadkill Sound, located to the southwest of and parallel to Broadkill Beach. While Primehook Creek is very narrow and unsuitable for navigation, the lower section of the Broadkill River has been navigable for most, if not all, of the historical period. The Broadkill River is approximately 300 feet wide near its confluence with Broadkill Sound and averages between 200 and 100 feet in width as one travels upstream to Milton.

Soils in the Broadkill Beach vicinity consist of coastal beach and dune land (Co), which is characterized as non-coherent, loose sand that is worked and reworked by waves, tides and wind. The portion of the beach that is washed by waves and tides is smooth and slopes gently upward away from the water. Irregular dunes and hummocks form above high tide and are constantly changed by wind action. Vegetation only occurs above high tide and consists of sparse stands of American beachgrass, beach goldenrod, and switch grass. The terrain to the west of the project area is predominantly Tidal marsh (Tm). This salty marsh, whose surface level fluctuates with the tide, is commonly underlain by sand to a depth of two or three feet. Vegetation in the wetter areas consists mostly of marsh-hay, cordgrass, neddlerush, Olney's three-square, saltgrass, and saltmarsh bulrush. On knolls just above the high tide line, the vegetation is bigleaf swampweed, groudsel bush, high-tide bush, smooth cordgrass, and switchgrass (Ireland and Matthews 1974).

CHAPTER 3

PALEOENVIRONMENT AND PREHISTORIC BACKGROUND

Barrier islands and adjacent Atlantic coastal regions are among the most dynamic environments currently found on earth, and dynamic change was no less of a hallmark of these areas in the prehistoric past. As a consequence, paleoenvironmental reconstruction for any given coastal geographical location, such as the Delaware Bay and Mid-Atlantic coastal zone, is an extraordinarily complex task fraught with uncertainty and a sparsity of scientific data.

The Pleistocene epoch witnessed a series of cold periods and associated "ice ages," the most recent of which terminated approximately 15,000 years ago. One of the most dramatic effects of these "ice ages" was the lowering of ocean levels worldwide as water was frozen and trapped in glaciers and continental ice sheets. Estimates suggest that eustatic levels worldwide were 95 to 130 meters lower during the final Pleistocene glaciation (Milliman and Emery 1968; Kraft et al. 1983). Along the Atlantic Coast, the sea front lay at the edge of the modern continental shelf, 50 to 60 kilometers east of the current Delaware ocean coastline (Kraft 1971, 1977).

Overall climatic patterns have changed on a regional and continental basis during the Holocene (or Recent) epoch, which began at the end of the Pleistocene and continues to this day. Sea levels have risen, and continues to rise, as a result of the release of water from melting ice sheets. As the sea level rose, it began to transgress, or cover, the land mass of the coastal plain (the current Atlantic continental shelf) to the west. The temporal progress of this westward movement of the coastline, which continues at present, is indicated in Figure 3.1.

The implications of such dynamic changes for a paleoenvironmental reconstruction of the physical locations currently occupied by Broadkill Beach and adjacent nearshore areas are profound. Climatic changes resulted in a succession of vegetation types moving northward, while the coastline and associated marine and estuarine environments were approaching from the east. As temperatures warmed and the climate alternated between dry and moister periods during the Holocene, open grassy environments were replaced by boreal evergreen forests and then by deciduous forests (Table 3.1). As the coastline steadily approached, the local environment shifted from inland forest to salt tidal marsh to lagoon to coastal sand barrier or nearshore underwater marine deposits. A paleoenvironmental reconstruction must therefore consider both the generally northward-moving vegetational patterns arising from regional climatic shifts and the westward-moving coastal geomorphology associated with coastal environments.

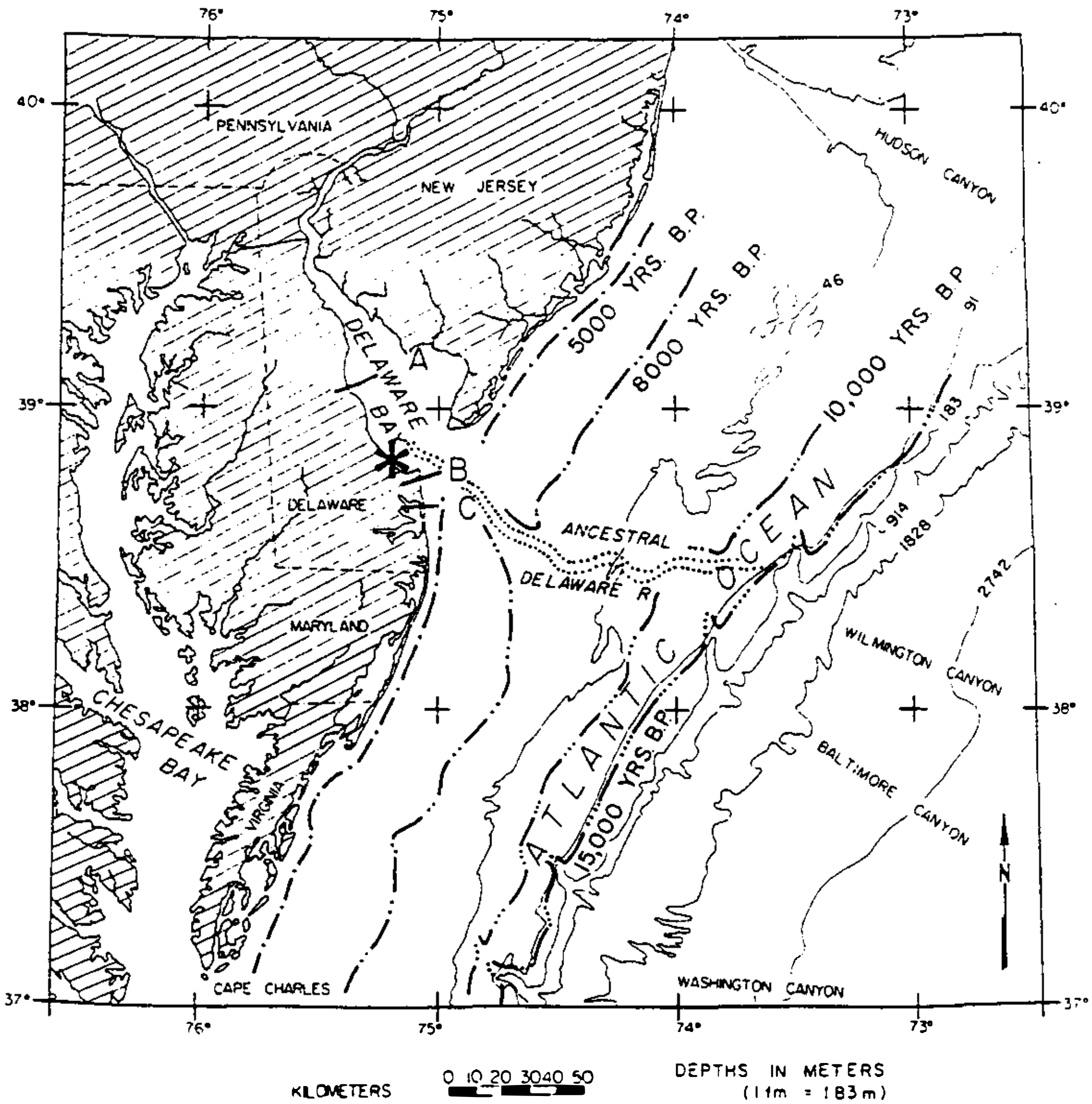


Figure 3.1. Shoreline Positions in the Mid-Atlantic United States at Successive Times in the Holocene (Source - Kraft et al. 1983:Figure 1). Project area starred.

TABLE 3.1

TEMPORAL CORRELATION OF PALEOENVIRONMENTAL AND CULTURAL DATA

Kyr B.P.	Climate	Vegetation	Culture
15			
	cool & wet Post-glacial	open tundra, spruce park-land	
	cool & wet (warmer) Pre-Boreal	spruce & fir forests	Paleo-Indian early Archaic
	10680		
10	warmer, drier Boreal	pine & birch pine & oak	
	9211		
	warm (near modern) Atlantic	oak, hemlock	Archaic
5			
	4610		
	warmest, driest Sub-Boreal	oak, hickory	Woodland I
	cooler, moister Sub-Atlantic	oak, chestnut	Woodland II
Present			

Source: Dent 1979; Custer 1989; Stewart 1990

The occupancy of prehistoric man within these dynamic and mobile environments is a primary focus of this study. Human occupation of the Upper Delaware River valley had begun by 11,000-10,500 years B.P. within a boreal forest primarily composed of pine and birch, with vegetation shifting, as the temperature warmed, to pine and oak (Dent 1979; Stewart 1990; Dent 1991; Stewart 1991). This vegetation cover extended throughout much of the region, although the presence of favorable microenvironments arising due to topography, solar exposure and water (ponds, lakes and rivers) exerted a significant influence on prehistoric subsistence and adaptations. Evidence of Paleo-Indian occupation on the coastal plains of New Jersey and across the northern half of the Delmarva Peninsula, generally in the form of isolated fluted point sites (Cavallo 1981; Custer et al. 1983; Custer 1989), reflect the presence of early human groups in the region.

As should be clear from the above discussion of transgressing sea levels, however, the region at the time of Paleo-Indian occupancy was not a coastal one. The current site of Broadkill Beach was covered by inland forest, perhaps near a tributary river flowing eastward towards the ancestral Delaware River (Figure 3.2). The Delaware River extended well out onto the modern continental shelf to the coastline (Swift 1973; Twichell et al. 1977). The Delaware Bay did not approximate its modern position until around 7,000 years B.P., and has continuously expanded since that time (Kraft and John 1978:46). Thus, any evidence of Paleo-Indian occupation in the vicinity of Broadkill Beach would therefore not relate directly to coastal environments but to exploitation of inland forest/riverine habitats.

Paleo-Indian hunting and gathering groups would of course have also occupied coastal areas, but these geographic locations currently lie on the continental shelf and are submerged. Fossil animal remains have been dredged from locations on the shelf (Merrill et al. 1965; Whitmore et al. 1967; Edwards and Emery 1977) which correlate with former estuarine locations and former shorelines, particularly the mid-shelf position of the shoreline around 10,000-9,000 years B.P. (Figure 3.3). The mammoth, oriented to more open habitats, may have occupied the region prior to the arrival of humans, but the forest mastodon was a contemporary of early Paleo-Indians. Deer and possibly caribou would also have been common inhabitants in the early Holocene forests. Fossil remains of walrus indicate the extent to which water temperatures were lower at the end of the Pleistocene and earlier in the Holocene (Edwards and Merrill 1977). The fossil shells of oysters, a shallow estuarine species, are another indicator of shoreline change (Merrill et al. 1965). Artifacts possibly associated with Paleo-Indian/Early Archaic groups are also occasionally found in underwater contexts, such as the bifacially-flaked point recovered recently from Blue Hill Bay on the coast of Maine (Crock et al. 1993).

Paleoenvironmental reconstructions suggest that in the Broadkill Beach vicinity tidal salt marshes may have emerged in advance of the transgressing shoreline by 7,000 years B.P. (Figure 3.3). Climatic conditions were warm and somewhat moister than in the preceding Boreal phase, with oak and hemlock as dominant vegetation species (Deevey 1952; Dent 1979), but perhaps with pine persisting in coastal areas.

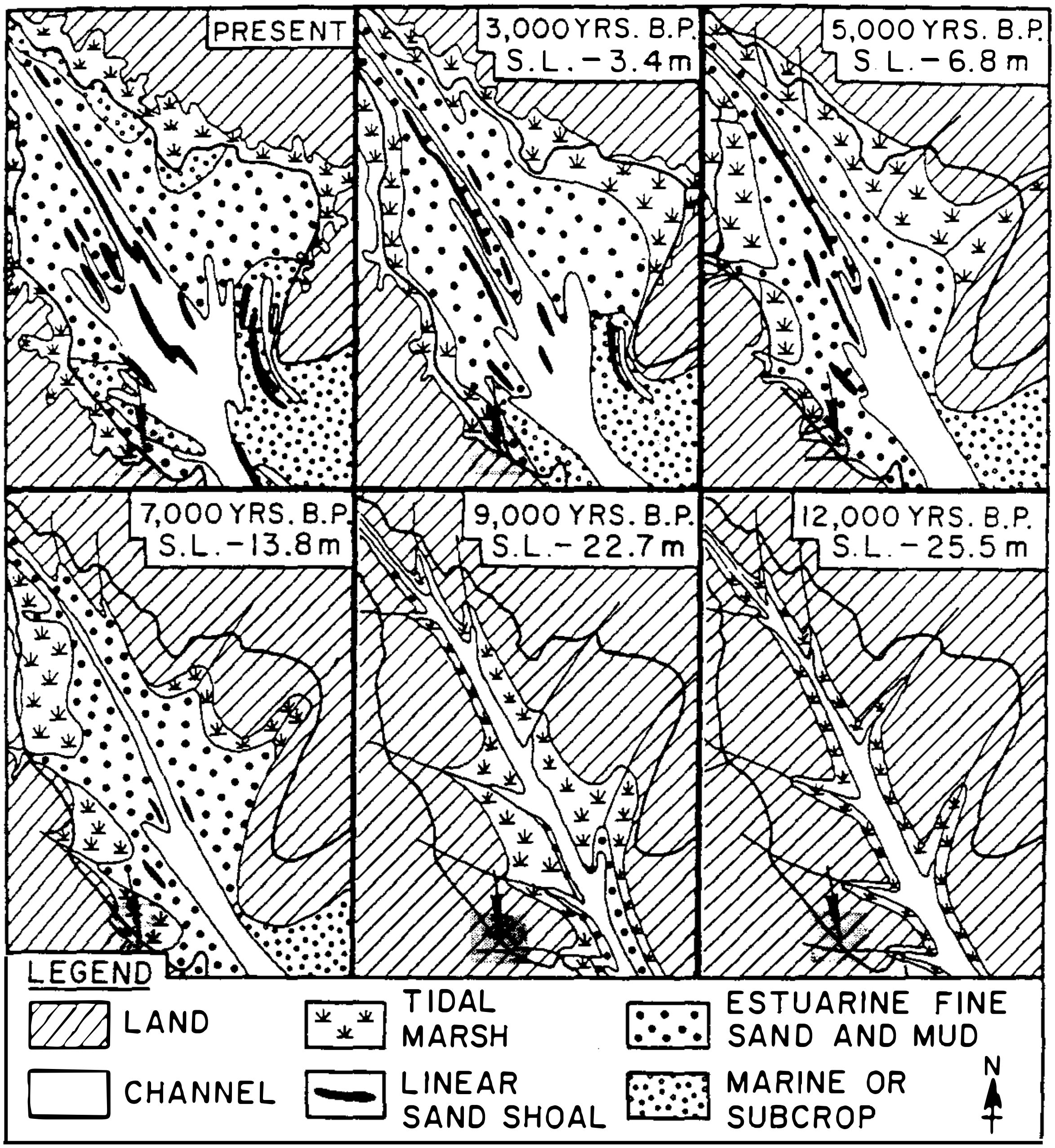


Figure 3.2. A Series of Paleogeographic Reconstructions of the Delaware Bay" (Source - Kraft and John 1978:Figure 4, modified from Weil 1977). The geographical location currently occupied by Broadkill Beach is marked on each successive map with an arrow.

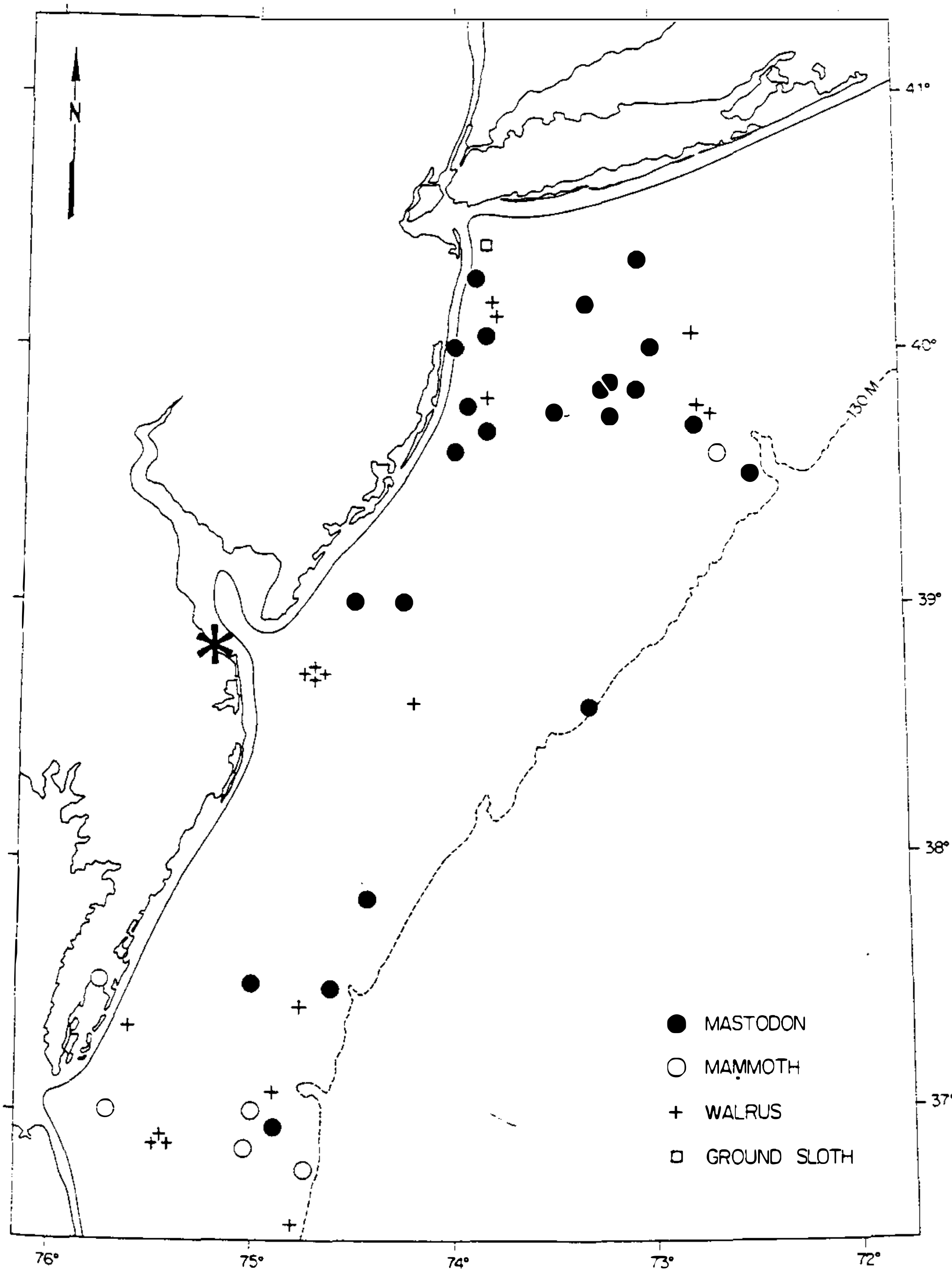


Figure 3.3. Fossil Finds on the Middle Atlantic Continental Shelf (Source - Edwards and Merrill 1977:Figure 7). Project area starred.

This period generally coincides with the local emergence of another archaeologically-defined human adaptational phase, the Archaic period. Material culture changes during the Archaic include the appearance of ground stone tools in addition to flaked stone artifacts. The raw materials utilized for tools also shifts from cryptocrystalline rocks to igneous rhyolite, suggestive of shifts in mobility and possibly of social organization (Custer 1989). Archaic sites in Delaware have been attributed to macro-band and micro-band base camps in areas of "maximum habitat overlap" as defined by Custer (1989), such as interior freshwater swamps and bay/basin areas. Coastal tidal salt marshes and estuarine environments would have remained food resource-rich habitats available for exploitation. One of the three prehistoric loci currently identified in the Broadkill Beach area, site 7S-D-42, has yielded a jasper Poplar Island projectile point attributed to the Archaic (MAAR, Inc. 1981) (Figure 3.4). The site is located adjacent to and slightly west of the modern salt marsh.

Climatic changes commencing about 4,600 years B.P. produced the warmest and driest conditions of the current post-glacial period, with oak and hickory becoming dominant tree species. These climatic changes appear to roughly coincide with the emergence of the archaeologically-defined Woodland I phase (Custer 1989). The Woodland I phase is typified by diagnostic lithic forms, an increase in base camps and the appearance of cache pits and ceramic storage vessels, indicative of a greater degree of sedentism. Evidence for long-distance trade/exchange is manifested in the presence of Adena material culture from the Ohio River Valley at habitation and mortuary sites dating from around 2,500 to 2,000 years B.P. Increasing exploitation of estuarine resources is noted during the period of Adena influence.

Two sites close to Broadkill Beach indicated Woodland I occupation. A site locus on land between the barrier beach and tidal marsh (7S-D-24) yielded shell-tempered ceramic sherds which probably date after the waning of Adena influence late in the Woodland I period. The previously-mentioned site 7S-D-42 contained a rhyolite Susquehanna Broadspear point, also associated with Woodland I. Paleoenvironmental reconstructions for the Woodland I suggest the proximity of tidal salt marsh, with perhaps the appearance of a lagoon environment after 3,000 years B.P. (Figures 3.2 and 3.4).

The warm and dry climatic phase began to yield to a cooler, moister modern climate with oak and chestnut vegetation about 2,000 years B.P., roughly coincident with the waning of Adena influence. By 1,000 years B.P. the trade and exchange network influence had disappeared, and the archaeologically-defined Woodland II phase emerges. Increasing evidence of sedentism is manifested in the expanded use of storage facilities and more permanent house structures. Increased gathering of shellfish and harvesting of plants reflect an intensification of food procurement evidently related to population growth. The emergence of agricultural production is also related to this sedentary settlement pattern which was maintained until European contact. Material culture is typified by distinctive ceramic forms and small triangular projectile points, the latter evidently indicative of bow-and-arrow technology (Custer 1989)

Two of the three local sites yielded evidence of Woodland II occupation. The previously-mentioned site 7S-D-42 yielded a Rappahannock fabric-impressed sherd attributable to the Townsend wares. The Teacup Island site (7S-D-44) represents a Woodland II shell midden, 20 to 50 cm thick, on a low wooded hummock surrounded by tidal marsh. Test pits on the hummock yielded 12 Rappahannock fabric-impressed sherds, one piece of fire-cracked rock, one jasper and one quartzite flake. Faunal remains were also present: 37 turtle shell and bone fragments, and shellfish remains. Clam and whelk predominated among the latter, but some oyster and scallop were present, as well as land snails (MAAR, Inc. 1981). Faunal evidence of exploitation of both marsh (turtle) and marine/estuarine (shellfish) resources was therefore apparent.

CHAPTER 4

HISTORICAL BACKGROUND

A. Historical Overview

The first documented European exploration of the Delmarva Peninsula occurred in the first half of the 16th century. Giovanni de Verrazano (1524) and Estevan Gomez (1525) were the first explorers to visit the Delaware Coast. However, Henry Hudson, sailing in the Half Moon in 1609, was the first individual to explore the region in any detail. Hudson first discovered the bay while surveying the northeast coast of North America for the Dutch East India Company. He documented the entrance of Delaware Bay, but did not explore up into the upper bay and river. His observations of the bay were recorded and eventually stimulated interest in additional exploration, trade and colonization of the region. In 1614 the State General of Holland granted the merchants of Amsterdam and Hoorn exclusive privileges to trade between forty and forty-five degrees of latitude in an area identified as the territory "New Netherland."

The first Dutch explorers came to the Delaware Bay from New Amsterdam (New York City) in October 1614. By decree from the Hague dated October 11, 1614, the owners of five Dutch ships were authorized to establish the United Company of Merchants with the exclusive rights to explore the area between New France in the north and Virginia to the south. Captain Cornelius Hendrickson then became one of the first to explore the bay aboard the Onrust (Restless). Captain Hendrickson produced the first chart of the Delaware Bay and River in 1616. Included in a brief report submitted to the Dutch merchants, Hendrickson claimed to have found "certain lands, a bay and three rivers situated between 38 degrees and 40 degrees" (Weslager 1961:45).

European settlement in Delaware commenced soon after the establishment of the Dutch West Indies Company in 1621 and was focussed initially in the Lewes area on the western side of the Delaware Bay inlet. As early as 1622, a brick house, probably serving as a trading station, was apparently in existence near the bay on Lewes Creek. In 1623, the Dutch East India Company constructed the first of several fortifications on the east shore of the bay. This was followed in the early 1630s by the creation of a Dutch patroonship, also centered in the vicinity of present-day Lewes. A small whaling station known as Swanendael was established here in 1631, but within a couple of years this was abandoned, following conflict with the local Indians.

Swedish explorers were also active in the Delaware Bay region. In 1629 the Swedish West Indian Company purchased from the Indians a two mile wide tract of land on the west side of the bay which extended 32 miles from Cape Henlopen north to a location above present Bowers Beach, Delaware. Although the purchase was ratified in 1630, it was not until Peter Minuit arrived with an expedition in 1638 that the Swedish attempted to settle the region. In this year a Dutch-Swedish trading enterprise established a more permanent presence further upstream in the Wilmington area, following the construction of Fort Christina.

After these early settlement attempts, Dutch interest in the area faltered, and in its place Swedish and, to a lesser extent, Finnish settlement gradually took root. This activity was characterized chiefly by a network of farmsteads scattered along the principal drainages flowing into the Delaware River from below the Christina River to the mouth of the Schuylkill. There appears to have been minimal European settlement activity in the Atlantic Coastal zone below Lewes in the first half of the 17th century (Hazard 1850; Scharf 1888; Pusey 1903; Munroe 1984:15-25; De Cunzo and Catts 1990:27-29).

In the early 1650s, the Dutch sought to re-establish their dominance over the Lower Delaware and erected a fort, named Fort Casimir, on the site of present-day New Castle. After sporadic skirmishing and political maneuvering, the Dutch eventually succeeded in exercising control over the Swedish-settled areas in 1655. In 1658, the Dutch re-colonized the settlement of Swanendael, but even with Dutch rule, much of Delaware remained strongly Swedish in a cultural sense. For example, a distinctive measure of Swedish settlement in the area was the preference for log-constructed houses. The period of Dutch control was also short-lived, which probably also helped to preserve the Swedish influence, for in 1664, following the fall of New Amsterdam, the English took over all Dutch holdings in the Middle Atlantic region (Weslager 1961; Munroe 1984:24-44; De Cunzo and Catts 1990:29-30).

King Charles II initially placed Delaware under the military control of Sir Robert Carr and made a grant of lands in the Delaware Valley to his brother James, Duke of York. The Duke sent a flotilla of warships under Carr's direction to subjugate the Dutch and Swedes and institute British control along the shores of the Delaware Bay.

In the late 1660s and early 1670s, there was a gradual transference of political power from the Dutch to the English. A brief hiatus in this process took place in 1673-74 when the Dutch recaptured many of their former New World possessions from the English during the third Anglo-Dutch War, but the latter soon re-established control of the Lower Delaware Valley region. From the late 1670s onwards new settlement resumed with a stronger English flavor, although land titles were the subject of considerable dispute between the Duke of York and Lord Baltimore (who had technically held claim to lands extending from the Potomac River north to the 40th parallel since 1632).

The land ownership situation was further complicated in 1684 when William Penn acquired the "lower three counties" (present-day Delaware) from the Duke of York to add to his Pennsylvania holdings received two years earlier. With Penn's involvement the colonization process and economic growth in Delaware became tied more closely to Philadelphia and neighboring Pennsylvania. Wheat, replacing the earlier crops of rye, barley and tobacco, was milled locally and marketed in Philadelphia. Lumber in the Lower Delaware Valley was similarly milled locally and shipped throughout the region. Most farmsteads were situated within eight miles or a half-day's journey of a mill or shipping wharf (Weslager 1961; De Cunzo and Catts 1990:30-35).

The later colonial period was one of settlement consolidation and intensification of agriculture. Between 1725 and the mid-1750s, large numbers of English and Scotch-Irish arrived in the three Lower Counties, most of these immigrants being Quakers, Presbyterians or Methodists, and many being indentured servants. Other European groups and African slaves were also represented in these population movements. Between 80% and 90% of the Lower Counties population was engaged in agriculture. Philadelphia remained the principal economic hub of the region, but secondary market towns and small port communities also developed. In the project vicinity, Wilmington (closely associated with the nearby Brandywine mills), New Castle and Lewes began to emerge as viable port communities and regional trade centers in the second quarter of the 18th century. Other nucleated settlements developed locally at Newport, Newark and Christiana Bridge (De Cunzo and Catts 1990:41-51).

For the entire later colonial period, central and southern Delaware remained predominantly agricultural, the landscape still being characterized by dispersed farmsteads and a loosely defined road network contained within a framework of long lot subdivision. The "long lot" settlement pattern was very much the norm for the Mid-Atlantic region, being strongly in evidence not only in Delaware, but also in New Jersey and Pennsylvania (e.g., Wacker 1975; Lemon 1972). This system of landholding emphasized the importance of river and coastal transportation over roads, and most farms required their own landings or easy access to the water to ensure their survival. In addition to farming, fishing and logging were the other main economic pursuits (Carter 1976; Hancock 1976).

The social and economic life of many Delaware inhabitants was considerably disrupted during the Revolutionary War, with the British blockading shipping and conducting raids along the shores of the Delaware Bay (De Cunzo and Catts 1990:51-52). Southern Delaware was largely unaffected by this activity, although trade and commerce were sporadically disrupted. In part, the pro-Loyalist sentiments of many of the southern Delaware planters ensured their being spared harassment by British warships and landing parties (De Cunzo and Garcia 1993:21).

In the early Federal period (circa 1780-1810), Delaware history was characterized by a rapid growth in population and a relative decline in agricultural productivity. In an effort to increase their crop and livestock yield, many farmers cleared and improved marginal land, but to little avail, and there was a noticeable outmigration of farmers to the west in the 1820s and 1830s. Commerce and industry fared somewhat better than agriculture, and there was an increase and diversification in water-powered milling during this period. Transportation improvements, chiefly the turnpikes and the construction of the Chesapeake and Delaware Canal, facilitated the process of urbanization in many locations, although the canal, by simplifying shipping of goods between the Delaware and Chesapeake, actually contributed to the decline of a number of the towns in the Upper Peninsula (De Cunzo and Catts 1990:51-64).

The Broadkill area remained largely agricultural in the federal period, with the lumber and fishing industries continuing to be important. Corn was the principal crop being grown, and the raising of hogs and beef cattle was also a substantial contributor to the local economy. The few pre-existing villages grew gradually and additional nucleated settlements took root in the cultural landscape, most often centered on road intersections in the developing inland transportation network or on gristmills and sawmills (De Cunzo and Garcia 1993:22-23).

During this period, much of northern (and to a lesser extent central and southern) Delaware began to experience far-reaching and complex change owing to major forces (industrialization, urbanization, and transportation improvements) that were affecting the United States as a whole. Philadelphia's influence over the state's economy began to be challenged by the rise of Baltimore as a regional and industrial center. Agriculture diversified to include an increased emphasis on dairying and fruit and vegetable growing, and also underwent many important changes in areas such as drainage techniques, mechanization and the use of fertilizers. Towards the end of the period, to maintain profitability, Delaware agriculture became increasingly specialized and export crop production declined substantially. An important factor in agricultural specialization and in the growth of manufacturing in the state was the development of the railroad network from the late 1830s onwards. The railroads cemented Wilmington's position as the state's pre-eminent manufacturing and commercial center, but also stimulated the growth of towns and villages throughout the Lower Delaware Valley (De Cunzo and Catts 1990:64-77; De Cunzo and Garcia 1993:24-30).

Locally, in Broadkill Hundred, agriculture continued to dominate with mixed crop and livestock farming being the norm. By mid-century, a relatively well-developed secondary road network was in place and was replacing coastal shipping as the chief means of marketing agricultural produce grown in Sussex County. However, there were still few settlements of any size in Broadkill Hundred in the late 1860s, except for few small villages and a scatter of hamlets focussed mostly on mill sites. By far the most dominant feature of the cultural landscape was the dispersed pattern of farmsteads.

From the final quarter of the 19th century through into the mid-20th century, Delaware saw continued population growth, agricultural specialization, an increase in manufacturing activity, expanding towns, and the emerging influence of the automobile on economic activity and settlement patterns. The dominant trends of urbanization and suburbanization especially affected the northern part of the state, such that New Castle County at the turn of the century contained almost 60% of the population. The two more southerly counties, Kent and Sussex, remained in contrast essentially rural, their economies being based chiefly on market gardening, poultry farming and dairy production. Products, for the most part, were marketed in the region's major urban centers, Baltimore, Philadelphia and Wilmington. In Sussex County, specifically, the lumber and charcoal industry also persisted well into the 20th century (De Cunzo and Catts 1990:77-86; De Cunzo and Garcia 1993:30-32).

B. Broadkill Beach

Broadkill Beach is located within Broadkill Hundred, Sussex County. Both the hundred and the beach derive their name from the Broadkill River which flows from the historic port of Milton through the center of the hundred towards the Delaware Bay. As shown on the first comprehensive navigational chart of the Delaware Coast, surveyed by Joshua Fisher in 1776 (Figure 4.1), Broadkill River was historically known as "Broadkiln Creek."

Within Broadkill Hundred most 18th- and 19th-century activity centered around three landings located along Broadkiln Creek at Milton, Drawbridge and Oyster Rocks. Outside of these shipping areas, the cultural landscape of Broadkill Hundred was characterized chiefly by scattered farmsteads, most of which were located a mile or more inland from the shoreline of the Delaware Bay. As shown by the D.G. Beers Atlas of the State of Delaware published in 1868 (Figure 4.2), the study area was located within a lightly settled, poorly drained section of Broadkill Hundred known as Broadkiln Neck. The nearest building to the study area, owned by Wm. Hazzard and A. Wolfe, was located on the south side of Broadkiln Neck Road (Route 16), nearly one-half mile to the southwest of the shoreline. Broadkiln Neck Road was most likely in existence by the first quarter of the 19th century and its original course terminated at the Delaware Bay, near present-day Wall Island, approximately 3,500 feet to the southeast of its current alignment. The Beers map also shows that Broadkill Sound was much wider than it is today, while nearly half of present-day Broadkill Beach fell on the historic Cape Lewes.

As late as the first quarter of the 20th-century, as indicated by a circa 1914 Farm Journal Map of Sussex County (Figure 4.3), the study area was still undeveloped. However, by this time, the current Route 16 had been constructed from present-day Petersfield Island to the tip of Cape Lewes. A road roughly paralleling the coast was also in existence connecting the former Broadkiln Neck Road with this new section of Route 16, while a third road had been constructed along the north side of Broadkiln Creek, to the southeast of Broadkiln Neck Road. No buildings are shown at Broadkill Beach, but three buildings are shown within one-half mile of the project area. These include the previously mentioned Hazzard and Wolfe building, as well as two additional unnamed structures: one on present-day Petersfield Island; the other lying to the southwest of Broadkill Beach at the end of the new road that runs along Broadkiln Creek.

Files of the Delaware State Historic Preservation Office indicate that in 1983 an architectural survey of Broadkill Beach was completed by Kathy Goodard. With the exception of one building noted as a possible late-19th-century remodeled farmstead (Site S-3004), all of the buildings included in the survey (19 in total), were believed to have been constructed around the second quarter of the 20th-century. These buildings, all located within 2,000 feet of the terminus of Route 16, represent the original settlement on Broadkill Beach, and they mostly consisted of one to two and one-half story frame structures, with either log pier or cinderblock foundations. Most buildings also had cedar shake shingles on their roofs and sides. Since that time, the size of Broadkill Beach has increased dramatically, and today, Broadkill contains over 300 buildings, most of them frame residences.

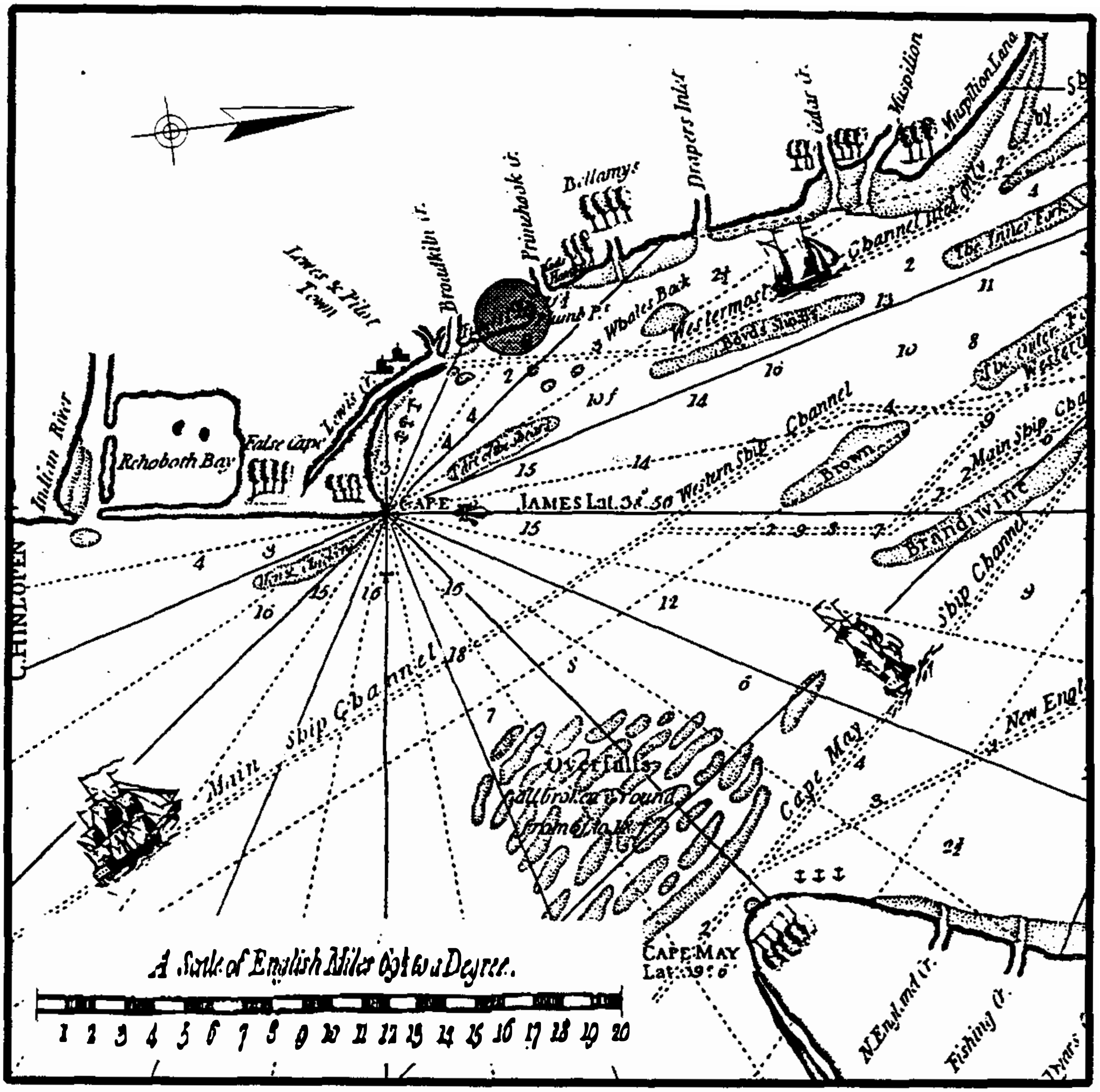


Figure 4.1. Fisher, Joshua. A Chart of Delaware Bay and River. 1776. Project area shaded.

Figure 4.2. Beers, D.G. Atlas of the State of Delaware. 1868. Scale 1 inch: 1 mile. Broadkill Beach Shoreline indicated by arrows.

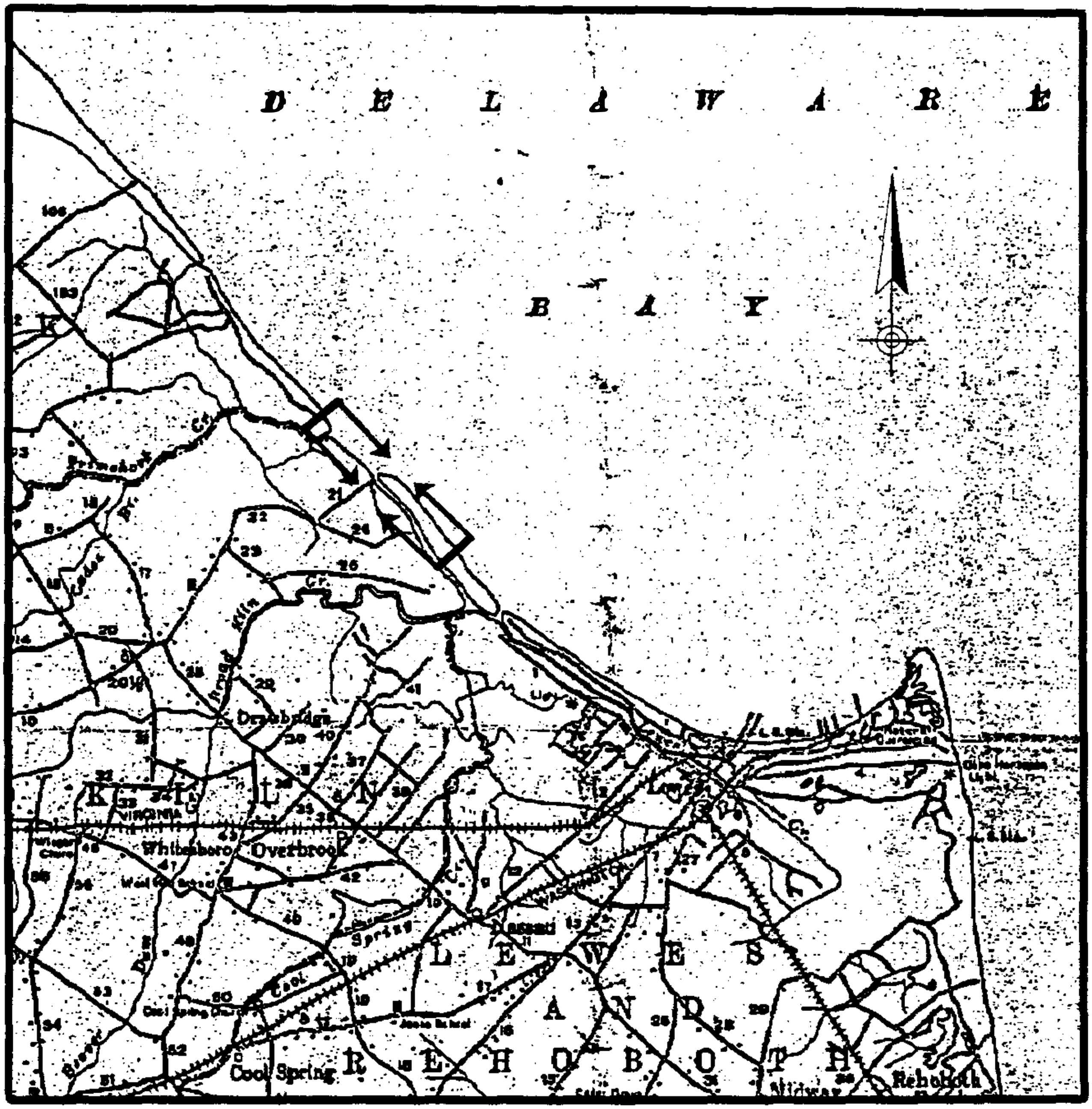


Figure 4.3. Farm Journal Road Map of Sussex County, Delaware. Circa 1914. Scale 1 inch: 2 miles. Broadkill Beach Shoreline indicated by arrows.

C. Navigational Aids

Although the Delaware Bay was visited by Henry Hudson in 1609 and explored by others within the next decade, the first comprehensive navigational chart of the Delaware Coast vicinity was not completed until 1776. In that year Joshua Fisher charted the waters of the Delaware Bay and provided the first bottom contours based on soundings (see above, Figure 4.1). In the first half of the 19th century several other maps and charts of the vicinity were privately published, but standardized charting of the coast was not initiated until the first United States Coast Survey was completed in the middle of the 19th century (Figure 4.4). In 1878, this agency was reconstituted as the United States Coast and Geodetic Survey and, from this time on, has periodically updated the chart of the vicinity with increasingly detailed and more accurate hydrographic information.

As the Delaware Bay affords the only suitable deepwater inlet along the 295-mile stretch of the Atlantic Coast between Chesapeake Bay and New York Bay, mariners frequently sought refuge in the mouth of the bay during periods of inclement weather. The earliest known aid to navigation in Delaware was the Cape Henlopen Light which was erected in 1767. The light helped to guide vessels into the bay and also served as a warning that the cape was nearby. The lighthouse continued to aid vessels entering and exiting Delaware Bay until it was destroyed by erosion in 1926. A second lighthouse was constructed on Fenwick Island in 1858 to further aid mariners traversing the Delaware coastal waters.

A major aid to navigation in the area was the construction of a pair of breakwaters inside Cape Henlopen and the creation of a Harbor of Refuge, thereby providing protection to vessels from storms and ice at the mouth of the Delaware Bay. Before the construction of these breakwaters, conditions at the mouth of the Delaware Bay were often more perilous than in the open ocean. Mariners, shipping companies, port officials and insurers all raised the issue of the need for a protective breakwater near the mouth of the bay to protect shipping. In a plea made to Washington, D.C in 1826, Alex Stewart encouraged officials to:

> "... place a shelter at the entrance of the bay [because] the commerce of the Delaware will not alone be protected and preserved by it, but that of the whole coast, daily passing and repassing its capes, together with foreign vessels who resort there when overtaken by accident at sea. All will find a haven where their crews can be recruited; damages repaired, and their wants fully supplied secure from mishap or danger, thereby the interests of merchants, and the lives of hundreds of individuals will be saved from jeopardy or untimely death" (cited in Hazard 1828:70).

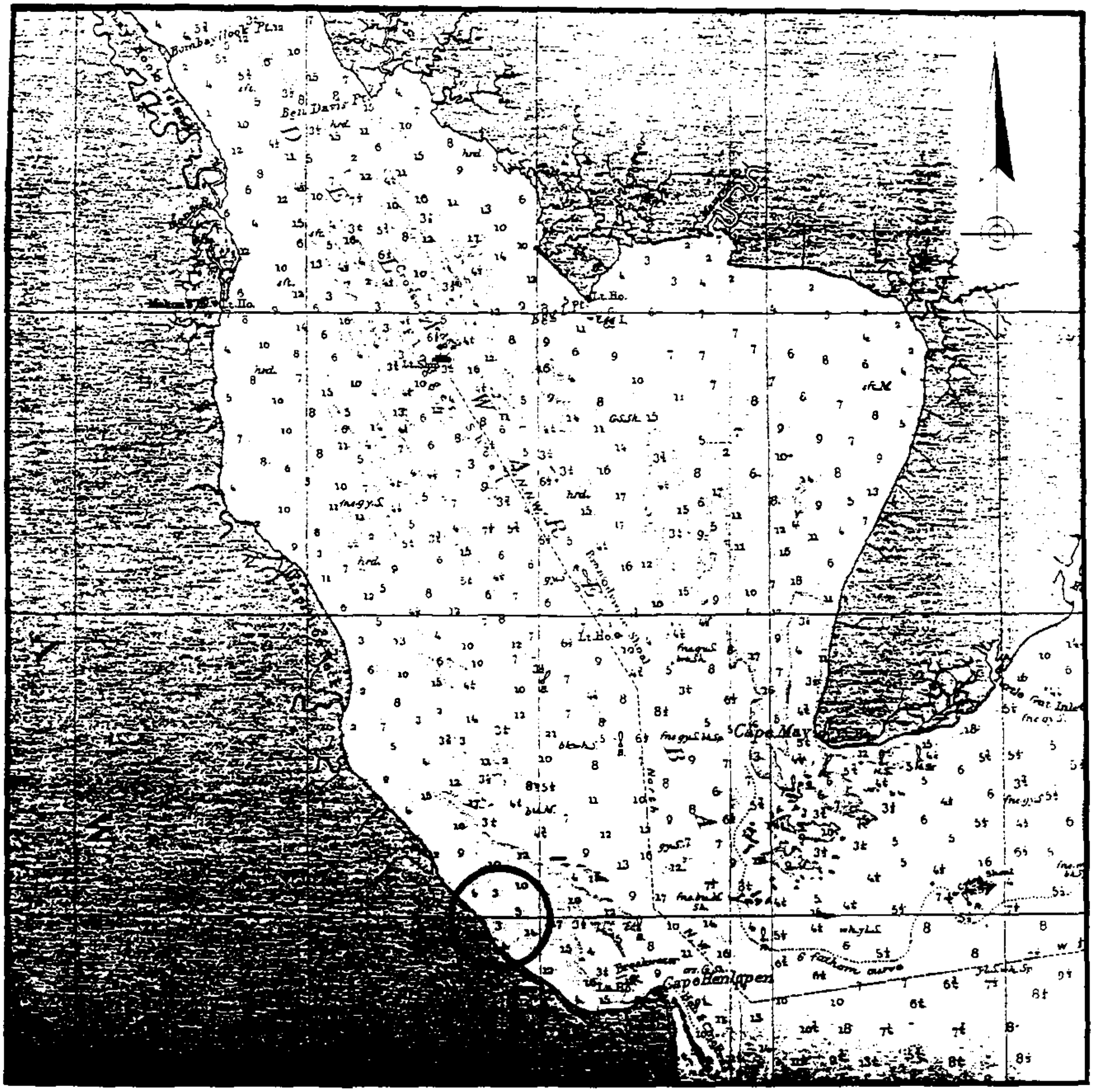


Figure 4.4. F.R. Hassler and A.D. Bache. U.S. Coast and Geodetic Survey of the Delaware and Chesapeake Bays. 1866. Scale 1 inch: 5.75 miles (approx.). Project area circled.

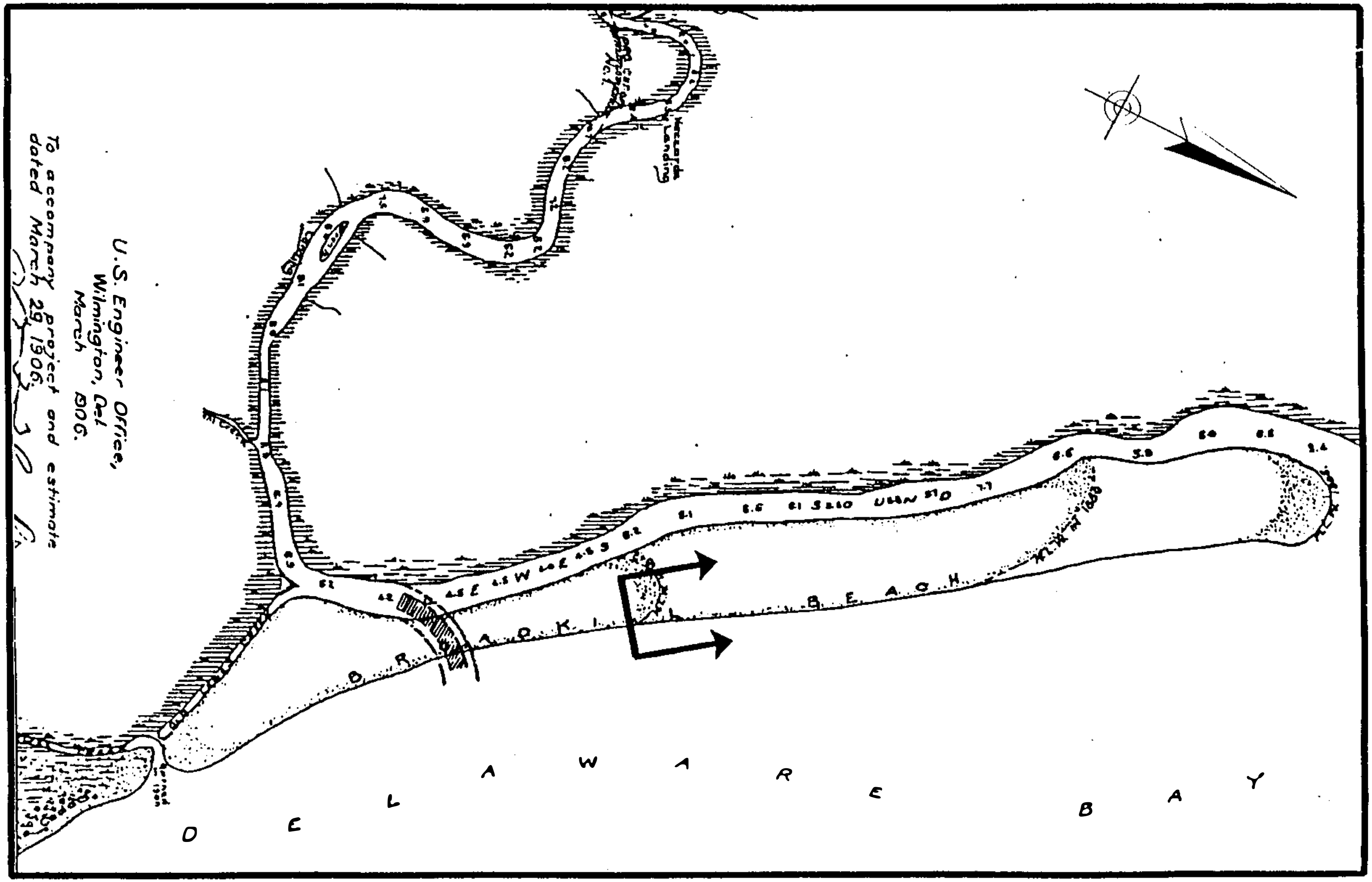
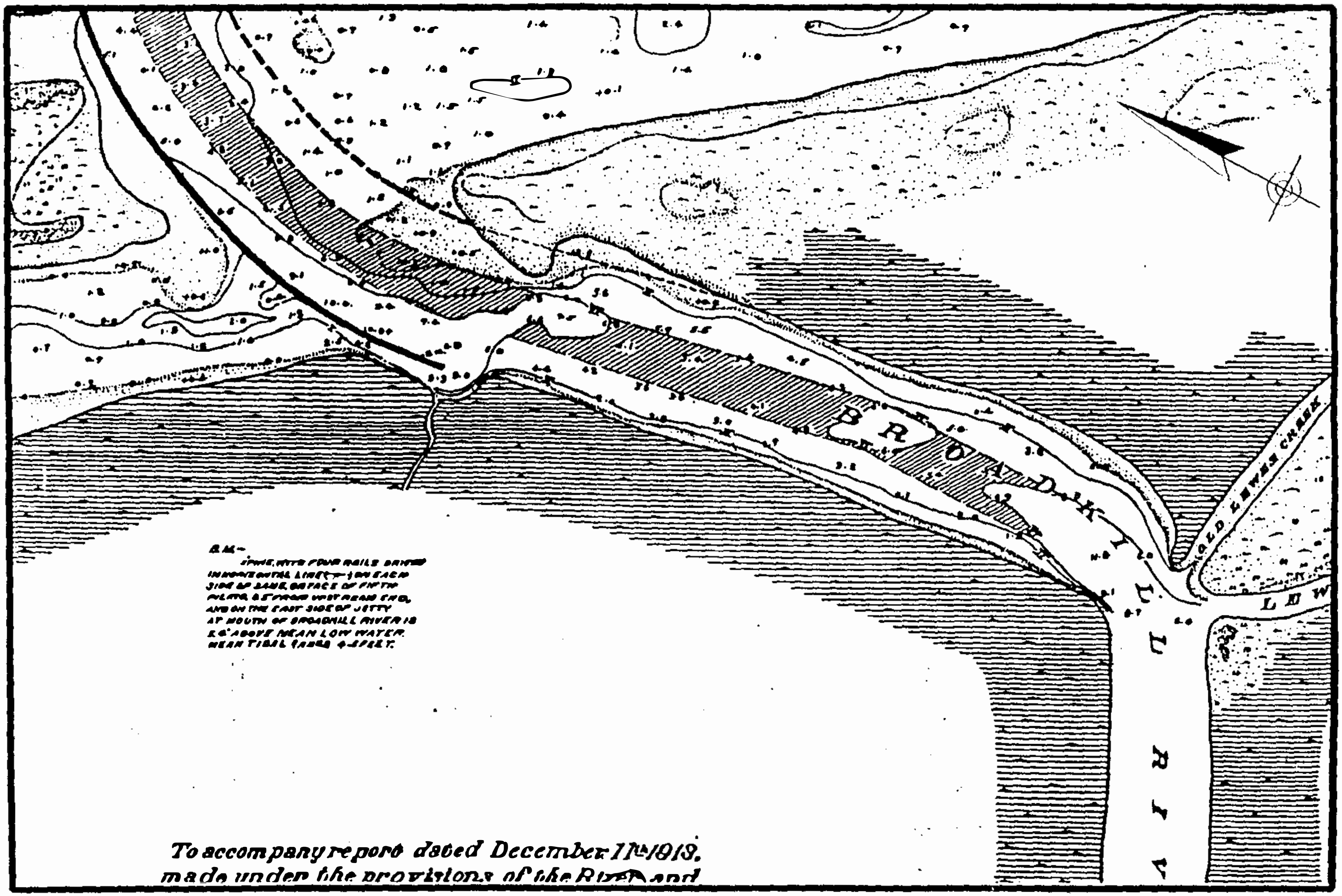


Figure 4.5. U.S. Army Corps of Engineers. Chart of Broadkill River showing ptoposed location of jetty. 1906. Scale 1 inch: 1,760 feet (approx.). Southeastern end of Broadkill Beach Shoreline indicated by arrows.

Figure 4.6. U.S. Army Corps of Engineers. Chart of Broadkill River showing existing jetty. 1913. Scale 1 inch: 240 feet (approx.).



In 1822 an Act of Congress was approved which appropriated over $22.000 for a survey calling attention to the suitability of the Delaware Bay as a Harbor of Refuge. After numerous delays. this survey led to the construction of the original, or inner breakwater. which was eventually completed in 1869. This structure was 2,558 feet long and had a detached ice breaker that was 1,359 feet long and separated by a gap of 1,390 feet. In 1882 a project was adopted which involved closing the gap between ice breaker and the breakwater, a task that was accomplished by 1898. However, even before this project was completed, the need for a more inclusive breakwater was evident. An outer breakwater was thus authorized by a Congressional Act in 1896. The resulting 8,040-foot-long breakwater was finished in 1901, providing the community of Lewes with the Harbor of Refuge that still remains in existence today (U.S. Army Corps of Engineers 1916).

Broadkill River, known until 1889 as Broadkiln Creek and then Broadkill River, rises in the neighborhood of Georgetown in central Sussex County. Milton, the historic head of navigation on the waterway lies approximately 12.5 miles above the mouth. In 1872, the Federal Government inaugurated an improvement project on the Broadkill. By 1907, a curved jetty was constructed to create a new mouth of the river, south of the existing mouth (Figures 4.5 and 4.6). A channel five feet deep was also cleared and maintained to Milton. In 1909, the jetty was repaired and reinforced with additional stone filling (U.S. Army Corps of Engineers 1913). However, a major storm breached a new opening from the Delaware Bay through to the Broadkill River, to the south of the jetty. This diverted the water flow and the former mouth of the river at the jetty eventually closed in the absence of any further improvements. By 1953, the Federal project which provided for an entrance channel from the Delaware Bay to the Broadkill River was abandoned. In addition to activity at the mouth of the Broadkill River, the Federal Government constructed a series of groins at Broadkill Beach in 1950 to stabilize the shoreline and control erosion (U.S. Army Corps of Enginers 1968).

D. Shipping Activity

The Delaware Bay was a major thoroughfare for shipping activity calling on the ports of Philadelphia and Wilmington throughout the colonial period. A small portion of that commerce plied the several tributaries that originate in the State of Delaware and feed into the Delaware Bay. Maritime activity within the offshore sand borrow areas was almost exclusively transient. Vessels crossing these areas were participating in the coastal trading networks that linked the Delaware River ports with other coastal ports from Maine to Texas. Additionally, maritime traffic crossing the study areas may have originated from or been bound for ports in the Caribbean, Central America or South America.

Farmers in Delaware's Sussex and Kent Counties used landings along most of the major Delaware Bay tributaries (e.g., Appoquinimink Creek, and the Murderkill, Broadkill, St. Jones, Smyrna, Mispillion, and Leipsic Rivers) to ship agricultural products to Philadelphia in exchange for manufactured items. Residents engaged shipwrights to build various types of vessels, primarily sloops and schooners, at strategic locations along the river banks so that this trade could be conducted with Philadelphia. By 1860, three-masted schooners carrying up to 400 tons of cargo were routinely entering and clearing the rivers of Delaware (Valle 1984).

Milton, at the head of navigation on the Broadkill River, had three shipyards producing sailing vessels. Between 1815 and 1915, it has been estimated that these three yards built 271 vessels. Vessel types included shallops, two-, three-, and four-masted schooners, brigs, brigantines, barkentines, steamers, barges and canal boats. The size of these vessels was continually increased so that they could remain competitive until they reached their maximum dimensions and were still able to be floated, completely empty, out of the winding river and into the bay. To launch these large vessels builders had to schedule their completion to coincide with high water from a spring tide. A typical vessel of this size was the Georize Taulan Jr. (1882) which was over 150 feet long with a gross tonnage of 465. Typically these vessels had to be towed to Philadelphia for completion of their masting, rigging and outfitting (Conwell 1983).

A regular steamboat service was established between Milton and Philadelphia during the second half of the 19th century. The steamer Mary M. Vineyard, 250 tons gross, carried a wide variety of general merchandise and passengers on a regular schedule between Milton and Philadelphia U.S. Army Corps of Engineers 1906). In addition to the steamers, freight boats, steam barges, and two- and three-masted schooners were actively engaged in transporting farm produce, piling and brick, fertilizer and coal from the Broadkill River to Philadelphia. However, shallow water at the mouth and the winding course of the river greatly constrained navigation on the Broadkill, and by the early 20th century, commercial maritime activity on the river had declined considerably. Railroads and all weather highways offered strong competition to the steamboat lines and by the Depression era most of the shipping lines had ceased operation (Valle 1984).

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CHAPTER 5

CULTURAL RESOURCES POTENTIAL

This chapter addresses in broad terms the potential for cultural resources within the proposed offshore sand borrow areas and along the 2.5-mile section of the tidal zone and shoreline of Broadkill Beach. First, the potential for prehistoric (and historic) terrestrial resources is discussed, i.e., resources that were formed on land and have since been inundated by water or sediment as a result of rising sea level and other offshore depositional activity. Second, the potential for underwater resources is examined, i.e., resources such as shipwrecks, downed airplanes or jetties, whose original formation occurred in a marine environment.

A. Submerged and Shoreline Terrestrial Resources

Much research has focused upon the geomorphology of Atlantic coastal regions and the Delaware Bay shoreline (Emery and Milliman 1970; Kraft 1971; Sheridan et al. 1974; Belknap and Kraft 1977; Weil 1977; Kraft et al. 1979) and of the implications of geomorphological change for archaeological site preservation (Kraft 1977; Belknap and Kraft 1981; Kraft et al. 1983). Sea level along the Delaware Bay appears to have risen fairly rapidly until around 7,000 years B.P., and then risen at a slower rate, with pronounced reductions around 5,000 years B.P. and 2,000 years B.P. (Kraft and John 1978:Figure 2). However, evidence exists to indicate that sea-level rise on a local basis was not a completely linear trend, but was to some degree cyclical with fluctuating transgressive rises and regressive falls (Kraft et al. 1983:105).

As land environments are ultimately swallowed by coastal marshes, barrier beaches and eventually ocean/bay waters, tectonic activity related to the offshore Baltimore Canyon Trough geosyncline and the potential "water loading" effect have resulted in a downward dip of stratigraphy below sea bottom (Kraft and John 1978:106) (Figure 5.1). Analyses of marine cores provide evidence of a transgressive sequence stratigraphy of sedimentary facies at increasing depths as one moves offshore: shallow fine marine sands (top); coarser barrier sands; lagoonal muds; tidal salt marsh; mud and peat; and Pleistocene land surface (bottom). Radiocarbon data reflect a parallelism of sea level dates as depth increases relative to the modern coastal plain (Belknap and Kraft 1977; Kraft and John 1978:106). Kraft and John cite these coastal Delaware data as classic examples of Walther's Law of Correlation of Sedimentary Facies, by which the horizontal distribution of sediments in present geographic environments is expected to be reflected in a similar vertical distribution of sediments from environments moving through geologic time (1978:106-108).

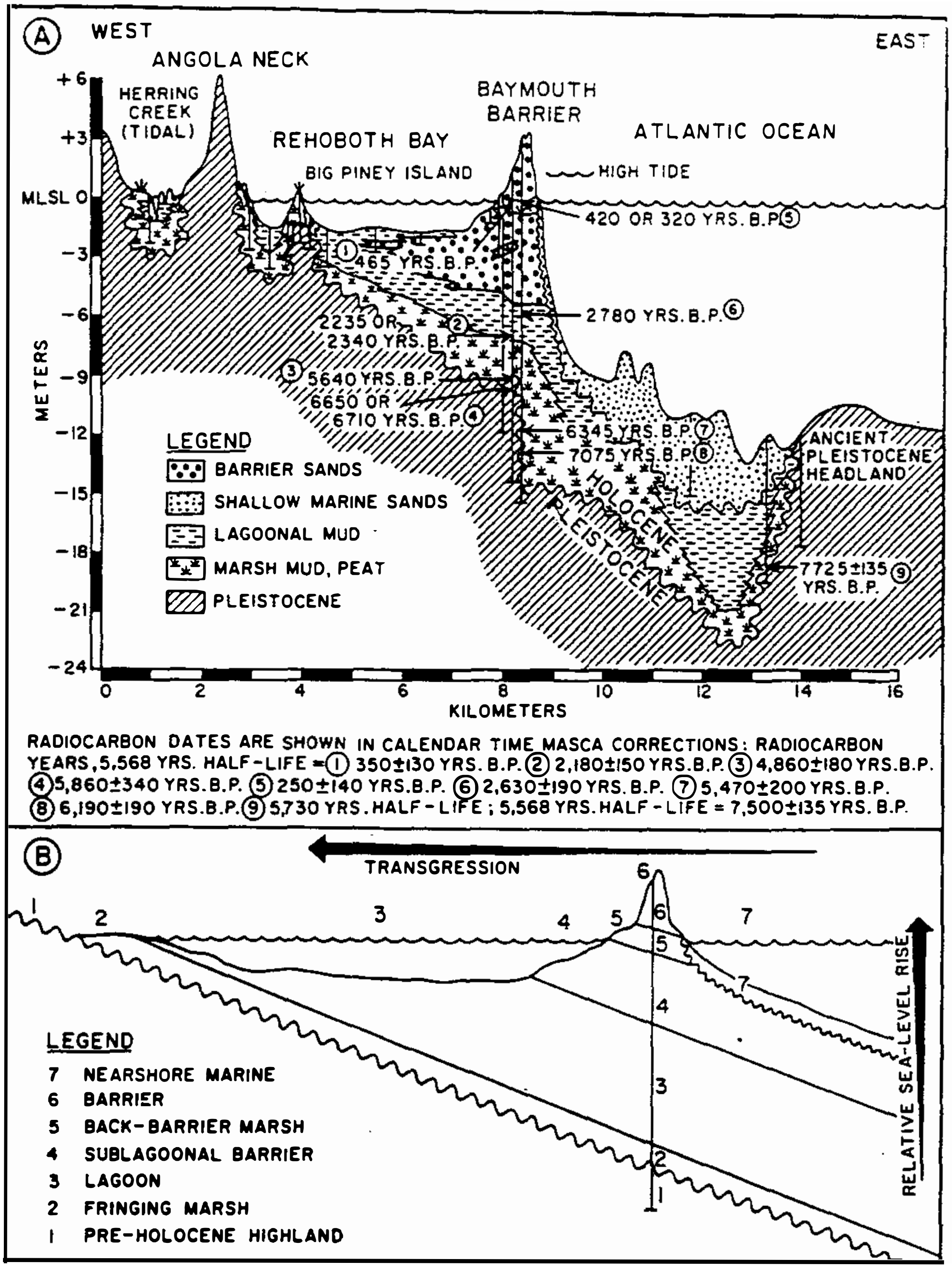

Figure 5.1. (A) A Geologic Cross Section across the Barrier Coast and Rehoboth Bay (Section line C on Figure 3.1). Note the similar sequence of geographical distribution of coastal sedimentary environments with the vertical sequence encountered in the drill boring. (B) A Schematic Illustration of the Nature of a Marine Transgression and Walther's Law of Correlation of Sedimentary Facies. Source - Kraft and John 1978:Figure 3.

Despite the horizontal movement of coastal environments, the sedimentary sequences discussed above indicate that the environmental structure and relative positions of environmental types have remained stable, i.e. as lagoon/barrier shorelines with fringing coastal marshes which often were cut by large estuaries of (presently drowned) rivers (Kraft et al. 1983:59). Kraft et al. (1983:111) emphasize that the preservation potential for a submerged archaeological site is a function of two principal variables: the pre-Holocene topography on which the site was deposited; and the rate of sea-level rise.

Figure 5.2, taken from Kraft et al. 1983:Figure 8, illustrates the potential impact of changes in coastal geomorphology upon archaeological site preservation. The bold arrows indicate areas of ideal site discovery potential beneath marine sediments. These locations occur along the flanks of former interfluves which lie below the marine eroded zone, yet are still shallow enough to be accessible (Kraft et al. 1983:112). Other site preservation scenarios are also considered in this illustration. Site 1, a headland site near a freshwater source, is based upon the Woodland mortuary site of Island Field; continued landward migration of the coastal barrier and sea would most likely consume this locus. Site 2, a shell midden at the edge of a marsh and lagoon (similar to the Teacup Island site mentioned above in Chapter 3) may conceivably be preserved in the marsh/lagoon mud facies below a rising sea level. Site 3 would have originated adjacent to an estuary or tidal river. Due to the delay between burial and arrival of the eroding shoreline, it would be more deeply buried and stand a greater chance of survival, although its accessibility is reduced (Kraft et al. 1983:110-111).

A geologic section through Lewes Creek Marsh (Figure 5.3; taken from Kraft and John 1978:Figure 16), a location a few miles south of Broadkill Beach, reveals a nearshore bottom of marine/estuarine silts and clays at Cape Henlopen. These muds rest upon earlier barrier beach/spit sands, which in turn rest unconformably upon Pleistocene coastal plain sediments. The section indicates that a relatively short-lived shallow lagoon had formed by late Archaic-early Woodland periods. Indeed, a regional paleogeographic reconstruction of particular relevance to Broadkill Beach (Figure 5.4; taken from Kraft and John 1978:Figure 15) suggests a series of lagoons had formed behind the coastal barrier. These lagoons and surrounding marshes provided rich habitats which were exploited by Woodland occupants of the region, including those of Teacup Island. If the offshore sediments represent earlier estuary or modern marine bottom, preservation of in-situ prehistoric remains would seem unlikely. It should be emphasized, however, that paleoenvironmental conditions and modern sedimentary sequences in the nearshore area off Broadkill Beach may be more conducive to site preservation.

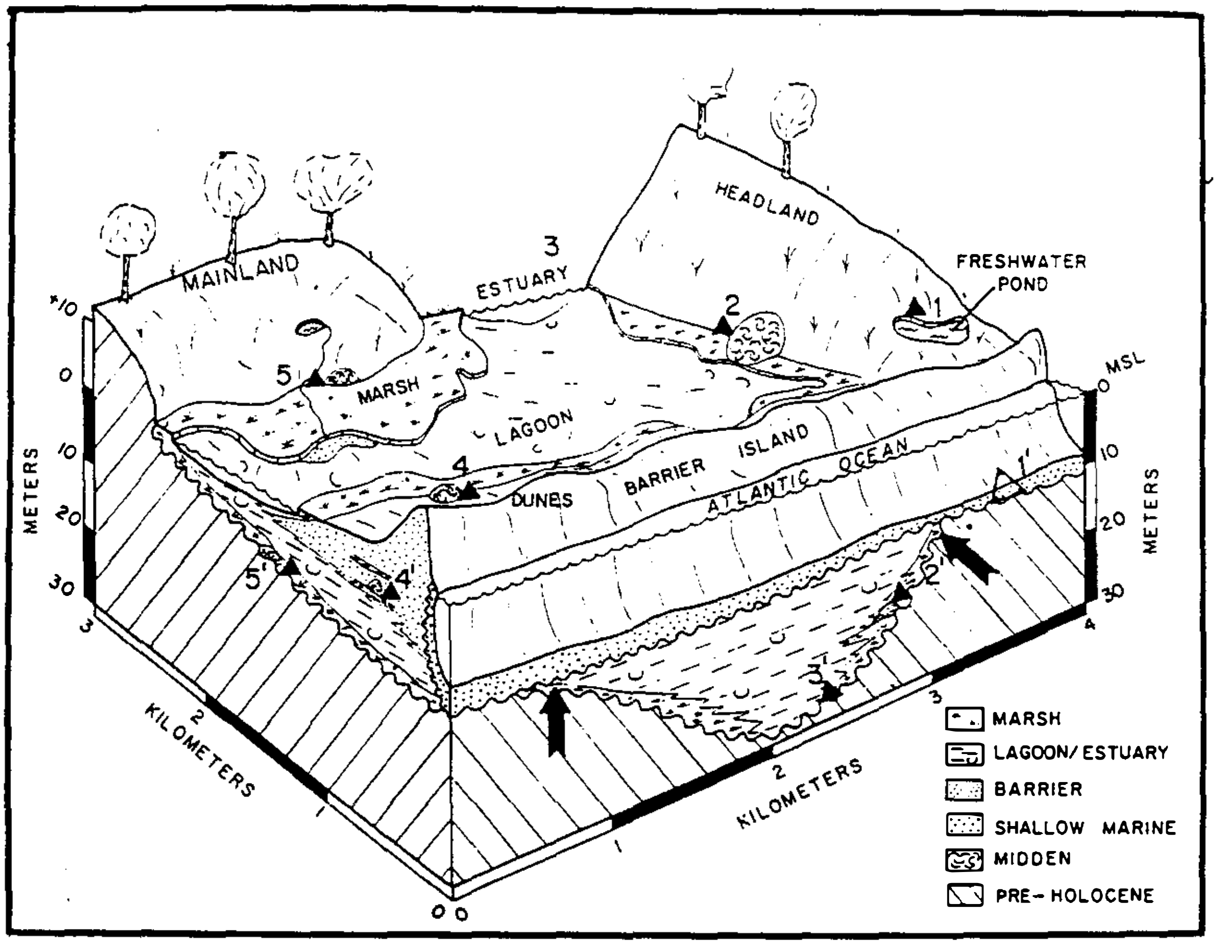

Figure 5.2. Block Diagram Illustrating Geologic Setting of Coastal Archaeological Sites in Delaware. Site numbers 1-5 indicate original environments of deposition; numbers 1'-5' reflect the geological settings of those sites after sea-level rise, coastal inland movement and/or burial beneath sediments. Source - Kraft et al. 1983:Figure 8.

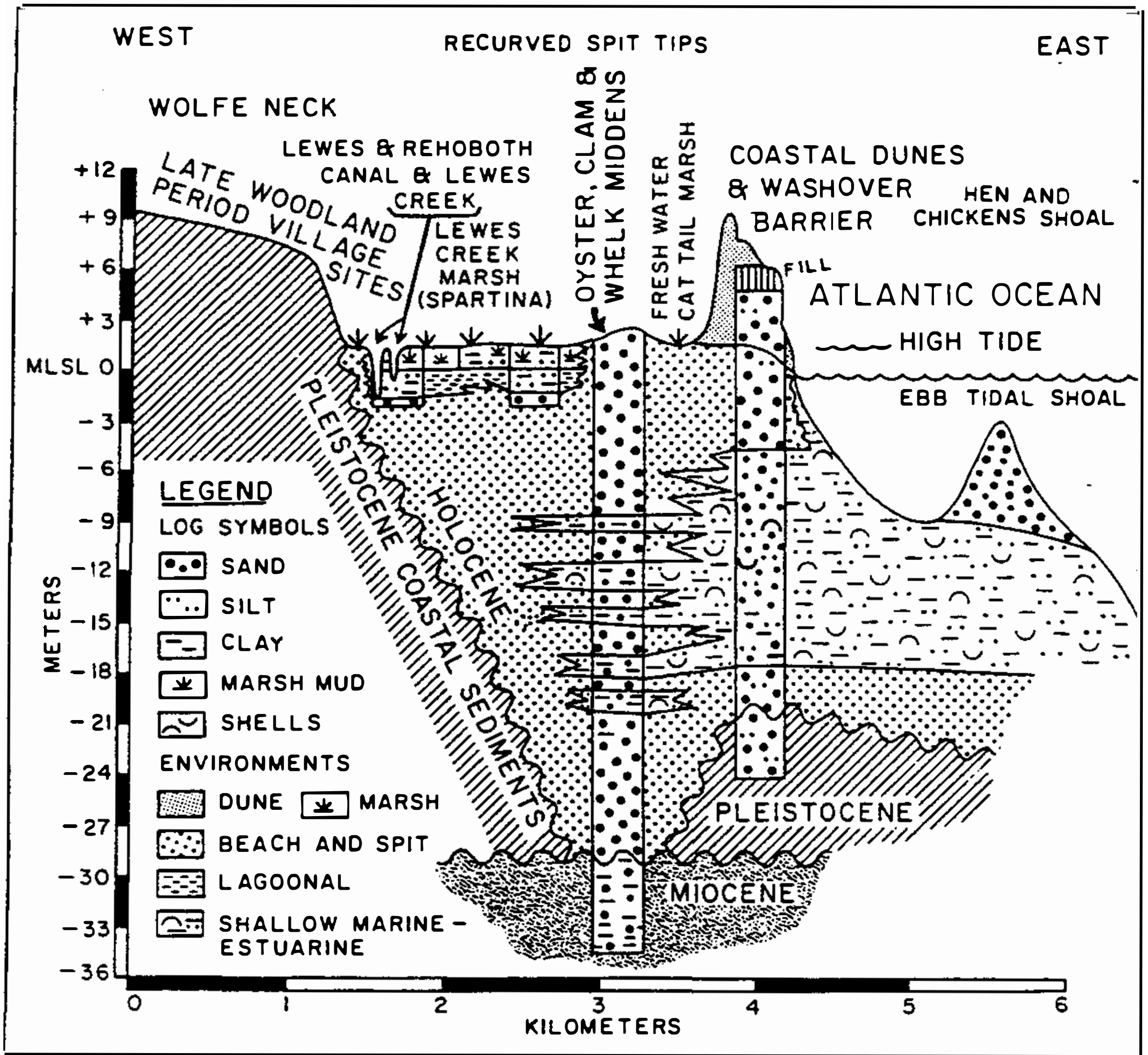

Figure 5.3. A Geological Cross Section across the Lewes Creek Marsh and Recurved Spit Tips of Cape Henlopen (Section line B on Figure 3.1). Source - Kraft and John 1978:Figure 16.

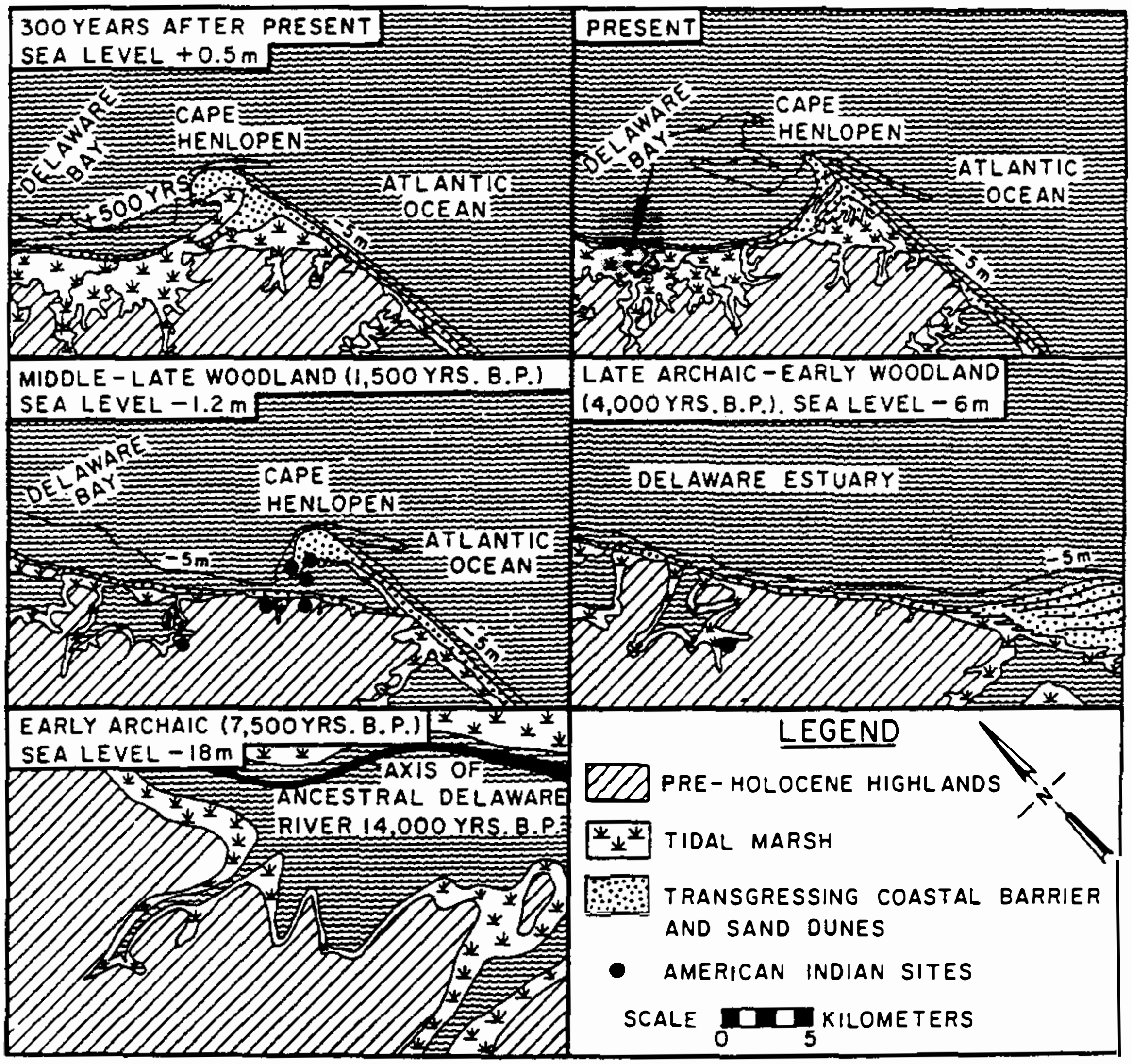

Figure 5.4. A Sequence of Paleogeographic Reconstructions of the Cape Henlopen Region at the Confluence of Delaware Bay and the Atlantic Ocean. Source - Kraft and John 1978:Figure 15. The modern location of Broadkill Beach is indicated with an arrow.

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Clearly, the work of Kraft and others along the Delaware shoreline demonstrates that the study of coastal geomorphology and environments is capable of providing useful insights into the nature and condition of submerged cultural resources that might exist in the Broadkill Beach vicinity. It is also clear that the inundation of prehistoric (and early historic) archaeological sites may result in extensive resorting or removal of the archaeological record. Furthermore, while isolated artifacts preserved in the bottom sediments could survive in an excellent state of preservation, the associated context of human activity may have been destroyed. The high energy environments that are often present along coastlines, such as is the case at the mouth of the Delaware Bay, will lessen the likelihood that fragile evidence of prehistoric populations would survive. Nevertheless, elsewhere offshore from the continental United States, there are examples where submerged terrestrial resources have survived inundation processes. For instance, inundated karst formations in Sarasota County, Florida and in the Gulf of Mexico off Fort Myers have produced evidence of prehistoric occupation (Ruppe 1979).

In addition to the relatively few documented occurrences of inundated terrestrial resources, considerable effort has been expended over the past quarter century in attempting to develop effective predictive models that can guide researchers intent on locating submerged prehistoric resources and assessing site preservation potential. Much of this work has taken place in the Gulf of Mexico and along the Continental Shelf of the Atlantic seaboard in connection with offshore gas and oil leasing activities (e.g., Coastal Environments, Inc. 1977; Bourque 1979). For the most part, these studies conclude that paleogeographic analysis (with particular reference to sea level change and coastal geomorphic processes), coupled with remote sensing and selective core sampling, can assist in narrowing down offshore areas where site preservation potential is high. As just one example, although the location and identification of submerged Archaic sites would be difficult, their association with shell middens should increase the chances of their being detected. Indeed, investigations in the Gulf of Mexico off the west coast of Florida have confirmed both the association of prehistoric material with submerged middens and the detectability of these sites using side scan sonar remote sensing (Ruppe 1979).

The macro-scale model-building studies noted above are valuable as an overall guide to preservation potential of terrestrial resources within large expanses of ocean, but they tend to be too broad and generalized for effective application in the study of small offshore tracts such as those proposed for sand borrowing off Broadkill Beach. The need for detailed, local paleogeographic data will always be paramount for site-specific offshore studies, and in most instances, such data is not readily available, and both expensive and logistically awkward to derive and interpret. The Delaware coastline is unusual in having a body of paleogeographic information available for reference which has allowed for a more deliberate assessment to be made concerning site preservation potential in the Broadkill Beach vicinity.

B. Underwater Resources

As with inundated terrestrial resources, the effect of coastal geomorphic processes may either erode or bury underwater resources, and the processes may occur rapidly or slowly over time. However, because of the "accidental" and rapid manner in which many underwater resources (notably shipwrecks) are formed, and the shorter elapsed time involved before their remains are sought, they are frequently better preserved and generally more easily discovered. Underwater resources, such as shipwrecks, because they usually constitute a stronger physical (topographic, magnetic) anomaly than most inundated terrestrial resources are also far more easily identified by remote sensing techiques involving the use of magnetic, acoustic or sonar detection equipment.

In many cases, the remains of shipwrecks may be submerged, but not buried beneath sediment. Shipwreck material deposited in even the shallowest environment can settle rapidly into the bottom with its associated archaeological record intact. The wreck of the De Braak (1798), discovered near the Delaware Breakwater close to the study area, provides a classic example. A good portion of the lower hull survived intact, along with an extensive associated artifact assemblage (Shomette 1993). Even in extremely high-energy environments, evidence of the ship structure frequently survives. Numerous other underwater archaeological investigations along the eastern seaboard of the United States -- off Massachusetts, North Carolina, Florida, and Texas -- and in the waters off other countries around the world (such as England, Israel and Turkey) offer examples where ship remains have survived largely intact with valuable archaeological data.

At many shipwreck sites, sand and light mud similar to the bottom sediments in portions of the study area provide an excellent environment for preservation. Given the level of maritime activity at the mouth of Delaware Bay, the extent of vessel losses in the vicinity of the study area, and the level of preservation at shipwreck sites in other similar environments, it is highly possible that well-preserved shipwreck sites could exist in the project vicinity.

As a major conduit for exploration, colonization and expanding coastal commerce, the Delaware Bay is an obvious and natural repository for underwater resources. Strong coastal storms, often with a lethal combination of treacherous northeast winds and swift tidal currents, coupled with the presence shallow water and historically heavy bay and coastal traffic, have conspired to make the Delaware Bay the final resting place for dozens of documented sailing vessels, steamships, barges, tugs and large modern ships over the last three centuries. Many types of ships and vessels have been wrecked while passing up and down the bay. Several vessels attempting to reach the Harbor of Refuge at Lewes in the lee of Cape Henlopen have instead been wrecked in the mouth of the bay.

A recent Bureau of Land Management study of the Continental Shelf from the Bay of Fundy to Cape Hatteras has characterized the Delaware Coastal Zone as an area of "moderately heavy" predicted shipwreck density (Bourque et. al., 1979). An inventory of shipwrecks and all types of ship losses near the mouth of the Delaware Bay was compiled during the background research phase of this study and confirms this predicted density (Appendix A) More than 300 shipwrecks and ship losses can be documented in the lower Delaware Bay and near the mouth of the bay since the first reported loss in 1641. Drawn from a range of available primary and secondary sources, this extensive shipwreck list, while far from comprehensive, nonetheless gives an indication of the variety of shipwrecks that have occurred in the project vicinity over the last 350 years. Although there are no documented underwater resources within the boundaries of the two proposed sand borrow areas, Appendix A and secondary and primary historical sources show that numerous vessels have been deposited in the general vicinity of the project areas throughout the historic period. The study area is therefore considered on the basis of background research to hold a high potential for yielding underwater resources of a caliber suitable for inclusion in the National Register of Historic Places.

Based on the information in Appendix A, the types of underwater resources that may be present in the Broadkill Beach vicinity include a variety of materials dating from the early 17th century through the Second World War. Appendix A also lists several recent shipping disasters which have occurred within the last 40 years. Potential vessel types include wrecks representative of all phases of commercial and naval activity taking place in the Delaware Bay and along the Delaware portion of the Atlantic Coast. Wood-hulled ships, ranging from small fishing sloops, shallops, recreational sailing and motor craft, and coastal schooners, to sail-rigged warships, have been lost near the mouth of Delaware Bay. Iron-hulled vessels, including paddle wheel steamboats and World War II-era merchant ships sunk by German submarines, have also been lost in the project vicinity. Large 20th-century steamships and freighters are also among the listed losses in the region. Many of these types of vessels would potentially lend historic insights into a wide range of maritime topics, including the contexts of naval activity, shipbuilding and regional shipping, and patterns of trade and industry.

CHAPTER 6

SURVEY INVESTIGATIONS

The purpose of the fieldwork component of these cultural resources investigations was twofold: to conduct a visual inspection of the tidal zone and shoreline of the 2.5-mile section of Broadkill Beach for evidence of potentially significant cultural resources; and to carry out a comprehensive remote sensing survey within two proposed offshore sand borrow areas in the Delaware Bay. The major work effort was directed at the latter underwater archaeological survey, the purpose of which was to locate, identify and preliminarily assess the significance of submerged prehistoric and historic resources that might be affected by future dredging activity. The underwater survey was designed to generate sufficient magnetic, acoustic, and bathymetric remote sensing data to identify anomalies caused by submerged cultural resources. Analysis of the remote sensing data aimed to isolate targets of potential historical significance that might require further investigation or avoidance. No diving was undertaken on these targets.

A. Terrestrial Survey

Field investigation along the 2.5 mile stretch of the Broadkill Beach tidal zone and shoreline was completed by two archaeologists at low tide on August 21, 1994. Field photography was undertaken during a second visit to the study area on September 19. In addition to inspecting and photographing the waterfront, project staff asked local residents whether they had any knowledge of buried or submerged cultural resources in the Broadkill Beach vicinity.

The field investigation and associated interviewing of local residents failed to identify any evidence of prehistoric or historic cultural resources within the 2.5-mile beach segment. Three wooden groins and two interlocking steel sheet groins were noted extending out into the bay, but all five of these structures have been constructed since 1950 in an effort to control beach erosion. Approximately 2,000 feet southeast of the southeastern end of the study area, remains of the 1907 jetty erected at the mouth of the former Broadkill River are still visible to the north of the existing inlet. These remains consist of a series of worn, wood pilings that extend out into the water on the north side of the former inlet. The various early 20th-century frame residential and commercial structures that make up the core of the settlement of Broadkill Beach are located inland from the shoreline, also outside the area of study.

B. Underwater Survey

1. Field Survey and Analytical Procedures:

All remote sensing fieldwork was carried out from a 25-foot survey vessel suitable for open and shoal water operations. A *Geometrics*, G-866, proton precession magnetometer, capable of +/- one gamma resolution, was employed to collect magnetic remote sensing data. A two-second sampling rate by the magnetometer's towed sensor, coupled with a 3.5- to 4-knot vessel speed, assured a magnetic sample every ten feet. A *Klein* two-channel acoustic recorder with a 500 kHz side scan sensor was used to collect acoustic data. Acoustic data were recorded on wet chemical paper with an analog recorder. An *Odem* Echotrac precision depth sounder with a narrow beam transducer was used to collect bathymetric data.

Survey vessel trackline control and position fixing were obtained by using a laptop PC-based software package *(Hypack)* in conjunction with a *Navstar* Differential Global Positioning System (DGPS) on board the survey vessel. The onboard computer and black/white monitor were interfaced with the DGPS satellite positioning system. In addition to the onboard GPS receiver, a GPS station was set up at an established ACOE survey location, "Inlet West" (on the west side of Roosevelt Inlet), to provide differential corrections. Positioning data from the DGPS was converted by the onboard computer to Delaware NAD 83 X,Y coordinates in real time. These X,Y coordinates were used to guide the survey vessel precisely along predetermined tracklines. While surveying, vessel positions were continually updated on the computer monitor to assist the vessel operator, and the processed X,Y data were continually logged on computer disk for post-survey processing and plotting.

Magnetic, acoustic and bathymetric data were collected simultaneously. Position coordinates, magnetic and bathymetric data were logged into the onboard computer. To allow for the detection of subtle magnetic anomalies typically associated with smaller wooden vessels, survey lane spacing for the survey was established at 75-foot offsets. Since the side scanning sonar transducer has an effective range of more than 150 feet in each channel, 75-foot lane offsets provided comprehensive acoustic coverage for each area. Bathymetric data was logged into the onboard computer continuously, and DGPS position fixes were recorded every 25 feet along each survey lane. Magnetic and acoustic records were event marked at regular intervals along each lane. This allowed researchers to rapidly integrate the acoustic, magnetic and bathymetric records into a survey map and to pinpoint the location of each identified target.

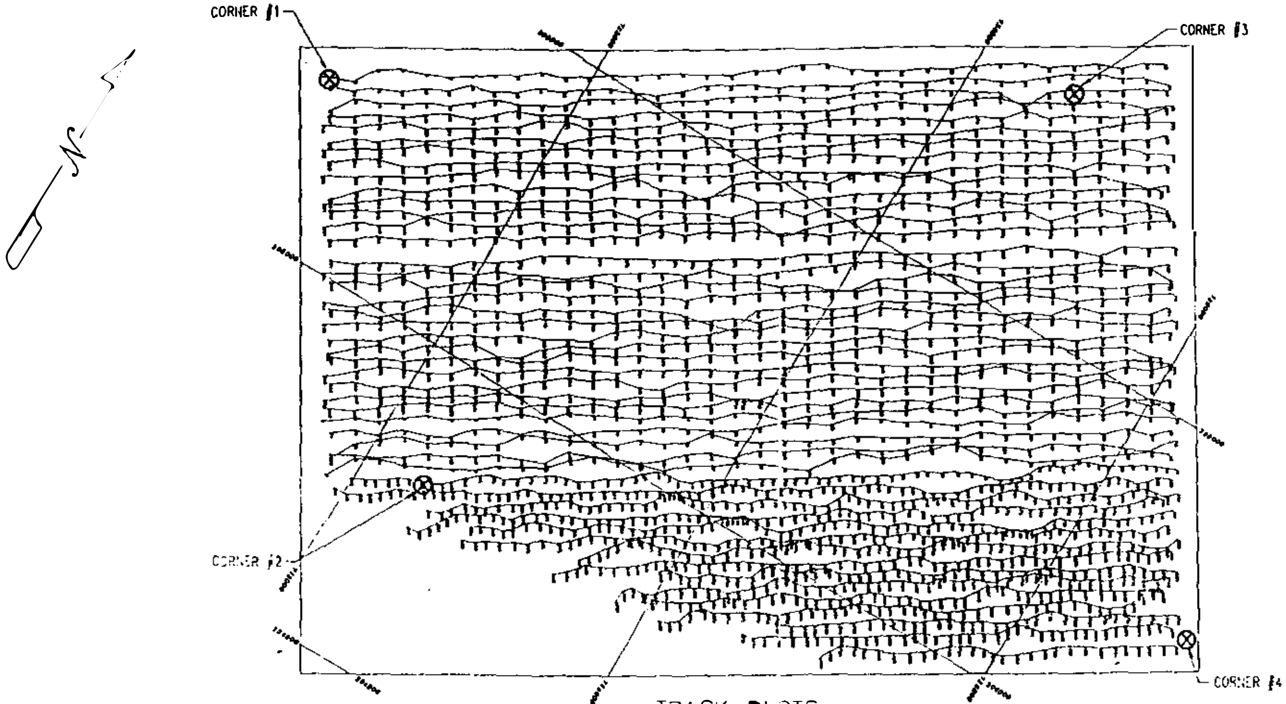
Magnetic data was contour plotted at 10 gamma intervals. Sonagram records were inspected for potential manmade features present on the bottom surface. After fieldwork data was collected, magnetic data was correlated with sonar records, and targets of potential significance were identified and designated. Targets signatures located during the survey were refined to permit highly accurate positioning and to facilitate signature analysis.

At Borrow Area 1 (Primehook), 48 lengthwise lanes spaced 75 feet apart were completed in a northeast-southwest orientation. At Borrow Area 2 (Broadkill), 28 lengthwise lanes spaced 75 feet apart were also completed in a northeast-southwest orientation.

Magnetometer data were contour plotted and each anomaly was analyzed in terms of the following parameters: magnetic intensity (total distortion of the magnetic background measured in gammas); pulse duration (detectable signature duration); signature characteristics (negative monopolar, positive monopolar, dipolar, or multi-component); and spatial extent (total area of disturbance). Acoustic (side scan sonar) targets were analyzed according to their spatial extent, configuration, location and environmental context. Magnetic records were correlated with the acoustic targets and integrated with bathymetric data to provide comprehensive remote sensing information on the identity of the material generating the remote sensing signatures. The integrated data for each target site were finally assessed with reference to typical submerged cultural resource signatures generated during three decades of magnetic and acoustic remote sensing surveys, enabling the isolation of target signatures that were suggestive of significant submerged cultural materials.

These procedures for analyzing remote sensing targets have been developed in the course of compiling a database of target signatures over the last three decades. Starting in the 1960s, archaeologists primarily relied on magnetic remote sensing data, collected with proton precession magnetometers, to locate submerged cultural resources. However, magnetic data collected alone often provides inconclusive or partial evidence about submerged cultural resource sites. Underwater archaeological research conducted over the last two decades indicates that shipwreck sites may produce a variety of magnetic signatures. Furthermore, modern debris often generates magnetic signatures that share similar characteristics with certain types of shipwreck sites.

The ambiguous nature of magnetic signatures has led researchers to use acoustic and occasionally sub-bottom remote sensing equipment in conjunction with a magnetometer on most underwater archaeological surveys. Acoustic data, in the form of sonagram records, are produced by processing sound waves emitted into the water column on both sides of the submerged sensor and bounced back off the bottom surface and exposed objects. State-of-the-art sonar units can produce a high resolution sonagram record which is almost photographic in quality. However, a certain degree of structural integrity must remain above the bottom for a site to produce a reliable shipwreck signature on side scan sonar. Where no structure survives above the bottom surface researchers must rely on magnetic data to help locate shipwreck remains. Additional data provided by acoustic instruments frequently permit target identification to be made solely from remote sensing information. A combination of magnetic and acoustic remote sensing data has proven to be the most effective method of accurately identifying and assessing submerged archaeological sites. Typically, the most attractive targets produce both well-defined magnetic and acoustic signatures.



TRACK PLOTS

SCALE 1"=500

NOTES:

1. HORIZONTAL CONTROL PROVIDED BY U.S. ARMY CORPS OF ENGINEERS, PHILADELPHIA DISTRICT DELAWARE STATE TRAVERSE MERCATOR PROJECTION - NAD 83 - ZONE 2900 INDICATED IN FEET

2. COORDINATES FOR SURVEY AREA CORNERS

1. N 307037 E 720580	3. N 309377 E 724619
2. N 305225 E 722395	4. N 306921 E 727078

3. SURVEY CONDUCTED ON: 7/2/94, 7/6/94

DOLAN RESEARCH, INC.
•UNDERWATER ARCHAEOLOGY
•HISTORICAL RESEARCH
•MARINE SURVEY

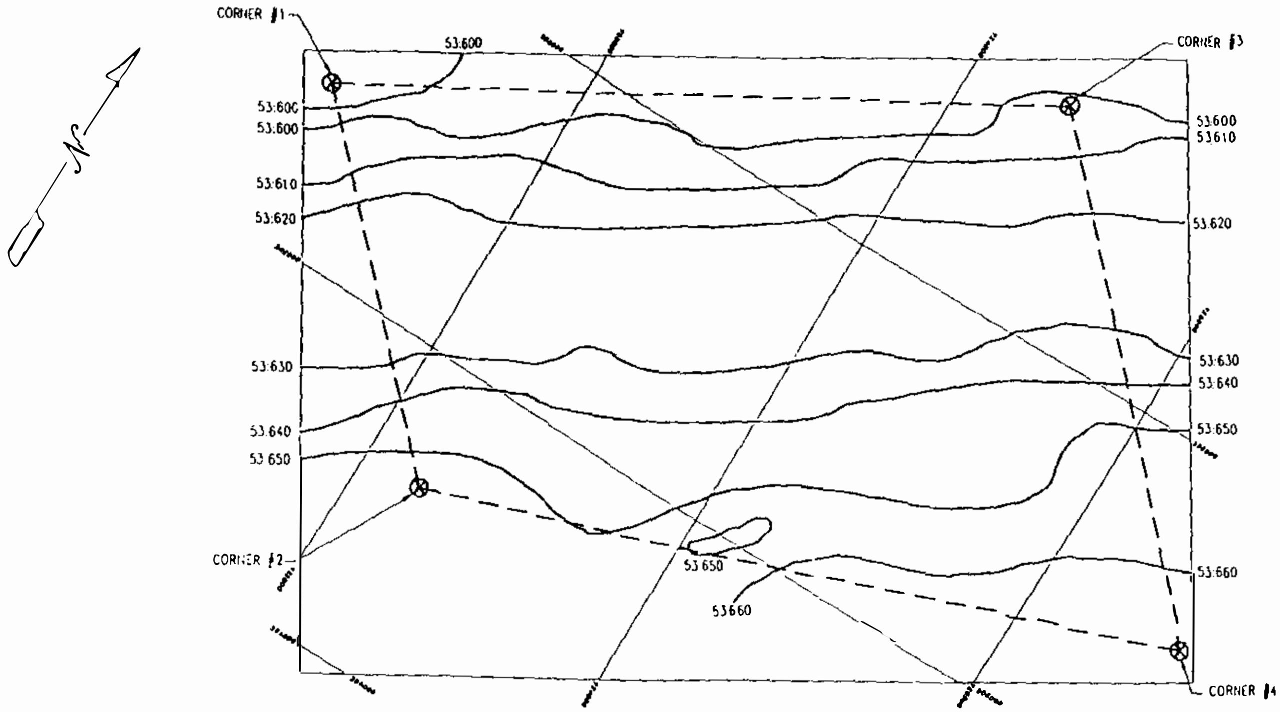
4425 Osage Avenue
Philadelphia, PA 19104
215-387-2577

DELAWARE BEACH REPLENISHMENT PROJECT

UNDERWATER ARCHAEOLOGICAL INVESTIGATION

BORROW AREA 1 (PRIMEHOOK)

FIG. NO. 6.1



MAGNETIC CONTOUR MAP
SCALE 1" =500'

NOTES:

1. HORIZONTAL CONTROL PROVIDED BY U.S. ARMY CORPS OF ENGINEERS, PHILADELPHIA DISTRICT DELAWARE STATE TRAVERSE MECATOR PROJECTION - NAD 83 - ZONE 2900 INDICATED IN FEET
2. MAGNETIC CONTOUR INTERVALS = 10 GAMMAS
3. MAGNETIC BACKGROUND = 53.620
4. COORDINATES FOR SURVEY AREA CORNERS

1. N 307037 E 720580	3. N 309377 E 7[illegible]4619
2. N 305225 E 722395	4. N 306921 E 7[illegible]7078

5. BOUNDARY OF SURVEY AREA — — —
6. SURVEY CONDUCTED ON 7/2/94, 7/6/94

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•HISTORICAL RESEARCH
•MARINE SURVEY

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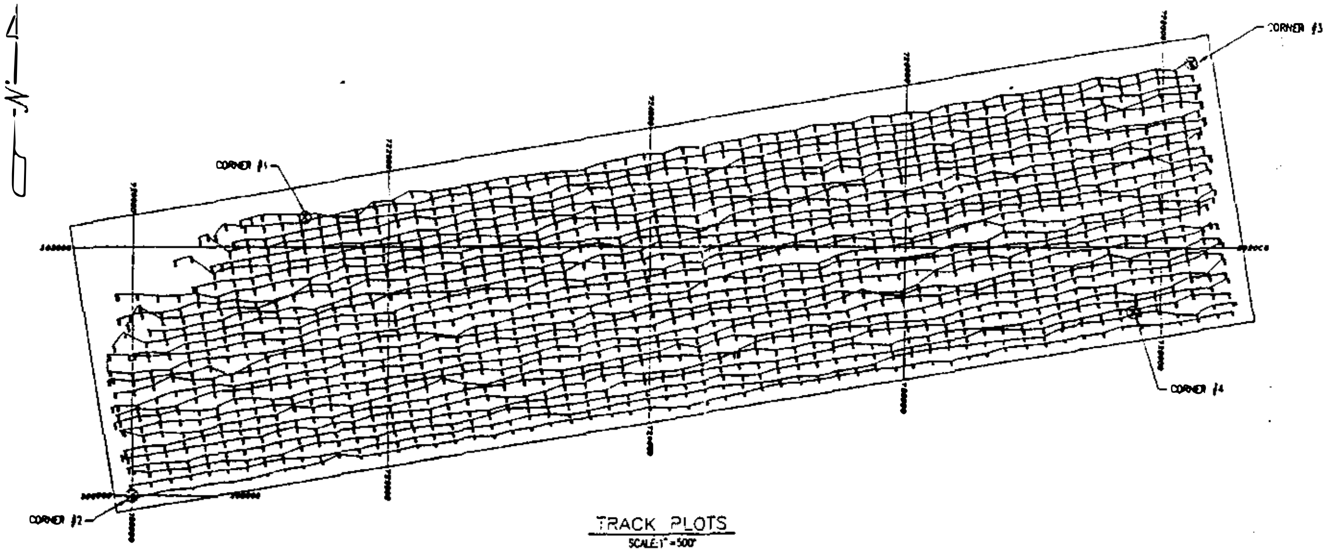
DELAWARE BEACH REPLENISHMENT PROJECT
UNDERWATER ARCHAEOLOGICAL INVESTIGATION

BORROW AREA 1 (PRIMEHOOK)

FIG No 6.2



TRACK PLOTS
SCALE: 1" = 500'

NOTES:

1. HORIZONTAL CONTROL PROVIDED BY U.S. ARMY CORPS OF ENGINEERS, PHILADELPHIA DISTRICT DELAWARE STATE TRAVERSE MERCATOR PROJECTION - NAD 83 - ZONE 1900 INDICATED IN FEET
2. MAGNETIC CONTOUR INTERVALS = 10 GAMMAS
3. MAGNETIC BACKROUND = 53650
4. ⊡ MAGNETIC TARGETS
5. △ SONAR TARGETS
6. COORDINATES FOR SURVEY AREA CORNERS:
   1. N 302245 E 74366
   2. N 300000 E 720000
   3. N 303528 E 728541
   4. N 301481 E 727780
7. SURVEY CONDUCTED ON: 7/1/94

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•HISTORICAL RESEARCH
•MARINE SURVEY

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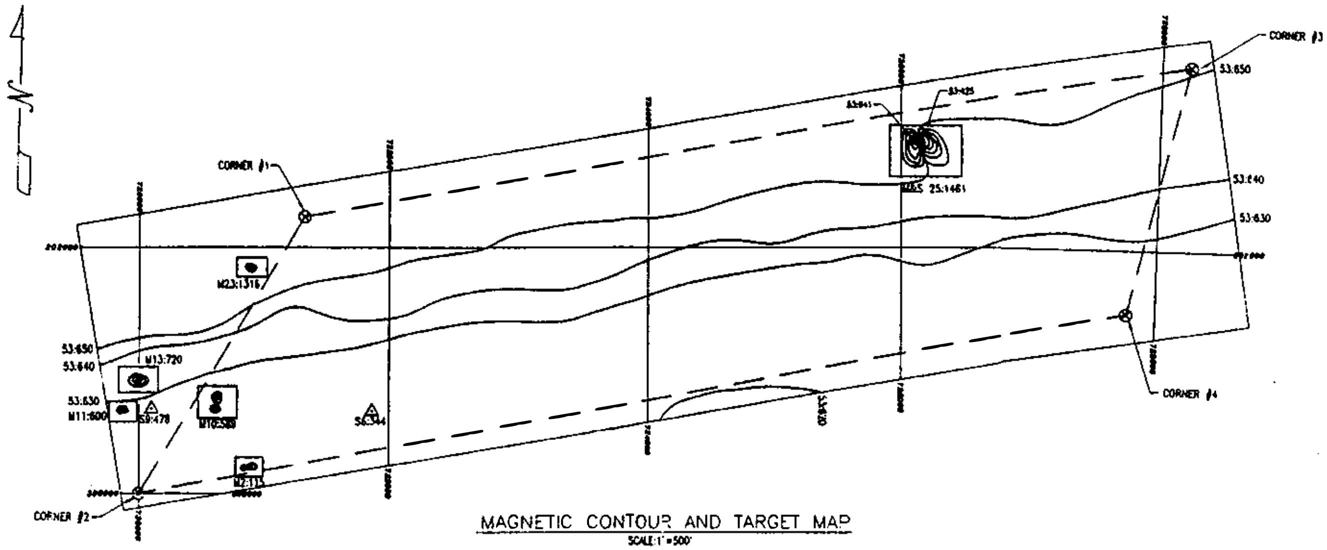
Philadelphia, PA 19104
215-387-3877

DELAWARE BEACH REPLENISHMENT PROJECT
UNDERWATER ARCHAEOLOGICAL INVESTIGATION

BORROW AREA 2 (BROADKILL)

FIG. No. 6.3



MAGNETIC CONTOUR AND TARGET MAP

SCALE: 1" = 500'

NOTES:

1. HORIZONTAL CONTROL PROVIDED BY U.S. ARMY CORPS OF ENGINEERS, PHILADELPHIA DISTRICT DELAWARE STATE TRAVERSE MECATOR PROJECTION – NAD 83 – ZONE 2900 INDICATED IN FEET
2. MAGNETIC CONTOUR INTERVALS = 10 GAMMAS
3. MAGNETIC BACKGROUND = 53:650
4. ⊡ MAGNETIC TARGETS
5. △ SONAR TARGETS
6. COORDINATES FOR SURVEY AREA CORNERS:
   1. N 302245 E 74366
   2. N 300000 E 720000
   3. N 303528 E 728541
   4. N 301481 E 727780
7. SURVEY CONDUCTED ON. 7/1/94

DOLAN RESEARCH, INC.
- UNDERWATER ARCHAEOLOGY
- HISTORICAL RESEARCH
- MARINE SURVEY

4425 Osage Avenue
Philadelphia, PA 1910-
215-387-5877

DELAWARE BEACH REPLENISHMENT PROJECT
UNDERWATER ARCHAEOLOGICAL INVESTIGATION

BORROW AREA 2 (BROADKILL)

FIG. No. 6.4

2. Findings of the Remote Sensing Survey:

Underwater survey was completed in the Delaware Bay by a four-person project crew from Dolan Research, Inc., between July 1 and July 6, 1994. All underwater survey field notes, magnetometer and sonar records, are stored at the offices of Dolan Research, 4425 Osage Avenue, Philadelphia, PA 19014. The vast majority of the two survey areas contain a featureless, mud and sand bottom with little or no magnetic background variation.

Borrow Area 1 (Primehook)

A total of 48 lanes were surveyed in Borrow Area 1 (Figure 6.1). No magnetic or sonar anomalies suggestive of submerged cultural resources were identified (Figure 6.2)

Borrow Area 2 (Broadkill)

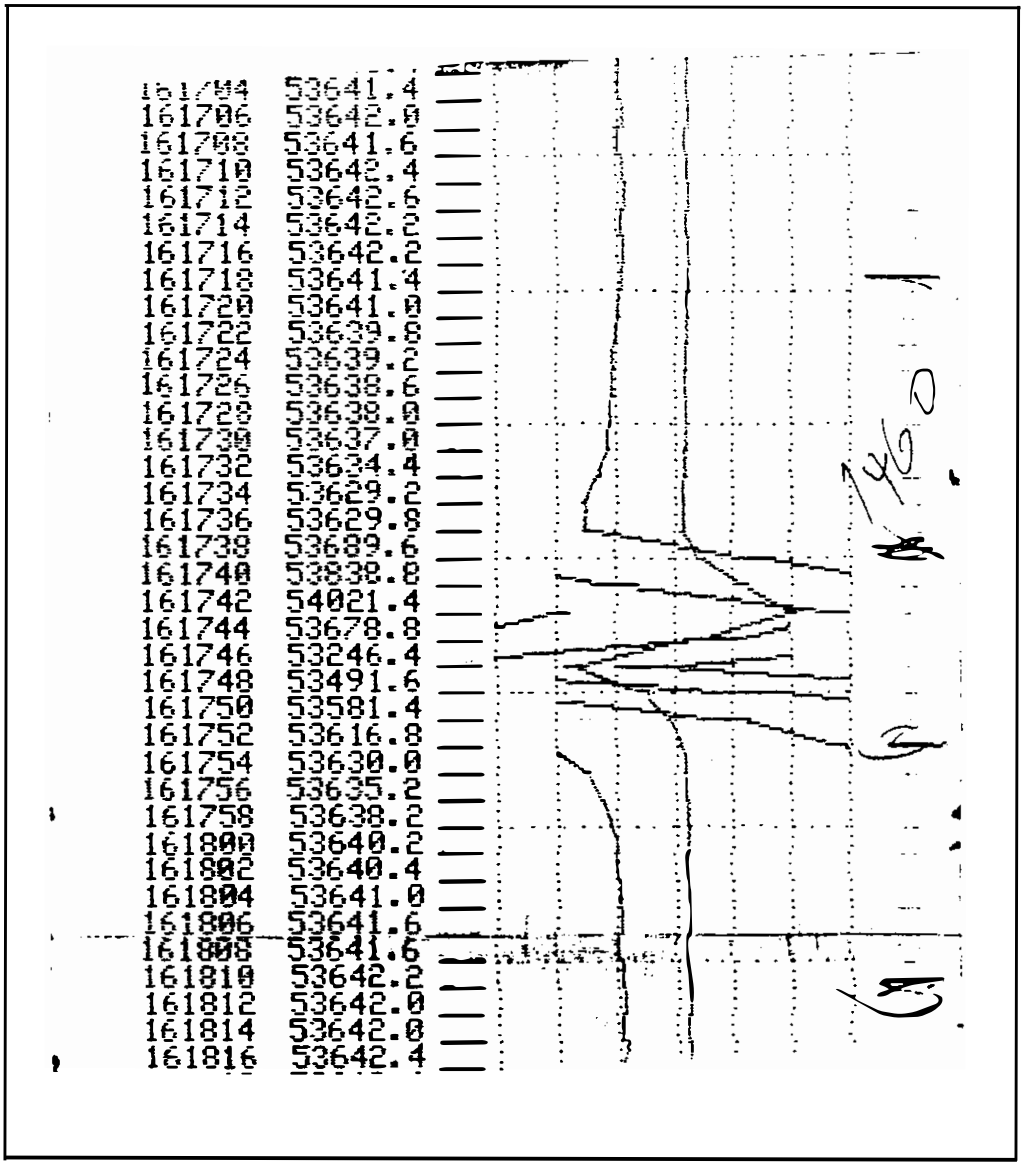
A total of 28 survey lanes were surveyed in Borrow Area 2 (Figure 6.3). Analysis of the remote sensing data confirmed the existence of eight remote sensing targets in Borrow Area 2 (Figure 6.4). Of these targets, one is a combined magnetic-acoustic anomaly, five are magnetic anomalies, and two are acoustic anomalies. The combined magnetic-acoustic target, designated as Target 25:1461, generated a remote sensing signature that is suggestive of a submerged cultural resource. The other seven targets identified within Borrow Area 2 (Broadkill) displayed signature characteristics typically generated by modern debris, or single, isolated objects on the bottom.

The remainder of this chapter is given over to a more detailed description of the observed anomalies. Target designations include the lane number(s) that the target was identified on, the target itself being identified by the lane number which came closest to intersecting the center point of the anomaly, followed by a colon and the event mark number along the specified lane. Delaware State Plane Coordinates (NAD 83) are provided for the high probability submerged cultural resource identified as a combined magnetic-acoustic anomaly.

High Probability Magnetic-Acoustic Targets

Target #: **25:1461**

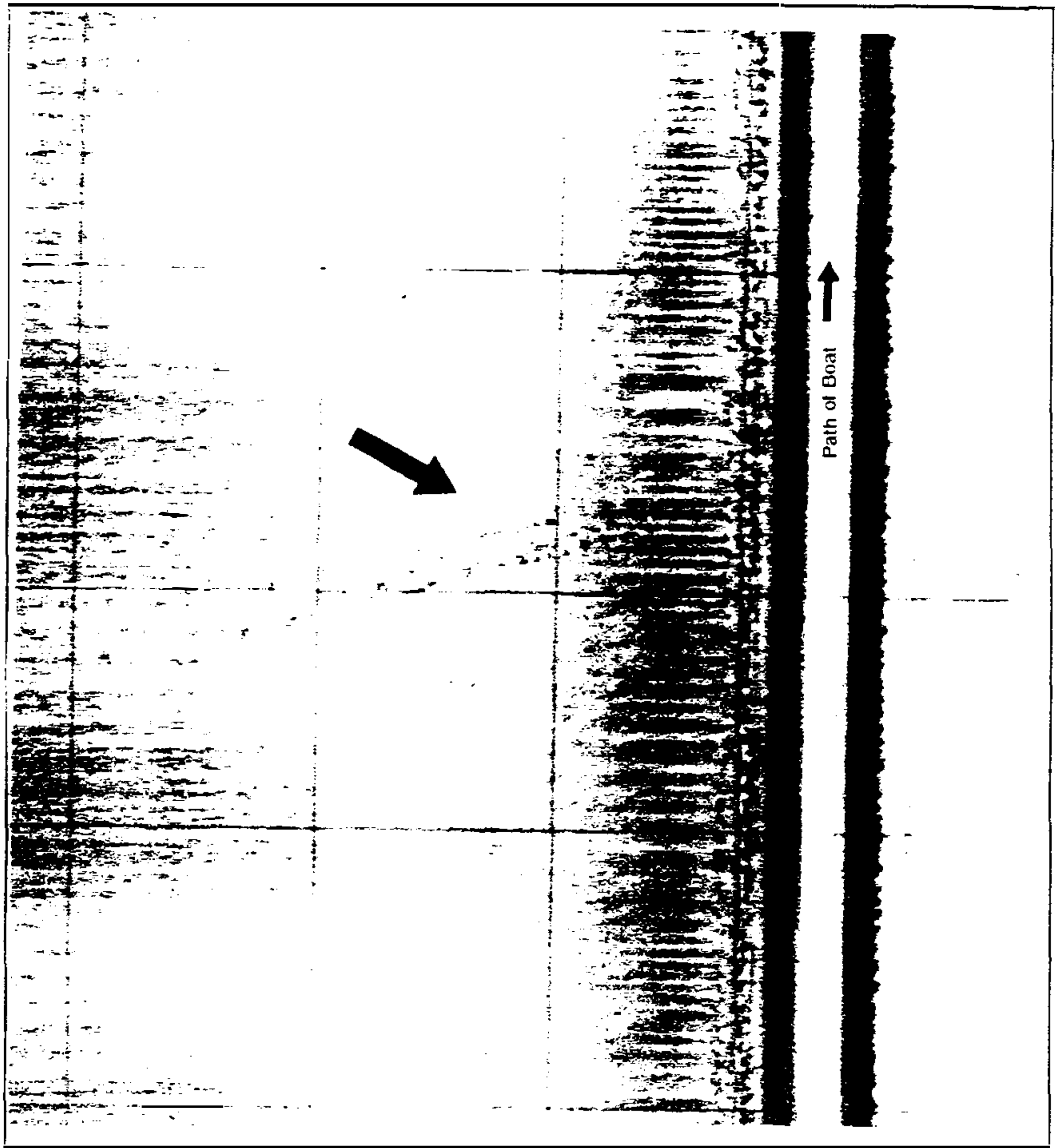
Magnetic distortion generated by a broad anomaly was detected in lanes 23, 24, 25 and 26. The dipolar signature had a maximum distortion of 775 gammas that was detected over an 8 pulse duration - 16 seconds (Figure 6.5). Influence from the ferrous material at the site was identified across an area approximately 200 feet by 100 feet. Water depth across the target location varied



MAGNETIC SIGNATURE
M&S 25:1461

Borrow Area 2 (Broadkill)

Figure 6.5



SONAR TARGET
M&S 25:1461

Borrow Area 2 (Broadkill)

Figure 6.6

from 12 to 14 feet. There was a subtle, associated acoustic signature at the magnetic target location. The image of the target is almost completely buried, but a series of small hard objects appear to break the bottom surface in a pattern suggestive of a wreck-like structure (Figure 6.6). The broad duration of the magnetic anomaly and associated acoustic signature is similar to signatures generated by documented submerged cultural resources.

Coordinates: N 302920
E 726198

Other Magnetic Targets

Target #: **2:115**

Evidence of the magnetic signature of this target was only detected in Lane 2. The dipolar signature had a maximum distortion of 37 gammas that was detected over a 4 pulse duration. Water depth at the target location was 12 feet. There was no associated acoustic image at the target location, indicating that the material responsible for generating the magnetic signature is buried beneath the bottom surface. The lack of signature duration and dispersion indicates an isolated object.

Target #: **10:589**

Evidence of the magnetic signature of this target was detected in Lanes 9 and 10. The dipolar signature had a maximum distortion of 364 gammas that was detected over a 3 pulse duration. Water depth at the target location was 12 feet. There was no associated acoustic image at the target location, indicating that the material responsible for generating the magnetic signature is buried beneath the bottom surface. The lack of signature duration and dispersion indicates an isolated object.

Target #: **11:600**

Evidence of the magnetic signature of this target was only detected in Lane 11. The positive, monopolar signature had a maximum distortion of 39 gammas that was detected over a 4 pulse duration. Water depth at the target location was 12 feet. There was no associated acoustic image at the target location, indicating that the material responsible for generating the magnetic signature is buried beneath the bottom surface. The lack of signature duration and dispersion indicates an isolated object.

Target #: **13:720**

Evidence of the magnetic signature of this target was only detected in Lane 13. The positive, monopolar signature had a maximum distortion of 204 gammas that was detected over a 3 pulse duration. Water depth at the target location was 10 feet. There was no associated acoustic image at the target location, indicating that the material responsible for generating the magnetic signature is buried beneath the bottom surface. The lack of signature duration and dispersion indicates an isolated object.

Target #: **23:1316**

Evidence of the magnetic signature of this target was only detected in Lane 23. The dipolar signature had a maximum distortion of 36 gammas that was detected over a 2 pulse duration. Water depth at the target location was 11 feet. There was no associated acoustic image at the target location, indicating that the material responsible for generating the magnetic signature is buried beneath the bottom surface. The lack of signature duration and dispersion indicates an isolated object.

Other Acoustic Targets

Target #: **6:344**

Three small acoustic images were detected 25 feet out in the left channel along lane 6. The small, hard objects were all less than four feet in diameter. They may be rocks and pieces of debris abandoned at this location. There was no magnetic anomaly at this location.

Target #: **9:478**

A small scatter of acoustic images was detected 35 feet out in the left channel along lane 9. The scatter was spread across an area approximately 30 feet in size and appears to consist of modern debris abandoned at this location. There was no magnetic anomaly at this location.

CHAPTER 7

EVALUATION, IMPACT ASSESSMENT AND RECOMMENDATIONS

As with Chapter 5, this chapter maintains a distinction between inundated terrestrial resources (i.e., resources that were formed on land and have since been inundated by water or sediment as a result of rising sea level and other offshore depositional activity) and underwater resources (i.e., resources such as shipwrecks, downed airplanes or jetties, whose original formation occurred in a marine environment).

A. Submerged and Shoreline Terrestrial Resources

During the period of prehistoric and historic human activity in the Mid-Atlantic region, which extends over the past 15,000 years or so, the areas investigated during this study in the Broadkill Beach vicinity have experienced ongoing and increasing inundation as a result of rising sea level. For the most part, inundation has been accompanied by accumulation of sediments on the bay floor, although offshore scouring and shifts in littoral drainage may also have produced local erosional effects. Cultural resources that were originally formed on land may now therefore lie submerged beneath the waters and variable depths of sediment in the Delaware Bay. Alternatively, they may also have been eroded through natural forces, such as water or wind action, or through human agency such as dredging.

It is extremely difficult to reconstruct in detail the natural environment (topography, drainage, soils, flora and fauna) and land use history of areas that are now submerged beneath the Delaware Bay and thereby derive an accurate assessment of prehistoric archaeological potential. The work of Kraft and others studying the geomorphology of the Delaware coastline is a valuable aid in understanding the processes that are at work and providing a hypothetical model for predicting cultural resource occurrence (see above, Chapter 3). However, testing such a model and reconstructing the geomorphology and geoarchaeology of any given section of inundated terrain within the Delaware Bay would require extensive and systematic bathymetrically-referenced sampling of the bay floor sediments, a task that is well beyond the scope of the current investigation. For this reason, it is not possible to offer a definitive evaluation of prehistoric archaeological potential for either the proposed sand borrow areas or the tidal zone on the basis of the research conducted to date.

A better sense of the paleoenvironment and prehistoric archaeological potential of the study area could be obtained from a limited program of sediment sampling conducted jointly by coastal geomorphologists and archaeologists. Specifically, sampling of this type within the proposed sand borrow areas could establish the depth below the bay floor of prehistoric land surfaces and

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the thickness of overlying (i.e., post-depositional in a cultural sense) sands and muds. This would enable the depth to which sand borrowing could take place without affecting possible cultural strata. Such core samples would also constitute the beginnings of a geoarchaeological data bank for the bay floor and would serve as a valuable reference for other dredging and sand borrowing actions within the bay.

With regard to Delaware's statewide management plan for prehistoric resources (Custer 1983), paleoenvironmental (or, indeed, archaeological) data from within the Delaware Bay would add considerably to the geographic and settlement-subsistence context within which the few known terrestrial Paleo-Indian and Archaic archaeological resources in the Delaware Shore Zone are currently analyzed. The contribution of offshore paleoenvironmental and archaeological research to studies of Woodland period cultures is likely to be less significant, but there remains some potential for inundated procurement sites around the peripheries of former tidal marsh environments.

Since the tidal zone and shoreline are to be "nourished" through the deposition of additional sand, buried prehistoric land surfaces and associated cultural resources, if these exist, should receive additional protection as a result of the proposed project action. There would not appear, therefore, to be any need to sample sediments along the tidal zone or shoreline in conjunction with the present project. No further prehistoric archaeological study is therefore recommended for the shoreline and tidal zone segment of the study area.

The potential for historic period terrestrial resources within the proposed sand borrow areas is negligible. These areas can be safely assumed to have been inundated throughout the historic period. Similarly, the present-day tidal zone and shoreline has constituted a dynamic environment throughout the historic period, and it is only during this century that the shoreline has been built upon and received any serious human attention. While transient activities, such as hunting and fishing, were probably pursued in this area, no documentary or field evidence has been found for substantive or "permanent" pre-20th-century cultural features along this section of the Broadkill Beach shoreline. The 20th-century settlement of Broadkill Beach is located inland from the zone where beach nourishment will take place and should not be adversely affected by the project actions. No further investigation of historic period terrestrial cultural resources is considered necessary in connection with the proposed project.

B. Underwater Resources

Historic maritime activity in the Delaware Bay dates from the first half of the 17th century when Dutch, Swedish and English pioneers commenced trading and settlement in the region. Since that time, the Delaware Bay and its tributaries have served as transportation arteries for the subsequent colonization and socio-economic development of Delaware, New Jersey and Pennsylvania. Locally, in the Broadkill Beach vicinity, a small-scale trade developed along the Broadkill River between Milton and Philadelphia, but the vast majority of maritime activity within the adjoining section of the Delaware Bay involved regional and international trade and occasional naval activity. Thus, vessels crossing through the proposed sand borrow areas were engaged in the coastal trade between various Delaware River ports (e.g., Philadelphia, Wilmington, Burlington) and ports along the eastern and southern seaboards from Maine to Texas and overseas (e.g. in the Caribbean, Europe and Africa). In addition, much coastal maritime traffic sought shelter from Atlantic storms behind the breakwaters at Lewes near the mouth of Delaware Bay, just southeast of the study area.

As a result of the extensive historic maritime activity in the Delaware Bay, a plethora of underwater resources may be anticipated in the Broadkill Beach vicinity. Indeed, more than 200 shipwreck losses and accidents have been documented near the mouth of Delaware Bay since the 17th century. The identification of underwater resources relating to this historic maritime activity is critically relevant to the goals developed in Delaware's recently published statewide historic preservation planning documents. Indeed, the top priority below-ground historic context in the Delaware Comprehensive Historic Preservation Plan is identified as: Historic Theme - Settlement Patterns and Demographic Change, Chronological Period/Theme - 1630 to 1730+/-, Exploration and Frontier Settlement; to which other important themes, notably Fishing and Oystering, and Transportation and Communication, are intimately related (Ames et al. 1989:86). Similarly, in the companion Management Plan for Historical Archaeological Resources, the second-ranked statewide priority is identified as the preservation and management of historical archaeological maritime resources for the entire period of historic activity, 1630-1940 (De Cunzo and Catts 1990:186). Clearly, underwater resources in the Delaware Bay are potentially important both in elaborating key statewide historic contexts, themes and property types and in the appropriate management of Delaware's cultural heritage.

Comprehensive remote sensing survey of Borrow Area 1 (Primehook) using magnetic, acoustic and bathymetric instrumentation failed to identify any underwater resources. However, a similar survey procedure in Borrow Area 2 (Broadkill) resulted in the identification of eight targets, one of which exhibited a combined magnetic-acoustic signature suggestive of a submerged cultural resource. The other seven targets identified within Borrow Area 2 (five of them noted as magnetic anomalies and two as acoustic anomalies) displayed signature characteristics typical of modern debris, or single, isolated objects lying on the bay floor. No additional archaeological investigation is recommended at these latter seven target locations. Although no remote sensing was undertaken in the tidal zone, no visual evidence was observed of shipwrecks or other historic underwater resources. No further underwater investigation or remote sensing is considered necessary for the tidal zone.

The single target of potential historic interest in Borrow Area 2 (designated here as Combined Magnetic-Acoustic Target #: **25:1461**) generated a broad 775 gamma magnetic signature that was detected across an area approximately 200 feet long. Magnetic distortion was recorded on four adjacent survey lanes. The associated acoustic image indicated an object that appears to be almost completely buried. However, a series of small hard objects do break the bottom surface in a pattern suggestive of a wreck-like structure.

Consideration should be given to avoiding this target location during sand borrow dredging activities. If avoidance is not a viable option, additional archaeological investigation (diving observation and recording) is recommended at this target to determine the nature of the object(s) responsible for generating the remote sensing signature. Ground truthing of this target should also aim to preliminarily evaluate whether this potential underwater cultural resource is of sufficient caliber to merit inclusion in the National Register of Historic Places. As part of the resource identification and preliminary evaluation process, field data should also be correlated with background historical information. If the resource is considered potentially suitable for inclusion in the National Register, it should then become the focus of a more detailed Phase II archaeological investigation and the subject of National Register-level documentation.

C. Summary

In summary, the conclusions and recommendations from this submerged and shoreline cultural resources investigation are as follows:

1. The potential for significant submerged prehistoric terrestrial resources in the sand borrow areas is unclear, in large part because detailed reconstruction of the paleoenvironment is not possible at this level of study.

2. No further investigation of prehistoric terrestrial resources in the tidal zone or along the shoreline is considered necessary, since deposition of sand will enhance preservation of buried prehistoric resources (if indeed these exist).

3. No further investigation of historic terrestrial resources in the sand borrow areas, in the tidal zone or along the shoreline is considered necessary. No documentary or field evidence has been found for such resources and they are considered extremely unlikely to exist.

4. One combined magnetic-acoustic underwater target has been identified in Borrow Area 2 (Broadkill) and may represent a significant underwater resource such as a historic shipwreck. If this target cannot be avoided, further investigation is recommended to clarify the character of this anomaly and to evaluate its eligibility for inclusion in the National Register of Historic Places.

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APPENDIX A

LOWER DELAWARE BAY SHIPWRECK LIST

APPENDIX A

LOWER DELAWARE BAY SHIPWRECK LIST

The following list of shipwrecks and marine accidents in the lower Delaware Bay has been compiled from various primary and secondary sources. Among the sources used during the compilation of this list were: Maritime Records: Record of Wrecks 1874 - 1937 (Pennsylvania Historical Society); Encyclopedia of American Shipwrecks (Berman 1972); Shipwrecks off the New Jersey Coast (Krotee and Krotee 1965); "A Preliminary Survey to Analyze The Potential Presence of Submerged Cultural Resources in the Delaware and Susquehanna Rivers" (Dolan Research, Inc. 1984); Shipwrecks in the Americas (Marx 1971); Shipwrecks of Delaware and Maryland (Gentile 1990); Shipwrecks of New Jersey (Gentile 1988); The Pennsylvania Navy, 1775 - 1781: The Defense of the Delaware (Jackson 1974); Automated Wreck and Obstruction Information System - AWOIS (National Oceanographic and Atmospheric Administration); Merchant Vessels of the United States. Wreck List; The Steamship Inspection Service. Wreck File, 1852-1937 (National Archives); Wreck Chart of the North American Coast of America (General Records of the Hydrographic Office, National Archives); Philadelphia, Port of History, 1609-1837 (Philadelphia Maritime Museum 1976); Hazard Annuals of Pennsylvania 1609 - 1682 (Hazard 1850); The Majestic Delaware, The Nation's Foremost Historic River (Brandt 1929); and articles in various newspapers, including: The Philadelphia Inquirer; The Wilmington Evening Journal.

Many of the wrecks, particularly those resulting from the more recent accidents occurring in or near the shipping channel, were subsequently salvaged or removed because they were threats to safe navigation.

Name	Year Lost	Comments
Comelia	1757	Captain Smith, sailing from Philadelphia to Gibraltar, sank between Capes Henlopen and May.
Vaughan	1763	English merchantman, under Captain Foster, sailing from Bristol to Philadelphia, wrecked in Delaware Bay.
Pitt Packet	1763	English merchantman, under Captain Montgomery sailing from Belfast to Philadelphia with a large number of passengers, foundered in Delaware Bay with a total loss of life.

APPENDIX A, cont.   LOWER DELAWARE BAY SHIPWRECK LIST

Name	Year Lost	Comments
Charlestown	1766	American merchantman, under Captain Simpson, sailing from Hamburg to Philadelphia wrecked on January 25 on Brandywine Bank in Delaware Bay.
Kildare	1768	Captain Nicholson, sailing from Barbados to Philadelphia, lost at the mouth of Delaware River.
Commerce	1771	English merchantman, under Captain Addis, sailing from England to New York, wrecked at Cape Henlopen.
Severn	1774	English merchantman, under Captain Hathom sailing from Bristol to Philadelphia, wrecked in Delaware Bay, but all of her crew was saved.
9 unidentified ships	1783	Wrecked at Cape Henlopen during a severe gale in the fall.
Faithful Steward	1785	Scottish immigrant ship, under Captain M'Causland, sailing from Londonderry to Philadelphia sank near Cape Henlopen, over 200 persons perished.
Santa Rosalea	1788	Spanish merchantman, under Captain Pardenus sailing from Baltimore to Havana wrecked near Cape Henlopen.
Pomona	1789	English ship, under Captain Hopkins arriving from Quebec, sank in Delaware Bay in October.
John	1790	English merchanttnan, under Captain Staples, arriving from England, wrecked on December 5, in Delaware Bay.
San Joseph	1794	Spanish merchantman, sailing from Philadelphia to Cuba, was lost in Delaware Bay when ice crushed her hull.

Name	Year Lost	Comments
Peggy	1794	American merchantman. sailing from Philadelphia for Savannah. was lost in Delaware Bay.
Lively	1795	Sailing from Amsterdam to New York. under Captain Lawrence. ship sank near Lewes.
Henry & Charles	1796	American merchantman. sailing from Hamburg to Philadelphia wrecked near Cape Henlopen.
Favorite	1796	American merchantman, sailing from Cadiz to Philadelphia sank in Delaware Bay.
Minerva	1796	American merchantman. sailing from Lisbon to Philadelphia wrecked near the mouth of Delaware River.
DeBraak	1798	A British Sloop of War which capsized approximately one mile off Cape Henlopen.
New Jersey	1799	American merchantman. under Captain Clay sailing from Puerto Rico to Philadelphia. wrecked on the west side of the Delaware Bay.
Susannah	1800	Merchantman, sailing from Hamburg to Philadelphia under Captain Medlin wrecked in Delaware Bay.
Adriana	1801	American merchantman, sailing from Philadelphia to Dublin sank in Delaware Bay due to heavy ice.
Constellation	1801	American merchantman sailing for New York sank in Delaware Bay.
China	1805	Merchantman, under Captain M'Pherson sailing from Batavia for Philadelphia sank in Delaware Bay.
Fanny	1805	Merchantman, under Captain Wing, sailing from France for Philadelphia sank in Delaware Bay.

APPENDIX A, cont. LOWER DELAWARE BAY SHIPWRECK LIST

Name	Year Lost	Comments
Friendship	1807	Schooner from St.Thomas driven ashore near Lewistown (Lewes).
Nancy	1808	Brig from Havana was driven ashore on the oyster beds in Delaware Bay in January.
Clementina	1810	Schooner bound for Laguira was cut by ice and sank in the bay in February.
Growler	1810	Brig, inbound from Havana was driven upon "the Brandywine" and lost in December.
Three Brothers	1812	Brig inbound from St. Thomas was driven ashore and lost under Cape Henlopen in January.
Juliet	1812	Schooner inbound from Havanna was driven ashore near the point of Cape Henlopen in January.
Unidentified prize vessel	1812	Schooner, prize vessel, was driven ashore near Lewistown (Lewes) in January and all were lost.
Perseverance	1812	Schooner, inbound from Havanna was driven ashore on Lewistown (Lewes) beach in January.
Unidentified vessel	1812	Spanish schooner, was driven ashore on Lewistown (Lewes) beach in January and all were lost.
General Apodaca	1813	Spanish brig was driven ashore at Cape Henlopen in January and her cargo was lost.
Helen	1817	Schooner was driven by ice from her anchors onshore at Lewistown (Lewes) in March and was totally lost.
Ann Marie	1818	Schooner, bound for Darien drove ashore on Cape Henlopen and bilged in February.

Name	Year Lost	Comments
Orleans	1821	Ship-rigged sailing vessel from New Orleans, was sunk by ice in the bay in February.
Unidentified sloop	1821	Sloop, under the direct of Master Winslow, drove on her anchors and was lost near Lewistown (Lewes).
Concordia	1822	Brig, was driven from her anchors on Mispillion and was totally lost in February.
Seaman	1822	Sloop, from New York, was driven on the Overfalls; afterwards in a heavy storm was totally lost in May.
Polly	1822	Schooner, carrying naval stores, was driven on the Flogger and totally lost in June.
Adeline	1824	American merchantman, under Captain Israel, sailing from North Carolina to Philadelphia wrecked in December at Cape Henlopen.
Spartan	1825	Sloop, from Savannah, was driven ashore in a gale above Lewistown (Lewes) and was probably totally lost in April.
Louisiana	1825	Brig, from Baltimore, was driven on the Flogger and lost in May.
31 vessels	1825	A June gale caused considerable damage throughout the bay. Numerous vessels including the sloops Kitty Ann, George Ogden, and Friendship, and 13 other vessels were driven ashore near Cape May. An additional 8 other sloops were driven ashore under Cape Henlopen. Seven vessels were driven ashore between Cohanzy and Back Creeks.
Uno	1825	Vessel, from New York, was not heard from after June gale and supposed lost with all hands within Delaware Bay.

Name	Year Lost	Comments
Emeline	1825	Vessel was lost within the bay during June gale.
Cicero	1826	Schooner, from Baltimore, was driven on the Brandywine, cargo and vessel totally lost.
Mountaineer	1850	Steamer foundered at Cape Henlopen.
John McMakin	1860	Steamer foundered at Lewes.
Adelaide	1874	Steam towing boat (tug) ran ashore on Brandywine Shoals, Delaware Bay in dense fog and became a total loss on October 29.
Mary and Martha	1875	Wood-hull sloop sank at Delaware Bay Ice Breaker.
Cienfuegos	1875	Wood-hull, bark-rigged sailing vessel sank 3 miles south southwest of Cape Henlopen.
Mary	1875	A steam propeller schooner sailing from Providence to Philadelphia struck rocks at the Delaware Bay ice breaker, filled with water and sank on February 8.
New Castle	1876	Wood-hull, steam tug schooner struck a rock at Joe Flogger Shoal, and attempted to run boat to shoal water but sank.
Rillie S. Derby	1876	Wood-hull schooner was lost at Delaware Breakwater.
Jonathon May	1876	Wood-hull schooner stranded on Brandywine Shoal.
Scud	1876	Bark-rigged sailing vessel foundered at Fenwick Light
Babel H. Irons	1877	Wood-hull schooner carrying coal and iron foundered during a sudden cyclone near Delaware Breakwater.

Name	Year Lost	Comments
Vashti Sharp	1877	Wood-hull schooner, stranded at Fenwick Island Shoals, Delaware Bay.
Trade Wind	1877	Wood-hull schooner, stranded three quarters of a mile opposite Lewes.
J.B. Austin	1877	Wood-hull, two-masted schooner foundered north of breakwater during severe October gale.
Mary E. Smith	1877	Wood-hull schooner foundered at anchor near the Delaware Breakwater during October gale.
Bessie Morris	1877	Three-masted wood-hull schooner foundered at anchors near the Delaware Breakwater during a severe October gale.
M.A. McGahan	1877	Wood-hull schooner carrying coal foundered inside the Delaware Breakwater.
E. Sinnickson	1879	Schooner foundered at Delaware Breakwater.
Champion	1879	Steamer collided with bark Lady Octavia at Cape Henlopen and sank on November 7.
D.V. Streaker	1880	Steamer stranded at Brandywine Shoal.
Wanderer	1880	Steamer enroute from New York to Apalachicola, Florida, was lost due to ice at the Delaware breakwater on December 26.
Archer & Reeves	1881	Schooner foundered at Delaware Breakwater.
Josephine	1882	Schooner foundered at Delaware Breakwater.
F.W. Cushing	1882	Foundered on Brandywine Shoal.
W.N. Gesner	1882	Schooner foundered three miles north of Mispillion Light.

Name	Year Lost	Comments
Minnie Hunter	1883	Wood-hull bark-rigged sailing vessel foundered at Cape Henlopen.
Sarah L. Simmons	1883	Schooner stranded at Brandywine Shoals.
Hattie Page	1884	Schooner foundered at Delaware Breakwater.
Walter S. Massey	1885	Wood-hull barkentine-iigged sailing vessel foundered at Cape Henlopen.
Adolphus	1886	Schooner enroute from Antwerp to Philadelphia foundered on the breakwater, she went ashore and went to pieces.
Brinkbum	1886	Iron-hull brig-rigged steamer stranded on Fenwick Island Shoals, Delaware Bay, after mistaking lights and the absence of the bell buoy named on charts.
William Snow	1886	Vessel stranded at Fenwick Island Shoals.
William G. Bolton	1886	Steam tug sank in 20 feet of water near Fourteen Foot Bank due to heavy ice on January 10.
J.I. Van Doren	1886	Steamer was destroyed by fire at Broadkill Creek, Delaware on December 2.
Gladiolus	1887	Tug foundered on fishing banks, Delaware Bay.
Aldora	1887	Bark-rigged sailing vessel foundered at Lewes.
Baylies Wood	1887	Schooner foundered at Cape Henlopen.
Allie H. Belden	1888	Schooner foundered in Delaware Bay during storm on March 12.
C.B. Hazeltine	1888	Schooner foundered in Delaware Bay during storm on March 12.

APPENDIX A, cont. LOWER DELAWARE BAY SHIPWRECK LIST

Name	Year Lost	Comments
Tamesi	1888	Wrecking steamer was pounded by gale winds against the breakwater and sank on March 12.
George W. Slmpson	1888	Tug was driven from pier at breakwater by gale on March 12; anchored off Stonepile and sank in 7 fathoms of water.
Elizabeth de Hart	1888	Schooner foundered at Cape Henlopen.
Flora A. Newcomb	1888	Schooner foundered off Lewes.
George H. Bent	1888	Schooner foundered at Delaware Breakwater.
Geo. W. Anderson	1888	Schooner foundered off Lewes.
Jan Melchers	1888	Bark-rigged sailing vessel foundered on Fenwick Island Shoal.
Hannah	1888	Bark-rigged sailing vessel foundered at Lewes.
Lewis Clark	1888	Steamer foundered at Cape Henlopen.
Moro Castle	1888	Bark-rigged sailing vessel foundered at breakwater in November.
Paul & Thompson	1888	Schooner foundered at Lewes.
William C. Bartlett	1888	Schooner foundered at Cape Henlopen.
Addie B. Bacon	1889	Schooner foundered at Delaware Breakwater on September 10.
Alena Covert	1889	Schooner foundered at Delaware Breakwater during storm on September 11.
Kate E. Morse	1889	Schooner foundered in Delaware Bay during storm on September 11.

APPENDIX A, cont. LOWER DELAWARE BAY SHIPWRECK LIST

Name	Year Lost	Comments
Mima A. Reed	1889	Schooner foundered at Breakwater during storm on September 11.
Patriot	1889	Bark-rigged sailing vessel foundered at breakwater on September 11.
S.A. Randolph	1889	Schooner foundered at breakwater during storm on September 11.
Sunrise	1889	Ship-rigged sailing vessel foundered at breakwater on April 6.
Independence	1889	Sloop-rigged sailing vessel foundered at Cape Henlopen.
Major Wm. H. Tantam	1889	Schooner foundered at Delaware Breakwater.
Walter F. Parker	1889	Schooner foundered off 14 Foot Shoal, Delaware Bay, after a collision with another vessel.
Chas. P. Stickney	1889	Schooner foundered at Delaware Breakwater.
Tonawanda	1889	Barge foundered at Brandywine Shoal.
Wallace	1889	Barge foundered at Brandywine Shoal.
Thos. Keillor	1889	Bark-rigged sailing vessel foundered at breakwater.
Cleopathra	1890	Steamer foundered off Delaware Capes.
Nellie C. Raine	1890	Schooner foundered in Delaware Bay on March 15.
Oceanus	1890	Schooner foundered off Delaware Capes.
Alsenbom	1891	Steamer foundered in Delaware Bay on January 11.
George Henry	1891	Schooner foundered in Delaware Bay on June 18.

Name	Year Lost	Comments
Minnie & Gussie	1891	Schooner foundered near Cape Henlopen.
William B. Orr	1891	Schooner foundered in Delaware Bay on April 28.
June Bright	1891	Schooner foundered at Brandywine Shoal.
Syringa	1891	Bark-rigged sailing vessel foundered in Delaware Bay.
Archer & Reeves	1891	Schooner foundered on Brandywine Shoal.
Wm. C. Bee	1893	Schooner foundered on Brandywine Shoal.
John A. Griffin	1894	Schooner foundered at Ice Breaker, Lewes.
Lois Penrose	1895	Barge foundered at Brandywine Shoal.
Aurelia	1896	Steamer caught on wreck off Mispillion Creek, careened and filled on August 23.
Addie Luddington	1899	Schooner collided with steamer Spartan off Brandywine (Shoals) and sank on June 12.
Lida Fowler	1901	Schooner foundered at 14 Foot Shoal, Delaware Bay.
Annie T. Bailey	1902	Schooner foundered at Cape Henlopen.
Carrigan	1903	Vessel foundered at Cape Henlopen.
Spartan	1903	Tug with two barges in tow bound from Salem, Massachusetts foundered in hurricane off Brown Shoal, Delaware Bay, on September 16.
Gilberton	1903	Schooner barge in tow of Spartan foundered off Brown Shoal on September 16.

APPENDIX A, cont. LOWER DELAWARE BAY SHIPWRECK LIST

Name	Year Lost	Comments
Kalmia	1903	Schooner barge in tow of Spartan foundered off Brown Shoal on September 16.
E.C. Allen	1904	Schooner foundered at the old breakwater. Lewes.
Nankeeta	1905	Yawl-rigged sailing vessel foundered at Brandywine Shoal.
Stetson and Ellison	1906	Schooner foundered in Delaware Bay.
Car float	1906	Towing steamer Defiance was towing two car floats when one sank about two miles below Brown Shoal Buoy on January 26.
John J. Ward	1907	Schooner stranded at Lewes.
Van Brunt	1907	Schooner, 1,191 gross tons collided with schooner Crosby near Delaware Breakwater on April 24. Schooner was towed and beached on mud flats inside Delaware Breakwater.
Frederica	1908	Schooner foundered in Delaware Bay.
White Band	1908	Barge, loaded with coal, being towed by towing steamer M.E. Scully parted from steamer and was rediscovered with hull awash one-half mile northwest of Overfalls Shoals spar buoy at the mouth of Delaware Bay on January 24.
John Proctor	1909	Schooner stranded at Cape Henlopen.
Goldsboro	1912	Freight steamer. while proceeding up Delaware Bay during a thick fog and stormy weather grounded on Brandywine Shoals. filled and sank on February 27.

Name	Year Lost	Comments
T. Morris Perot	1913	Schooner collided with steamer Shawmut 23 miles north north-east of Winterquarter light vessel. Schooner was towed toward Delaware Breakwater but sank one-half mile east of Fenwick Island buoy on September 28.
City of Georgetown	1913	Schooner collided with screw steamer Prinz Oskar at Delaware Capes.
Hero	1913	Barge foundered at Brandywine Lighthouse.
Dunlo	1914	Schooner foundered at Harbor of Refuge, Delaware.
Scully	1919	Schooner foundered at Delaware Breakwater.
George May	1921	Barge foundered in Delaware Bay.
Wade Hampton	1923	Screw steamer foundered in Delaware Bay.
Stroudsburg	1923	Seagoing barge, 693 gross tons, was being towed along with two other barges by the tug Jupiter, sank in a gale four miles southeast of Brandywine Lighthouse on April 14.
Corrotoman	1924	Barge foundered at Brown's Shoal, Delaware Bay.
Lenape	1925	Screw steamer burned at Delaware Breakwater.
Mohawk	1925	Screw steamer carrying 290 passengers and crew from New York to Jacksonville, Florida, caught fire while offshore of Atlantic City. Captain steered the burning vessel into Delaware Bay and beached here on shoal near Fourteen Bank Light on January 1. All were rescued.
Lottie	1928	Barge foundered at Lewes.
Emily A. Foote	1930	Oil screw ship foundered at Delaware Breakwater.

Name	Year Lost	Comments
Octoraro	1935	Barge, 807 gross tons, sank in Delaware Bay threequarters of a mile southwest of Brown Shoal Gas Buoy on January 25.
Saratoga	1935	Barge foundered Delaware Bay, three miles below Bowers Beach, Delaware.
Long Island	1936	Screw fishing steamer, 390 gross tons, foundered inside Overfall, Delaware Bay during a hurricane on September 18.
Laurence A.	1937	Barge, in tow of steamer Dauntless No. 7, sank in Delaware Bay in red sector of Miah Maull Light on May 13.
Talbot	1938	Barge burned at Delaware Breakwater.
Effie M. Lewis	1941	Oil screw ship foundered in Delaware Bay.
Freehold	1941	Screw steamer foundered off buoy #6, Liston Range, Delaware Bay.
Harry K. Fooks	1941	Fishing schooner out of Lewes sank after a collision.
William L. Hooper	1942	Barge foundered at Lewes.
Indian Arrow	1942	Vessel was torpedoed and sunk near mouth of Delaware Bay while in route from Texas to NewYork. Resting in 40 feet of water.
Gypsum Prince	1942	Steam freighter sank after a collision with the tanker Voco in 1942. Sank in 60 feet of water and was cleared to a 50-foot depth by demolition.
Hannah A. Lennen	1944	Screw steamer collided with tanker at entrance to Delaware Bay.
Harrison	1950	Screw steamer burned at Ben Davis Shoal, Delaware Bay.

APPENDIX B

RESUMES

J. Lee D. Cox Jr.

Curriculum vitae

Address
4425 Osage Avenue
Philadelphia, PA 19104

Date of Birth
June 24, 1959

OCCUPATION: Maritime Archaeologist

EDUCATION: East Carolina University, Greenville, N.C.
Maritime History and Underwater Research
M.A. Degree; May, 1985

Duke University, Durham, N.C.
Major; Anthropology/Archaeology
B.A. Degree; May 1981

EXPERIENCE: Career Related

June-July, 1994 — Principal Investigator in the Phase I and II underwater archaeological project in the Delaware Bay and River. The multi-faceted investigation, which was associated with the Delaware Comprehensive Navigation Project, included remote sensing of four sand borrow areas, the ground truthing of eleven targets near the shipping channel, and the Phase II investigation of two wreck sites in the river. Work was completed for Hunter Research and the Army Corps of Engineers, Philadelphia District.

March, 1994 — Principal Investigator in a Phase I underwater archaeological investigation in Vines Creek, near Dagsboro, Sussex County, Delaware. Work was completed for Hunter Research.

October, 1993 — Principal Investigator in a Phase I underwater archaeological investigation completed in conjunction with the Fort Mott (N.J.) Pier Rehabilitation Project. Work was completed for Hudson Engineers.

October, 1993 — Principal Investigator in a Phase I underwater archaeological remote sensing survey across Mantua Creek. Project was undertaken in conjunction with the proposed placement of a 30-inch force sewer main under the creek and adjacent tidal marsh. Work was completed for the Gloucester County Utilities Authority.

September, 1993 — Principal Investigator in a Phase I underwater archaeological and bathymetric remote sensing survey at two proposed sand borrow areas in the Atlantic Ocean, offshore of Delaware's Atlantic Coast. Work was completed for the Army Corps of Engineers, Philadelphia District.

August, 1993 — Archaeologist in a data recovery project on the shore of the Savannah River. Three vessels, including a center-board vessel, were excavated in conjunction with navigational improvement of the Savannah River. Work was completed for Mid-Atlantic Technology and the Army Corps of Engineers, Savannah District.

June-July, 1993 — Principal Investigator in the Phase I and II underwater archaeological project in the Delaware Bay and River. The investigation, which was associated with the Delaware Comprehensive Navigation Project, focused on selected channel deepening areas, channel side slope portions, and turns between various channel ranges. Five previously identified targets were also investigated. Work was completed for The Greeley-Polhemus Group and the Army Corps of Engineers, Philadelphia District.

April-May, 1993	Principal Investigator in a Phase I underwater archaeological survey in Great Egg Harbor Inlet, Ocean City, New Jersey. Work was completed for the Army Corps of Engineers, Philadelphia District, in conjunction with an on-going beach replenishment project.
March, 1993	Archaeologist in a Phase II underwater archaeological investigation of remote sensing targets at the mouth of the Cape Fear River, North Carolina. Work was completed for Tidewater Atlantic Research and the Army Corps of Engineers, Wilmington District.
December, 1992	Principal Investigator in a Phase I underwater archaeological survey in the Santee River, Georgetown County, South Carolina. Work was completed for Post, Buckley, Schuh, & Jernigan, and the South Carolina Department of Highways and Public Transportation.
November, 1992	Principal Investigator in a Phase I underwater archaeological survey in San Juan Harbor, San Juan, Puerto Rico. Work was completed for ArcheoMarine and the Army Corps of Engineers, Jacksonville District.
October, 1992	Archaeologist in a Phase I underwater archaeological survey in the Mississippi River, Prairie du Chein, Wisconsin. Work was completed for Tidewater Atlantic Research.
September, 1992	Archaeologist in a Phase I underwater archaeological survey in Aguadillo Harbor, Aguadillo, Puerto Rico. Work was completed for Mid- Atlantic Technology and the Army Corps of Engineers, Jacksonville District.
July, 1992	Principal Investigator in a Phase I underwater archaeological survey in the Stono River, Charleston, South Carolina. Work was completed in conjunction with the proposed completion of the Mark Clark Expressway.
July, 1992	Principal Investigator in a Phase I underwater archaeological survey in the Delaware River and Salem River, Gloucester County, New Jersey and New Castle County, Delaware. Work was completed for The Greeley-Polhemus Group and the Army Corps of Engineers, Philadelphia District.
June, 1992	Archaeologist in the Data Recovery Project at a mid-nineteenth century sloop rigged sailing vessel in the North East Cape Fear River, Wilmington, North Carolina. Work was completed for Tidewater Atlantic Research and the Army Corps of Engineers, Wilmington District.
May, 1992	Principal Investigator in a Phase I underwater archaeological survey in Rancocas Creek, Riverside, New Jersey. Work was completed for the Delran Sewerage Authority.
April, 1992	Principal Investigator in a Phase I underwater archaeological survey in the Delaware River, Gloucester County, New Jersey and Delaware County, Pennsylvania. Work was completed for Hunter Research and Sun Oil Company.
March, 1992	Principal Investigator in a Phase I underwater archaeological survey in the Delaware River, Gloucester County, New Jersey and New Castle County, Delaware. Work was completed for Keystone Cogeneration Systems.

January, 1992	Completed Statement of Historical Significance for the National Register Nomination Form of the U.S. Coast Guard Icebreaker Glacier. Work was completed for the U.S. Coast Guard.
December, 1991	Archaeologist in a Phase I remote sensing survey in Savannah River, Savannah, Georgia. Work was completed for Tidewater Atlantic Research and the Army Corps of Engineers, Savannah District.
December, 1991	Principal Investigator in Phase I underwater archaeological survey in Rancocas Creek, Riverside Park, New Jersey. Work was completed for the Delran Sewerage Authority.
November, 1991	Principal Investigator in Phase II Underwater Archaeological Investigation of three identified archaeological sites within the Burlington Coast Guard Station, Lake Champlain, Vermont. Work was completed for John Milner Associates and the United States Coast Guard.
October 1991	Archaeologist in a Phase I remote sensing survey at Brunswick, Georgia. Work was completed for Tidewater Atlantic Research and the Army Corps of Engineers, Savannah District.
September 1991	Archaeologist in Phase Ib underwater archaeological target investigation in Atlantic Ocean off Galilee, Rhode Island. Work was completed for Mr. Warren Reiss and AT&T.
September 1991	Archaeologist in Phase Ib target investigation in Atlantic Ocean adjacent to Beaufort Inlet, North Carolina. Initiated the documentation of a 19th century steamboat discovered in work area. Work was completed for Tidewater Atlantic Research and the Army Corps of Engineers, Wilmington District.
August 1991	Completed background research and compiled content outline for Liberty State Park's traveling exhibit on the New York/New Jersey Harbor Estuary. Work was completed for Van Sickle & Rolleri.
August 1991	Archaeologist in the data recovery project at the wreck site of a 19th century tug/tow boat on the bank of the Savannah River. After complete excavation, the hull and all surviving steam machinery was comprehensively documented. Upon completion of data recovery, the steam engine, drive shaft and propeller were all raised and removed from the hull for conservation and eventual display in a local museum. Work was completed for Tidewater Atlantic Research and the Army Corps of Engineers, Savannah District.
July 1991	Archaeologist in the Phase I remote sensing and diving survey in Tobago Harbor in an effort to locate 17th century French and Dutch shipwreck sites. Work was completed for the Trinidad & Tobago National Museum.
June 1991	Archaeologist in a Phase II investigation of two shipwreck sites in Lake Superior. An ROV was used to map and record the remains of the two vessels which rest in waters below 100 feet deep. A National Register Nomination was completed for one of the wreck sites. Work was completed for Tidewater Atlantic Research.
June 1991	Principal Investigator in Phase Ib Underwater Archaeological Investigation for the State Route 58, Clarksville Bypass Project, Kerr Reservoir, Clarksville, Mecklenburg County, Virginia. Project was completed by Dolan Research, Inc. for Harland Bartholomew & Associates and the Virginia Department of

Transportation.

May 1991	Archaeologist in a Phase 1 remote sensing survey adjacent to Beaufort Inlet, North Carolina. Work was completed for Tidewater Atlantic Research and the Army Corps of Engineers, Wilmington District.
April 1991	Principal Investigator in Phase Ib Underwater Archaeological Investigation for the Woodrow Wilson Bridge Improvement Study. Project was completed by Dolan Research, Inc. for DeLeuw, Cather & Company of Virginia and the Virginia Department of Transportation.
February-March 1991	Archaeologist in the mitigation of a nineteenth century derelict vessel in the Savannah River, Savannah, Georgia. Work was completed for GAI and the Army Corps of Engineers, Savannah District.
January 1991	Conducted historical research for Phase I archaeological investigation at Naval Weapon Station, Earle, New Jersey, and Naval Weapon Station, Charleston, South Carolina, in conjunction with Homeporting Study for AOE-6 ships. Work was completed for Tidewater Atlantic Research, Inc., and Turner, Collie and Braden, Inc.
December 1990	Archaeologist in Phase I Underwater Archaeological Survey of Foundry Cove, Cold Spring, New York. Work was completed for Tidewater Atlantic Research, in conjunction with Grossman & Associates, and the Environmental Protection Agency.
October 1990	Archaeologist in Phase I Underwater Archaeological Survey of the Cape Fear River, below Wilmington, North Carolina. Work was completed for the Army Corps of Engineers, Wilmington District, by Tidewater Atlantic Research.
August 1990	Archaeologist in Phase I Underwater Archaeological Survey of three potential borrow areas off of Sarasota and Venice, Florida. Work was completed for the Army Corps of Engineers, Jacksonville District, by Tidewater Atlantic Research.
July/September 1990	Archaeologist in the Phase I & II Underwater Archaeological Investigation of the Sheboygan, Wisconsin, waterfront. Excavation and site documentation was completed on a mid-nineteenth century schooner, identified during initial remote sensing survey. Work was completed for the city of Sheboygan by Tidewater Atlantic Research.
May 1990	Principal Investigator in the Phase I Underwater Archaeological Investigation for the MD 213 Relocated, Alternate N-1B Bridge across the Chester River, Chestertown, Maryland. Project was completed by Dolan Research for John Milner Associates and the Maryland State Highway Administration.
April 1990	Completed background historical and archaeological research in conjunction with the construction of a bridge for the U.S. Route 58, Clarksville Bypass, Mecklenberg County, Virginia. Research was completed by Dolan Research for John Milner Associates.
April 1990	Principal Investigator in the Phase I Underwater Archaeological Investigation at the Salem Maritime National Historic Site, Salem, Massachusetts. Project was completed by Dolan Research for Louis Berger Associates and the National Park Service.
March 1990	Principal Investigator in the Phase II documentation of a mid-nineteenth century centerboard sailing vessel in the Cohansey River, Bridgeton, New Jersey. Project was completed by Dolan Research for Alan Mounier, Archaeologist.

Jan. - April 1990	Directed historical research and planning for the interpretive exhibit at Fort Mott, NJ. In addition to producing historical data for the exhibition, information was compiled for a fort brochure which included a self guided tour. Project was completed by Dolan Research for Van Sickle and Rolleri.
Nov. 1989 - Jan. 1990	Archaeologist in the Phase I and II underwater archaeological investigation at nine proposed range light locations in the Chesapeake Bay. Project was competed by Dolan Research, in conjunction with Ocean Surveys, Inc.
August - Dec. 1989	Completed background research and preliminary planning on the proposed exhibition at the Philadelphia Maritime Museum on the topic of early history and formation of the United States Navy in Philadelphia. Work was completed by Dolan Research for the Philadelphia Maritime Museum.
August 1989	Principal Investigator in the Phase I underwater archaeological investigation in Rock Creek, Anne Arundel County, Maryland. Three areas within the creek water system were surveyed for submerged cultural resources. Project was completed by Dolan Research for Dames and Moore.
July 1989	Archaeologist in the Phase I underwater archaeological investigation at the Charleston Navy Base, Cooper River, Charleston, South Carolina. Project was completed by Tidewater Atlantic Research for the United States Navy.
June 1989	Archaeologist in the Phase I and II underwater archaeological investigation at South Shore, Milwaukee, Wisconsin. Project was completed by Tidewater Atlantic Research for the Milwaukee Sewerage Authority.
April 1989	Archaeologist in the Phase I investigation at Brown Shoal, Delaware Bay. Project was completed by Ocean Surveys, Inc. for the Corps of Engineers, Philadelphia District.
March 1989	Field Director in the Phase II underwater archaeological investigation for the proposed Route 58 Midtown Tunnel, Portsmouth and Norfolk, Virginia. Project was completed by John Milner Associates for the Virginia Department of Transportation.
March 1989	Archaeologist in the Phase II and III investigation of two mid-nineteenth century shipwrecks in the Atlantic Ocean, offshore Longbranch, New Jersey. Project was completed by Tidewater Atlantic Research for Alpine Engineering and the Corps of Engineers, New York District.
November 1988	Archaeologist in a Phase II underwater archaeological investigation in the Gulf of Mexico near Ship Island, Mississippi. Project was completed by GAI Consultants for the Army Corps of Engineers, Mobile District.
September 1988	Field Director for the Phase II and III underwater archaeological investigation at the mouth of Crosswicks Creek, Bordentown, NJ. Project was completed by Louis Berger and Associates for the New Jersey Department of Transportation.
September 1988	Archaeologist for East Carolina University's graduate fieldschool in Bermuda. Work completed included assisting the Bermuda Maritime Museum's excavation of the 1620 NOS Shipwreck.
July - Sept. 1988	Completed background research and planning for proposed exhibition at the Philadelphia Maritime Museum on the history of underwater exploration and research.

July 1988	Archaeologist in the Phase II and III underwater archaeological investigation at a colonial rice plantation canal at Litchfield Beach, South Carolina. The project was completed by Tidewater Atlantic Research for Steve Coggans and Associates.
June 1988	Archaeologist in the Phase I and II terrestrial investigation for cultural resources adjacent to Chocowinity Bay, Chocowinity, North Carolina. Work was completed by Tidewater Atlantic research for the Weyerhauser Corporation.
April 1988	Archaeologist in the Phase I investigation of the Savannah River, Savannah, Georgia. Work was completed by Tidewater Atlantic Research for the Corps of Engineers, Savannah District.
Apr. 1987-Mar. 1988	Guest Curator at the Philadelphia Maritime Museum for the exhibition, "Ironclad Intruder: U.S.S. MONITOR." The exhibition focused on the historical significance, mythic role and archaeological investigation of the MONITOR. In addition to planning and organizing the entire exhibition, the curator also edited the exhibition catalogue.
December 1987	Archaeologist in the Phase II investigation for the Grace Memorial Bridge replacement project in the Cooper River, Charleston, South Carolina. Work was completed by Tidewater Atlantic Research for the South Carolina Division of Highways.
Sept.- Oct. 1987	Principle Investigator in the Phase I investigation in the Delaware River. The project was completed by the Maritime Historical Institute for Corps of Engineers, Philadelphia District's Delaware Comprehensive Navigation Project. Sixteen specific areas were studied in the Delaware, Salem and Maurice Rivers.
August 1987	Archaeologist in the Phase II and III investigation in Pensacola Harbor, Florida. Work, completed by Tidewater Atlantic Research in conjunction with the Navy Experimental Dive Unit, Panama City, Florida, documented and mapped thirteen remote sensing targets identified by the Army Corps of Engineers, Mobile District.
August 1987	Principal Investigator for the Phase I and II Archaeological Investigation in Slaughter Creek, Dorchester County, Maryland. Project was completed by John Milner Associates for the Maryland Department of Transportation in conjunction with a planned bridge replacement project.
July 1987	Archaeologist working in conjunction with the Hampton Roads Naval Museum and the United States Navy's Mobile Diving and Salvage Unit, Little Creek, Virginia to document the remains of the Civil War Sloop of War CUMBERLAND. Documentation of the site was achieved with the *SHARPS* system (Sonic High Accuracy Positioning System).
June 1987	Archaeologist in the excavation of the War of 1812 Brig JEFFERSON, in Sacketts Harbor, Lake Ontario, New York. The project was funded in part by the National Geographic Society.
March 1987	Archaeologist in the Phase I survey assessing the potential for submerged cultural resources in conjunction with the proposed construction of a tunnel under the Elizabeth River, between Portsmouth and Norfolk, Virginia. Work was completed by John Milner Associates for the Virginia Department of Transportation.

August, Oct. 1986	Archaeologist in the Phase I investigation offshore of Ocean City, Maryland. The project was completed by Tidewater Atlantic Research for the Maryland Geologic Survey in conjunction with a proposed beach replenishment project.
July 1986	Principal Investigator in the Phase I, II and III investigation of Presque Isle Bay, Erie, Pennsylvania. The work, completed by the Maritime Historical Institute, was funded by a grant from the Pennsylvania Bureau for Historic Preservation, utilizing grant-in-aid funding from the Pennsylvania Division of Coastal Zone Management.
May - June 1986	Principal Investigator for the Phase III investigation of three shipwrecks in Pennsylvania waters. Two vessels in the Delaware River and one vessel in Misery Bay, Lake Erie, were documented. The work was funded by a grant from the Pennsylvania Bureau for Historic Preservation.
May - June 1986	Archaeologist in the Phase I underwater archaeological investigation in Long Island Sound, adjacent to New Rochelle, New York. Project was completed by Tidewater Atlantic Research for EBASCO.
April 1986	Principal Investigator for the Phase I investigation for submerged cultural resources in Delaware Bay. Work was completed for the Corps of Engineers, Philadelphia District.
March 1986	Principal Investigator for the Phase I and II investigation in Crosswicks Creek, Bordentown, New Jersey, in the vicinity of the right of way for a bridge span of I-295. In conjunction with a remote sensing survey in the creek, a site assessment of two eighteenth century wrecks was completed. The project was jointly funded by the Philadelphia Maritime Museum and the Pennsylvania Bureau for Historic Preservation.
December 1985	Archaeologist in the Phase I survey at Charleston, South Carolina. Work was completed by Tidewater Atlantic Research for the Corps of Engineers, Charleston District.
August 1985	Archaeologist in the Phase I and II underwater archaeological survey in the Potomac River at Alexandria, Virginia.
August 1985	Archaeologist in the Phase I and II survey in St. Michaels, Maryland, Harbor. The project was completed by Tidewater Atlantic Research for the Maryland Historic Trust.
July 1985	Principal Investigator for the Phase I and II investigation in Misery Bay, Lake Erie. The project was funded by the Pennsylvania Bureau for Historic Preservation and the Philadelphia Maritime Museum.
March 1985	Archaeologist in the Phase I survey offshore from Ocean City, New Jersey. The project was completed by Tidewater Atlantic Research for the Army Corps of Engineers, Philadelphia District.
December 1984	Archaeologist in the Phase I survey offshore from Kitts Hummock, Pickering Beach, Broadkill Beach and Bowers Beach, Delaware. Work was completed by Tidewater Atlantic Research for the Delaware Division of Soil and Water Conservation.
July 1984	Archaeologist representing the state of Pennsylvania during the Phase I and II underwater archaeological survey in Misery Bay, Lake Erie. The objective of the survey was to locate evidence of Oliver Perry's fleet from the War of 1812. The

Pennsylvania Bureau for Historic Preservation sponsored this project which was conducted jointly by the Philadelphia Maritime Museum and the United States Naval Reserve Mobile Diving and Salvage Unit II, Little Creek, Virginia.

May 1984 — Principal Investigator for the Phase I and II underwater archaeological survey in nine designated areas in the Delaware River. The work was funded by the Pennsylvania Bureau for Historic Preservation and the Philadelphia Maritime Museum and involved the participation of graduate students and personnel from East Carolina University.

June 1983 — Archaeologist in the Phase I and II underwater archaeological investigation in Wenona Harbor, Maryland. The project was completed by Tidewater Atlantic Research for the Maryland Geologic Survey.

October 1982 — Archaeologist in a Phase I and II underwater archaeological survey in the Chattahochie River at Columbus, Georgia. The investigation, completed by Tidewater Atlantic Research, was sponsored by the Confederate Naval Museum in an attempt to locate discarded ordnance from the Civil War.

GRANTS RECEIVED:

April 1986 — Wrote proposal and directed for the Maritime Historical Institute, the Presque Isle Bay Underwater Archaeological Survey. Funding for the project was made available by the Pennsylvania Bureau for Historic Preservation utilizing grant-in-aid funding from the Pennsylvania Division of Coastal Zone Management. A magnetometer and side scan sonar survey with diving investigations was completed in Presque Isle Bay, Lake Erie.

July 1985 — Wrote proposal and directed for the Philadelphia Maritime Museum a grant from the Pennsylvania Bureau for Historic Preservation which was designed to document and assess three shipwrecks in Pennsylvania waters to determine the archaeological and historical significance of each.

July 1984 — Wrote proposal and directed for the Philadelphia Maritime Museum a grant from the Pennsylvania Bureau for Historic Preservation which was designed to assess the potential presence of submerged cultural resources in the Monongahela, Ohio and Allegheny Rivers and the Lake Erie Shoreline.

July 1983 — Wrote proposal and directed for the Philadelphia Maritime Museum a grant from the Pennsylvania Bureau for Historic Preservation which was designed to assess the potential presence of submerged cultural resources in the Delaware and Susquehanna Rivers.

REPORTS:

February, 1994 — Submerged Cultural Resources Investigation Delaware Atlantic Coast From Cape Henlopen To Fenwick Island. Submitted to the Army Corps of Engineers, Philadelphia District.

January, 1994 — Submerged Cultural Resources Investigations, Delaware River Main Channel Deepening Project, Delaware, New Jersey, and Pennsylvania. Submitted to The Greeley-Polhemus Group and the Army Corps of Engineers, Philadelphia District.

November, 1993 — Phase IA & IB Underwater and Terrestrial Archaeological Survey; Gloucester County Utilities Authority, Mantua Creek Force Main, Gloucester County.

Submitted to Gloucester County Utilities Authority.

June, 1993	Submerged Cultural Resources Investigation, Great Egg Harbor Inlet & Peck Beach, Ocean City, New Jersey. Submitted to the Army Corps of Engineers, Philadelphia District.
May, 1993	Underwater Archaeological Reconnaissance: Route US 17A/SC 41, Santee River Bridge Replacement, Berkeley and Georgetown Counties, South Carolina. Submitted to Post, Buckley, Schuh & Jernigan.
October, 1992	Aquatic Cultural Resources Investigation, Salem Cove - Delaware River, Salem County, New Jersey and New Castle County, Delaware. Submitted to the Army Corps of Engineers, Philadelphia District.
June, 1992	Phase I Underwater Archaeological Remote Sensing Survey; Riverside Sewerage Authority STP Upgrade, Burlington County, New Jersey. Submitted to Richard Alaimo Associates.
April, 1992	Submerged Cultural Resource Survey; Keystone Cogeneration Plant, Delaware River, New Castle County, Delaware & Gloucester County, New Jersey. Submitted to Keystone Cogenerations Systems and the Delaware Division of Historical and Cultural Affairs.
April, 1992	Submerged Cultural Resource Survey; Keystone Cogeneration Plant, Delaware River, Gloucester County, New Jersey. Submitted to Keystone Cogenerations Systems and the Office of the New Jersey Heritage.
March, 1992	A Phase II Archaeological Evaluation of Identified Archaeological Resources at the USCG Station Burlington, Burlington, Vermont. Submitted to United States Coast Guard.
February, 1992	Statement of Historical Significance for the USCG Icebreaker Glacier. Statement was submitted to the United States Coast Guard in conjunction with the development of a nomination form for the National Register of Historic Places.
January, 1992	Phase I Underwater Archaeological Remote Sensing Survey; Delran Sewerage Authority Pipeline Extension, Burlington County, New Jersey. Submitted to Richard Alaimo Associates.
September 1991	Phase Ib Underwater Archaeological Survey for the U.S. Route 58, Clarksville Bypass Study, Clarksville, Mecklenburg and Halifax Counties, Virginia. Submitted to Harland Bartholomew and Associates, Inc.
June 1991	Phase Ib Underwater Archaeological Survey for the Woodrow Wilson Bridge Improvement Study. Submitted to DeLeuw, Cather & Company of Virginia.
December 1990	Phase 1a Cultural Resources Investigation for the U.S. Route 58 Corridor Study (Clarksville Bypass), Mecklenburg County, Virginia. Co-authored with Cheek, Stevens, Seifert and Meyer. Submitted by John Milner Associates to the Virginia Department of Transportation.
July 1990	MD 213 Relocated, Alternate N-1B Phase I Underwater Archaeological Reconnaissance Chester River, Chester River, Chestertown, Maryland. Submitted by Dolan Research and John Milner Associates to the Maryland State Highway Administration

May 1990	Underwater Archaeological Remote Sensing Reconnaissance, Salem Maritime National Historic Site, Salem, Massachusetts. Submitted by Dolan Research to Louis Berger Associates and the National Park Service.
April 1990	Archaeological Investigation: Cohansey River Wreck Site, Bridgeton, New Jersey. Submitted by Dolan Research to Alan Mounier, Archaeologist.
March 1990	Fort Mott Historical Narrative. Submitted by Dolan Research to Van Sickle and Rolleri.
January 1990	Archaeological Discussion of Magnetic and Acoustic Remote Sensing Data for the Chesapeake Range Lights Project, Maryland and Virginia. Submitted by Dolan Research to Ocean Surveys, Inc.
September 1989	Underwater Archaeological Investigation of Rock Creek, Anne Arundel County, Maryland. Submitted by Dolan Research to Dames and Moore.
June 1989	Phase II Archaeological Investigations for the Proposed Route 58 Midtown Tunnel Portsmouth and Norfolk, Virginia. Co-authored with Stevens and Heck. Submitted by John Milner Associates to the Virginia Department of Transportation.
February 1989	A Report on the Phase I and Phase II Archaeological Investigation for Revolutionary War Vessels Within the Alignment of I-295 (The Trenton Complex) Crosswicks Creek, Bordentown, New Jersey. Co-authored with Fokken. Submitted by Louis Berger & Associates to the New Jersey Department of Transportation.
July 1988	Submerged Cultural Resources Investigations, Delaware River, Main Navigational Channel, Philadelphia, PA. to Artificial Island, New Jersey. Submitted to the Corps of Engineers, Philadelphia District.
May 1988	Submerged Cultural Resources Investigations, Maurice River, New Jersey. Submitted to the Corps of Engineers, Philadelphia District.
April 1988	Submerged Cultural Resources Investigations, Salem Cove and River, New Jersey. Submitted to the Corps of Engineers, Philadelphia District.
January 1988	A Phase I Cultural Resources Survey for the Proposed Route 58 Midtown Tunnel Portsmouth and Norfolk, Virginia. Co-authored with Cheeks, Stevens, Meyer and Glendening. Submitted by John Milner Associates to the Virginia Department of Transportation.
December 1987	Underwater Archeological Survey and Evaluation for the Route 16 Bridge Replacement over Slaughter Creek, Dorchester County, Maryland. Co-authored with Struthers and Parrington. Submitted by John Milner Associates to the Maryland State Highway Administration.
December 1986	Presque Isle Bay Underwater Archaeology Survey. Submitted to the Pennsylvania Historical and Museum Commission.
November 1986	A Historical and Archaeological Assessment of Three Submerged Cultural Resources in Pennsylvania. Submitted to the Pennsylvania Historical and Museum Commission.
July 1986	A Marine Cultural Resources Reconnaissance and On Site Evaluation of Crosswicks Creek, Bordentown, New Jersey. Co-authored with Watts.

Submitted to the Philadelphia Maritime Museum.

April 1986	A Sensitivity Level Investigation of Cultural Resources in the Vicinity of; the Main Navigational Channel, Delaware River, Wilmington to the Sea and a Proposed Deepwater Port. Submitted to the Corps of Engineers, Philadelphia District.
October 1985	A Preliminary Survey to Analyze the Potential Presence of Submerged Cultural Resources in the Ohio, Monongahela and Allegheny Rivers and the Pennsylvania Portion of Lake Erie. Submitted to the Pennsylvania Bureau for Historic Preservation.
September 1984	A Preliminary Survey to Analyze the Potential Presence of Submerged Cultural Resources in the Delaware and Susquehanna Rivers. Submitted to the Pennsylvania Bureau for Historic Preservation.
July 1983	A Reconnaissance of the Chattahochie River at Columbus, Georgia. Co-authored with Watts, Still and Hall. Submitted to the Confederate Naval Museum at Columbus, Georgia.
June 1983	The Yorktown Shipwreck Project; Fall Work Season 1982. Co-authored with Newell. Submitted to the Virginia Branch for Underwater Archaeology, Gloucester Point, Virginia.
March 1983	Submerged Survey for Sir Walter Raleigh's Lost Colony: Roanoke Island, North Carolina. Submitted to the North Carolina Underwater Archaeology Branch, Fort Fisher, North Carolina.

PUBLICATIONS:

1990	*USS Shipwreck: Underwater Archaeology and U.S. Navy Divers.* In, Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference. Tuscon.
1988	Ironclad Intruder: U.S.S. MONITOR: A collection of essays on the history, symbolism and archaeological importance of the U.S.S. MONITOR. Co-edited with M. Jehle. Philadelphia Maritime Museum. Philadelphia.
1988	*Shipwrecks.* In, The Delaware Estuary: Rediscovering a Forgotten Resource. Edited by T. Bryan and J. Pennock. University of Delaware Sea Grant Program, Newark.
1987	*Preliminary Investigation of a Revolutionary War Era Vessel in Crosswicks Creek, Bordentown, New Jersey.* In, Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference. Savannah.

LECTURES:

Episcopal Academy Family Forum Lecture Series, 1994
Philadelphia Maritime Museum Friends of the Library Lecture Series, 1993
The 21st Annual Conference on Underwater Archaeology, Tuscon, AZ., 1990
The 43rd National Preservation Conference, National Trust for Historic Preservation, Philadelphia, 1989
New Jersey State Museum Lecture Series, 1988
Pennsylvania Historical and Museum Commission, 4th Annual Archaeology Workshop, 1988

The 18th Annual Conference on Underwater Archaeology, Savannah, GA, 1987
Philadelphia Maritime Museum Membership Lecture Series, 1986
The 16th Annual Conference on Underwater Archaeology, Boston, MA, 1985

MEMBERSHIPS:
Society for Historical Archaeology
Society of Professional Archaeologists (certified in museology, marine survey, and underwater archaeology)
Pennsylvania Archaeological Council
Florida Archaeological Council
Philadelphia Ship Preservation Guild
University City (Philadelphia) Arts League, Board of Directors.

RICHARD W. HUNTER
President/Principal Archaeologist, MA, SOPA

Education

Ph.D. Candidate, Geography, Rutgers University, New Brunswick, New Jersey, 1984-present

M.A., Archaeological Science, University of Bradford, England, 1975

B.A., Archaeology and Geography, University of Birmingham, England, 1973

Experience

1986- Principal Archaeologist, Hunter Research, Inc.
Cultural Resource Consultants, Trenton, NJ

Founder and principal stockholder of firm providing archaeological and historical research, survey, excavation, evaluation, and report preparation services in the Northeastern United States. Specific expertise in historical and industrial archaeology (mills, iron and steel manufacture, pottery manufacture), historical geography, historic landscape analysis.

Participation in:

- Project management, budgeting and scheduling
- Proposal preparation and client negotiation
- Hiring and supervision of personnel
- Supervision of research, fieldwork, analysis and report preparation

1983-1986 Vice-President/Archaeologist, Heritage Studies, Inc., Princeton, NJ

Principal in charge of archaeological projects.
Responsibilities included:

- Survey, excavation, analysis, and reports
- Client solicitation, negotiation, and liaison
- Project planning, budgeting, and scheduling
- Recruitment and supervision of personnel

1981-1983 Principal Archaeologist, Cultural Resource Group, Louis Berger & Associates, Inc., East Orange, NJ

Directed historical and industrial archaeological work on major cultural resource surveys and mitigation projects in the Mid-Atlantic region. Primary responsibility for report preparation and editing.

1979-1981	Archaeological Consultant, Hopewell, NJ
1978-1981	Adjunct Assistant Professor, Department of Classics and Archaeology, Douglass College, Rutgers University, NJ
1978-1979	Research Editor, Arete Publishing Company, Princeton, NJ Prepared and edited archaeological, anthropological, and geographical encyclopedia entries (Academic American Encyclopedia, 1980).
1974-1977	Archaeological Field Officer, Northampton Development Corporation, Northampton, England Supervised archaeological salvage projects executed prior to development of the medieval town of Northampton (pop. 230,000). Experience included: • Monitoring of construction activity • Supervision of large scale urban excavations • Processing of stratigraphic data and artifacts • Preparation of publication materials
1969-1970	Research Assistant, Department of Planning and Transportation, Greater London Council

Special Skills and Interests

- historic landscape analysis
- geographic information systems
- water-powered mill sites
- iron and steel manufacture before the Industrial Revolution
- scientific methods in archaeology

Publications

Hopewell: A Historical Geography. Township of Hopewell. Richard L. Porter, co-author. 1991.

"Contracting Archaeology? Cultural Resource Management in New Jersey, U.S.A" (with Ian Burrow). The Field Archaeologist (Journal of the Institute of Field Archaeologists) 12, March 1990, 194-200.

"American Steel in the Colonial Period: Trenton's Role in a 'Neglected' Industry." In Canal History and Technology Proceedings IX, 83-118, 1990. Richard L. Porter, co-author.

"The Demise of Traditional Pottery Manufacture on Sourland Mountain, New Jersey, during the Industrial Revolution." Ch. 13 in Domestic Potters of the Northeastern United States, 1625-1850. Studies in Historical Archaeology, Academic Press, 1985.

"Scientific Aids in Pottery Fabric Analysis." In Medieval Pottery, Processing and Publication. Department of the Environment, U.K. Government, 1983.

Excavations at St. Peter's Street, Northampton, 1973-74. Northampton Development Corp., 1979. John Williams, senior author.

"Excavations at Thorplands, Northampton, 1970 and 1974." Northamptonshire Archaeology 12, 97-154, 1977.

Professional Affiliations

Society of Professional Archaeologists (accredited 1979; certification in field research, collections research, theoretical or archival research)
New Jersey State Historic Sites Review Board (Member, 1983-present)
Professional Archaeologists of New York City (PANYC)
Society for Historical Archaeology
Society for Industrial Archaeology
Society for Post-Medieval Archaeology
Council for Northeast Historical Archaeology
Archaeological Society of New Jersey

HUNTER RESEARCH

Richard W. Hunter
President

Ian C. Burrow
Vice President

BROOKE S. BLADES
Principal Archaeologist, M.A.

Education

Ph. D. Candidate, Anthropology, New York University, New York, NY, 1988-present

M.A., American Civilization, University of Pennsylvania, Philadelphia, 1978

B.A., History, College of William and Mary, 1973

Experience

1994-present — Principal Investigator, Hunter Research, Inc., Trenton, N.J.

Technical and managerial responsibilities for selected research, field, laboratory and report preparation components of archaeoological projects. Participation in:
- research, survey, excavation, analysis and reports
- project supervision and on-site management
- management of laboratory operations and graphics production
- supervision of field, laboratory and drafting personnel
- preparation of proposals
- personnel recruitment

1991-1993, 1974-1988 — Archaeologist, Mid-Atlantic Regional Office, National Park Service, Philadelphia, PA

Responsibilities included:
- preparation of research designs
- preparation of requests for proposals
- consultant selection
- contract administration
- all aspects of project review, including research, fieldwork, analysis, and report

Also designed, executed and directed archaeological and historical research programs at numerous federally-owned managed historic sites, including:
- Fort McHenry National Monument, Baltimore, Maryland
- Valley Forge National Historical Park, Philadelphia, Pennsylvania
- Independence National Historical Park, Philadelphia, Pennsylvania
- Delaware Water Gap National Recreation Area, Pennsylvania
- George Washington Birthplace National Monument, Montross, Virginia
- Fredericksburg and Spotsylvania National Military Park, Virginia
- Petersburg National Battlefield, Virginia
- Shenandoah National Park, Virginia

1989-1990 Site Supervisor, SJS Archaeological Services, Inc., PA

Directed excavations on prehistoric sites.

Participation in:
- survey and excavation
- supervision of personnel
- field photography
- field recording

1982 Consulting Archaeologist, Longmeadow Historical Society, MA

1979-1980 Survey Director, Magee University College, New University of Ulster, Northern Ireland

Directed survey of 17th-century British village sites in County Londonderry, Ulster

1976-1978 Consulting Archaeologist, Historic Deerfield, MA

1973-1974 Supervisor and Field Excavator, Colonial Williamsburg, VA

Other Experience

1991 Teaching Assistant, Department of Geology and Earth Sciences, West Chester University, PA

1989-1990 Instructor/Graduate Assistant, Department of Anthropology, New York University, NY

Special Skills and Interests

- statistical analysis of survey and excavation data; statistical sampling; statistical analysis of anthropological data
- remote sensing: magnetometer and resistivity meter
- analysis of prehistoric lithics and historic ceramics
- computerization of survey, excavation and collections analysis data
- petrographic analysis of archaeological artifacts
- scanning electron microscopy and electron microprobe analysis
- photography of archaeological data related to electron microscopy and petrographic analysis, as well as of field and collection data

Publications

"English Villages in the Londonderry Plantation." Post-Medieval Archaeology 20: 257-269. 1986.

"Historic Archaeology and the Decorative Arts." CRM Bulletin 8(3&4): 14, 15, 18. D. Campana and D. Orr, co-authors. 1985.

"Uncovering Early City Point, Virginia." Archaeology 38(3):64, 65, 78. D. Campana and D. Orr, co-authors. 1985.

"The Discovery of the Taylor House at the Petersburg National Battlefield." Historical Archaeology 18: 64-74. B. Bevan and D. Orr, co-authors. 1984.

"'In the Manner of England': Tenant Housing in the Londonderry Plantation." Ulster Folklife 27:39-56. 1981.

"Dungiven Bawn Re-edified." Ulster Journal of Archaeology 43:91-96. N. F. Brannon, co-author. 1980

"Archeological Excavations at George Washington Birthplace, 1974-1977." In Chapters in the History of Popes Creek Plantation, Washington's Birthplace: Wakefield Memorial Association, 1979.

"Dr Williams' Privy: Cultural Behavior as Reflected in Artifact Deposition at the Dr. Thomas Williams House, Deerfield, Massachusetts." In New England Historical Archaeology, Boston University, 1977.

Awards

National Science Foundation Dissertation Improvement Grant, 1993-94
Dean's Dissertation Fellowship, New York University, 1993-94
University Fellowship, New York University, 1988-90
Fulbright-Hayes Fellowship, Senior Research Scholar, New University of Ulster (Northern Ireland), 1979-80

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Richard W. Hunter
Lee R. Burrow

MICHAEL TOMKINS
Senior Archaeologist/Historian, BA

Education

B.A. Anthropology/Geography, State University of New York at Albany, Albany, New York, 1990.

Experience

1993 -	Senior Archaeologist/Historian, Hunter Research Inc., Trenton, NJ
1991 -	Assistant Historian/Assistant Archaeologist Hunter Research, Inc., Trenton, NJ Technical and supervisory responsibilities for selected historical and archival research tasks, field and laboratory operations and report preparation. Participation in: - archival and cartographic research - survey and excavation - supervision of field personnel - field photography - stratigraphic and artifact analysis - report preparation
1990	Crew Chief, New York State Museum, Division of Historic and Anthropological Services, Albany, New York Field archaeologist on cultural resource surveys on proposed construction projects of the New York State Department of Transportation and Department of Corrections.
1987-1989	Field Archaeologist, New York State Museum, Division of Historic and Anthropological Services, Albany, NY (June - September) Field archaeologist on various cultural resource survey projects in upper New York State.
1988	Field Archaeologist, Public Archaeological Facility, SUNY at Binghamton, New York (summer months) Field archaeologist participating in excavations of human burials from a late nineteenth century psychiatric hospital in upper New York State.

Other Experience

1990 -	New York State Emergency Medical Technician Certification Volunteer Emergency Technician for Town of Guilderland
1984 -	NAUI Basic Scuba Diver Certification

APPENDIX C

PROJECT ADMINISTRATIVE SUMMARY

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APPENDIX C

PROJECT ADMINISTRATIVE SUMMARY

HUNTER RESEARCH, INC.
PROJECT SUMMARY

Project Name:	A PHASE 1 SUBMERGED AND SHORELINE CULTURAL RESOURCES INVESTIGATION, BROADKILL BEACH BROADKILL HUNDRED, SUSSEX COUNTY, DELAWARE
Level of Survey:	I
HRI Project:	94018
Date of Report:	1994, November
Client:	U.S. Army Corps of Engineers
Address:	The Wanamaker Building, 100 Penn Square East, Philadelphia, PA 19107-3390
Review Agency:	DELSHPO
Agency Reference:	

PROJECT CHRONOLOGY

Date of Contract Award:	07/05/1994
Notice to Proceed:	07/05/1994
Background Research:	August-September
Fieldwork:	August-September
Analysis:	October
Report Written:	October-November

PROJECT PERSONNEL:

Principal Investigator:	Richard Hunter
Background Research:	Lee Cox, Michael Tomkins and William Liebeknecht
Field Supervisor:	Lee Cox, Michael Tomkins
Field Assistants:	Wes Hall, Ralph Wilbanks and James Reedy
Artifact Analysis:	N/A
Draftsperson:	Vincent Maresca
Report Written By:	Lee Cox, Richard Hunter, Brooke Blades and Michael Tomkins

Artifacts and Records to be Deposited: N/A

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SECTION 6

PROJECT DESIGN

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EXISTING STRUCTURES

BROADKILL BEACH

In September 1994, a site inspection of the existing beachfront was conducted. The only coastal structures present in Broadkill Beach are five beach groins that were constructed in the 1950's and a dumped concrete rubble revetment built in 1964. The groins are located at Washington, Adams, North Carolina, Georgia, and Alabama Avenues; the coastal revetment is in the vicinity of Alabama avenue. The location of the existing structures in Broadkill Beach are shown in Figure 1.

The groins located at Washington and Adams avenues are timber bulkhead construction type. The groins are in fair condition, are approx. 20'-30' long(exposed section) and the exposed sections are at an elevation below mean high water. A small amount of sand appears to be building on the west side of the groins at Adams and Washington. In addition, it seems that the groins are being maintained; relatively new steel bolts were visible in the structures. The groin located at North Carolina Avenue is a timber crib-stone filled construction type. The groin is approx. 40' long (exposed section)and is only visible on the upper end of the beach berm. The groin appears buried beyond the high water line. The condition is extremely poor. The wood is rotted and there is almost no stone left in the cribbing structure. The groins located at Georgia and Alabama Avenues are made of dumped concrete rubble. The groins are in poor condition and do not appear to be functioning at all. The concrete rubble extends approximately 15' to 20' into the water and at most 10' onto the beach at low tide. There are no existing construction plans for these groins.

The other type of shore protection structure located within the study limits is a concrete rubble revetment. The revetment extends from North Carolina Avenue to approx. 700' north of Alabama Avenue. Only 30 l.f. of the revetment is visible just north of Alabama Avenue at the present time, the rest is buried under existing dune. The revetment is very low in height, approx. 3' from top to toe, and is in poor condition. The revetment is constructed of broken up concrete rubble and does not appear to be designed or engineered specifically for the site. In fact, the revetment does not even appear as an engineered structure, but as just randomly dumped concrete rubble.

A complete structure inventory of the study area including color photographs is attached for reference.

STRUCTURE INVENTORY
BROADKILL BEACH, DELAWARE
FEASIBILITY STUDY

GROINS

1. Timber bulkhead type groin located at Adams Avenue. Condition is fair. Small amount of sand appears to be building up on the west side of the groin. Exposed section of groin is approx. 25'-30' in length at low tide. Relatively new steel bolts are visible in the structure. Constructed during the 1950's. Photo #1.

2. Timber bulkhead type groin located at Washington Avenue. Condition is fair. Exposed section of groin is approx. 20' in length at low tide. Constructed during the 1950's. Photo #2.

3. Stone filled timber crib groin located at North Carolina Avenue. Currently is buried from high water line seaward, approx. 40 l.f. is exposed. Condition of groin is poor, timbers are rotting, steel is rusted and corroded, and stone is missing except for a few pieces of broken up concrete. Photo #3.

4. Concrete rubble groin located at Georgia Avenue. Poor condition. Extends into water approximately 15 l.f. at low tide. Appears as just randomly dumped concrete rubble. Photo #4.

5. Concrete rubble groin located at Alabama Avenue. Poor condition. Extends into water approx. 20 l.f. at low tide, 10' onto land. Photo #5.

NOTE: The three groins north of Route. 16 are approximately 500' apart. Timber bulkhead groins south of Route. 16 are approximately 300' apart and are approx. 1300' from groins north of Route 16.

SHORE PARALLEL STRUCTURES

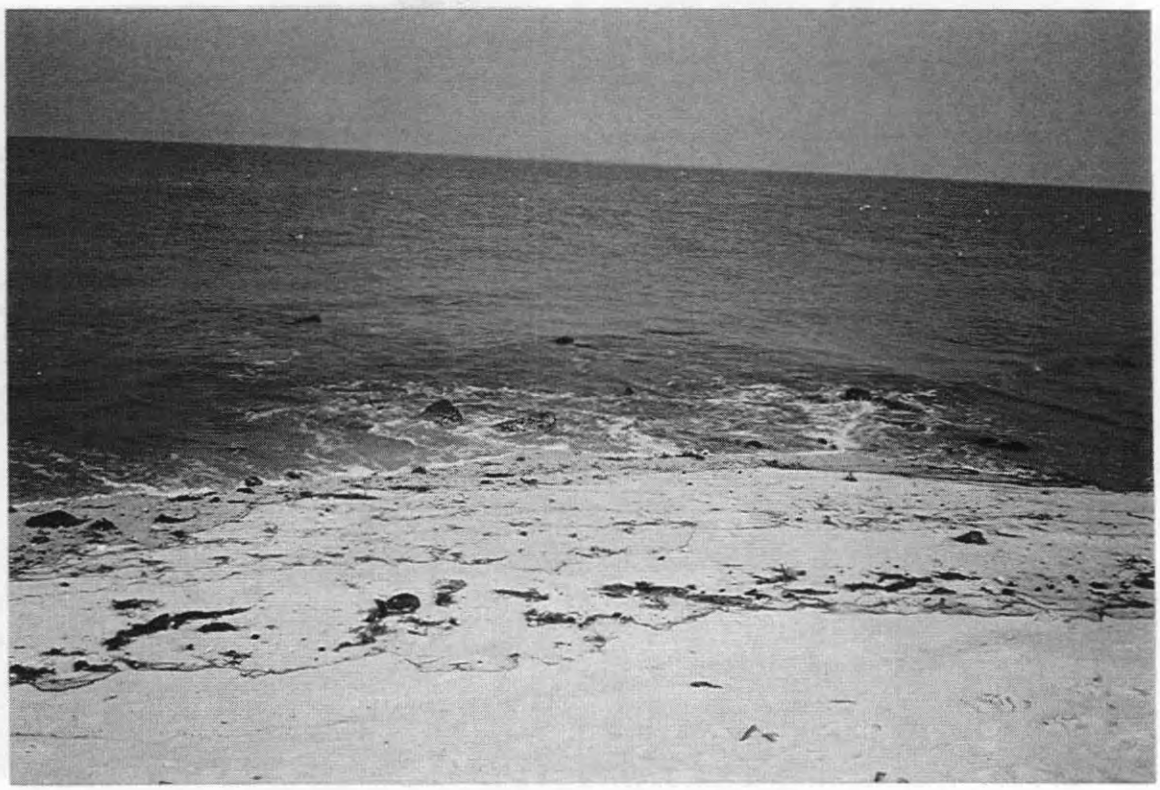
1. Concrete rubble revetment located 50' north of Alabama Avenue. Approximately 30 l.f. is exposed. Poor condition. Does not appear designed in any way - just randomly dumped broken up concrete. Height of structure is roughly 3' from toe to top. Photo #6&7.

1. TIMBER BULKHEAD GROIN LOCATED AT ADAMS AVENUE

2. TIMBER BULKHEAD GROIN LOCATED AT WASHINGTON AVENUE

973
915

3. STONE FILLED TIMBER CRIB GROIN
LOCATED AT NORTH CAROLINA AVENUE



4. CONCRETE RUBBLE GROIN LOCATED AT
GEORGIA AVENUE

5. CONCRETE RUBBLE GROIN LOCATED AT
ALABAMA AVENUE

6. CONCRETE RUBBLE REVETMENT LOCATED
NORTH OF ALABAMA AVENUE

975
9/7

7. CONCRETE RUBBLE REVETMENT LOCATED
NORTH OF ALABAMA AVENUE

WITHOUT PROJECT FUTURE CONDITIONS

The continual erosion of the protective beach face within the study area causes more deterioration of the existing groins and concrete rubble revetment.

Since there are no protective bulkheads in Broadkill Beach there is nothing to prevent the erosion of upland and private property. The continued erosion of land will cause damage to utilities and private property. Increased maintenance costs will be incurred to repair damaged utilities and street ends. Home owners will find their bay front property areas shrinking unless they continually backfill eroded areas.

INFRASTRUCTURE REPLACEMENT

Storm erosion causes damage to existing utilities within the project area. If nothing is done to prevent erosion (i.e., without project conditions) existing infrastructure will have to be replaced. To facilitate the economics analysis, the cost of replacing utilities within the project area was completed. Lists of the utilities affected and costs are shown in table 1 and 2 on the attached pages. Costs are based on October 95 price levels.

TABLE 1

BROADKILL BEACH UTILITY REPLACEMENT COSTS

TYPICAL BLOCK BETWEEN BEACH AND MAIN ROAD (PERPENDICULAR TO BEACH)

<u>WATER LINES AND SEPTIC TANKS</u>

ITEM	COSTS ≤20'	≤50	≤100	≤200	≤300
1. 4" PVC waterline	$87/lf	$36/lf	$19/lf	$14/lf	$10/lf
2. Waterline lateral 3/4" pvc	$1,600	$1,600	$3,200	$4,800	$8,000
3. Septic Tanks	$5,200	$5,200	$10,400	$15,600	$26,000

<u>ELECTRIC LINES</u>

1. Poles 3/600 l.f.			$3,000	$3,000	$6,000
2. Transformer assume one/pole			$1,100	$1,100	$2,200
3. Service Connections	$1,000	$1,000	$2,000	$3,000	$5,000
4. Wire	$59/lf	$20/lf	$10/lf	$5/lf	$3/lf

<u>TELEPHONE AND CABLE</u>

1. Service and Cable	$800	$800	$1,600	$3200	$4,800
2. Wiring	$40/lf	$16/lf	$8/lf	$4/lf	$3/lf

TABLE 2

BROADKILL BEACH UTILITY REPLACEMENT COSTS

TYPICAL LENGTH OF ROAD ALONG MAIN ROAD PARALELL TO BEACH

ASSUME 100' OF SPACING
BEACH SIDE OF ROAD

WATER LINES AND SEPTIC TANKS

ITEM	COSTS ≤20'	≤50	≤100	≤200	≤300
1. 4" PVC waterline	$87/lf	$36/lf	$19/lf	$14/lf	$10/lf
2. Waterline lateral 3/4" pvc	$1,600	$1,600	$1,600	$3,200	$4,800
3. Septic Tanks	$5,200	$5,200	$5,200	$10,400	$15,600
ELECTRIC LINES					
1. Poles 3/600 l.f.	$3,000	$3,000	$3,000	$3,000	$6,000
2. Transformer assume one/2 poles	$1,100	$1,100	$1,100	$1,100	$2,200
3. Service Connections	$1,000	$1,000	$1,000	$2,000	$3,000
4. Wire	$50/lf	$20/lf	$10/lf	$5/lf	$3/lf
TELEPHONE AND CABLE					
1. Service and Cable	$800	$800	$800	$1,600	$2,400
2. Wiring	$40/lf	$16/lf	$8/lf	$4/lf	$3/lf

CYCLE 2
PRELIMINARY DESIGN ALTERNATIVES

BEACH RESTORATION

Typical beachfill sections for Broadkill Beach are shown in Figure 2. The sand would be placed over a length of approximately 15,000 feet along Broadkill Beach. The sand source is located approximately 1.6 miles offshore. The beachfill quantities used for cost estimating purposes were obtained using the typical sections and lengths mentioned above(Figure 2). Cost estimate for initial construction of the beachfill alternative is shown in Table 3.

BEACH RESTORATION WITH DUNE

Same as above except beachfill typical sections include dunefill as shown in Figure 3. Lengths of placement and sand source location are same as above. The beachfill and dunefill quantities used for cost estimating purposes were obtained using the typical sections shown in Figure 3.

TABLE 3

INITIAL CONSTRUCTION
COST ESTIMATE
CYCLE 2 ALTERNATIVES
BEACHFILL AND DUNEFILL
BROADKILL BEACH

ITEM	UNIT COST	UNIT	QTY.	COST
1. BEACHFILL	7.75	CY	820,000	$6,355,000
2. DUNEFILL	7.75	CY	100,000	$775,000
				$7,130,000

BEACH RESTORATION WITH GROINS

Beachfill would be placed along length of Broadkill Beach as described previously. A dune would be included to provide additional storm surge protection. All new groins would be constructed approx. 750' apart, requiring a total of 21 groins. Profiles and a typical section of beach groins for Broadkill Beach are shown in Figures 4 & 5. Beachfill that would be placed in conjunction with the groin construction is shown in Figures 2 & 3. The cost estimate for initial construction of the beach groin configuration for Broadkill Beach is shown in Table 4.

TABLE 4

COST ESTIMATE
CYCLE 2 ALTERNATIVE
BROADKILL BEACH GROINS

ITEM	UNIT COST	UNIT	QTY.	COST
1. CAPSTONE	48.22	TON	13,440	$648,077
2. CORESTONE	47.08	TON	12,726	$599,140
3. MATSTONE	42.18	TON	17,451	$736,083
4. BEDDING STONE	39.87	TON	10,710	$427,008
5. EXCAVATION	3.52	CY	6,300	$22,176
6. PLACEMENT	2.35	CY	6,300	$14,805
7. TIMBER BULKHEAD	615.31	LF	4,620	$2,842,732
			TOTAL	$5,290,134
			SAY	$5,290,200

BEACH RESTORATION WITH OFFSHORE BREAKWATER

Beachfill would be placed along the lengths of Broadkill Beach described previously as Beach Restoration. A dune would be constructed to provide additional storm surge protection. This alternative includes the construction of eleven segmented offshore breakwaters in Broadkill Beach. Each breakwater segment would be constructed 700' in length with a gap space between segments of 300'. The breakwaters would be located 600' offshore of the beach. Typical section of the segmented offshore breakwater is shown on figure 6. Cost estimate for initial construction of the breakwater segments is shown in Table 5.

TABLE 5
COST ESTIMATE
CYCLE 2 ALTERNATIVE
BROADKILL BEACH BREAKWATER

ITEM	UNIT COST	UNIT	QTY.	COST
1. CAPSTONE	62.76	TON	170,655	$18,443,580
2. TOE APRON STONE	53.28	TON	34,906	$1,859,822
3. MATSTONE	39.55	TON	82,418	$3,259,924
4. BEDDING STONE	33.29	TON	41,210	$1,371,708
5. EXCAVATION	8.25	CY	72,722	$2,316,514
			TOTAL	$28,695,210
			SAY	$28,700,000

CYCLE 3 BEACH RESTORATION ALTERNATIVES

Design Template Parameters

Design of the beach restoration alternatives was done in accordance with CETN II-5, the Shore Protection Manual and accepted coastal engineering practice.

Design baseline. A design baseline was established along the length of the project study area in order to determine the alignment of the proposed beach restoration alternatives. In Broadkill Beach the design baseline was located to follow as close as possible to the existing dune line or private property line. In other words, the line was established as close as possible to the landward edge of the existing beach berm while at the same time avoiding any abrupt shifts landward or seaward. For each option analysed, the seaward edge of the proposed berm was located by offsetting the beach width from the design line. For those options that included a dune, the design baseline was used to locate the toe of the dune. The design baseline is shown in Figures 7 & 8.

Berm Elevation. A berm elevation of +8.0 ft. NGVD was used to analyse all alternatives. The average berm elevation in the area is +7 to +8 NGVD.

Berm Width. Berm widths of 100' and 150' were evaluated.

Beachfill Slope. The slope of the proposed fill was 15H:1V down to the mean low water elevation. A 15 to 1 slope matches closely with existing beaches in the area. Below mean low water the slope follows that of the existing profile down to the elevation of closure.

Dune. Average dune heights in the vicinity of Broadkill Beach vary from +12 ft. to +15 ft. NGVD. Top dune elevations of +14.0 ft. ,+16 ft. and +18 ft. NGVD were used in the cycle 3 evaluations. Dune top width was 25' for all alternatives. The side slopes chosen for the dune were 5H:1V, which is the average for naturally occuring dunes in the area.

Dune Alignment. The landward toe of the dune was located as close as possible to the design baseline, at the landward edge of the berm. Where feasible the proposed dunes tie into existing dunes to take advantage of conditions that reduce required quantities.

Beachfill Closure. At the northern and southern end of the study area in Broadkill Beach a 1000' taper was used to terminate the various beachfill options.

Design Beachfill Quantities. To determine quantities for each alternative, the proposed design templates were drawn on the existing beach survey cross sections on a cell by cell basis. Average end area methods were used to compute the volumes. Total quantities for all plans investigated in cycle 3 are presented in table 6.

Nourishment Volumes. In order to maintain as a minimum the design profile, an advanced nourishment or maintainence volume is added to the initial quantity. Without renourishing on a regular basis the beachfill placed would eventually erode. In order to maintain the design profile, an advanced nourishment fill is placed in addition to the initial design beachfill. In this way the nourishment volume is sacrificial and protects the design beachfill. At the end of the periodic nourishment cycle the design profile should remain. The nourishment quantities were increased by an overfill factor of 1.4. The overfill factor takes into account differences in grain size between the native beach sand and the borrom sand. Initial construction volumes were determined by taking the quantities obtained from the cross sections and adding to it the advanced nourishment volumes.

Typical sections. Figure 9 shows the various beachfill alternatives superimposed on a typical profile of the existing beach in Broadkill.

SELECTED PLAN

In order to determine a selected plan an initial nourishment cycle of 3 years was chosen to screen the alternatives. Once the selected plan was determined the optimum nourishment cycle had to be chosen. Nourishment cycles of three thru seven years were examined. Total quantities are listed in Table 7. Since the nourishment quantities were refined after the cycle 3 initial screening the numbers shown in table 6 do not agree with the those listed in table 7. The selected plan is a beachfill restoration composed of a 100' berm width in Broadkill Beach. The plan contains a dune with a top elevation of +16 NGVD and a top width of 25'. A total initial volume of 1,305,000 c.y. of sand fill will be placed along a length of 14,500 linear feet. The fill volume includes initial design fill requirements plus advanced nourishment. Periodic nourishment of 358,400 c.y. would be placed every 5 years. Vehicular access to the beach would be provided at Rt. 16 in the center of the town. Access would be established by using sand fence to create a path 12' wide. The path would be established along both sides of the dune at a skewed angle to the dune alignment. This would allow vehicles to climb along the side of the dune at a flatter slope than 5H:1V. Pedestrian access would be provided in a similiar fashion as the vehicular, the difference being a smaller path width and a somewhat steeper slope. Pedestrian access paths would be located at each street end in Broadkill Beach. Dune grass would not be planted at either the vehicle or pedestrian access locations. The plan includes dune grass planting of 36 acres and the erection of 21,800 linear feet of sand fence. Total quantities for the selected plan are shown in table 8. Typical section of the selected plan is presented in figure 10 and profiles of the

TABLE 6
CYCLE 3 DESIGN ALTERNATIVES

	BERM C.Y.	DUNE C.Y.	ADVANCED NOURISHMENT 3 YR. CYCLE	TOTAL INITIAL QUANTITY C.Y.
100' BERM NO DUNE	487,364		210,000	697,364
100' BERM 14' DUNE	487,364	131,401	210,000	825,737
100' BERM 16' DUNE	487,364	220,115	210,000	917,479
150' BERM NO DUNE	803,468		210,000	1,013,468
150' BERM 14' DUNE	803,468	128,373	210,000	1,141,841
150' BERM 16' DUNE	803,468	220,115	210,000	1,233,583
150' BERM 18' DUNE	803,468	303,040	210,000	1,316,508

93i

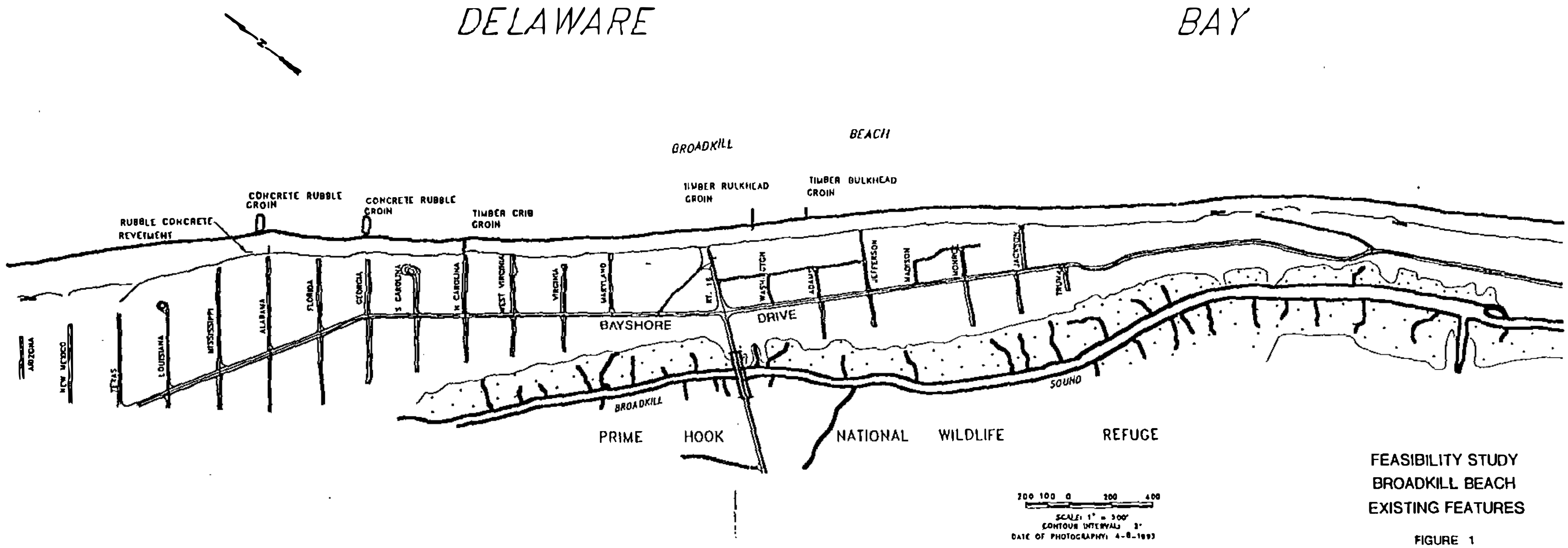
selected plan are shown in figures 11-16. Limits of the area to be beachfilled are shown on figures 7 and 8.

TABLE 7
EVALUATION OF NOURISHMENT CYCLES
WITH SELECTED PLAN-100' BERM, 16' DUNE

NOURISHMENT CYCLE YEARS	INITIAL REQUIRED QUANTITY C.Y.	NOURISHMENT C.Y.	DUNE QUANTITY C.Y.	TOTAL INITIAL QUANTITY C.Y
3	685,583	190,400	260,784	1,136,767
4	"	239,400	"	1,185,767
5	"	358,400	"	1,304,767
6	"	547,400	"	1,493,767
7	"	806,400	"	1,752,767

TABLE 8
TOTAL QUANTITIES FOR SELECTED PLAN

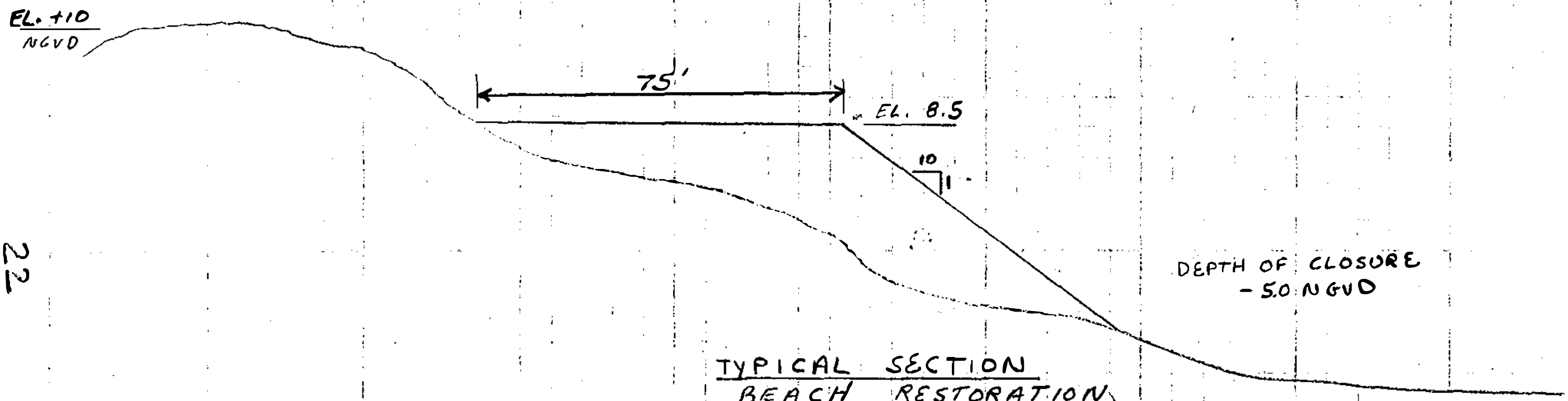
	BERM C.Y.	DUNE C.Y.	NOURISHMENT C.Y.	TOTAL FILL C.Y.	SAND FENCE L.F.	GRASS PLANT. AC.
TOTALS	685,583	260,784	358,400	1,304,767	21,800	36.1



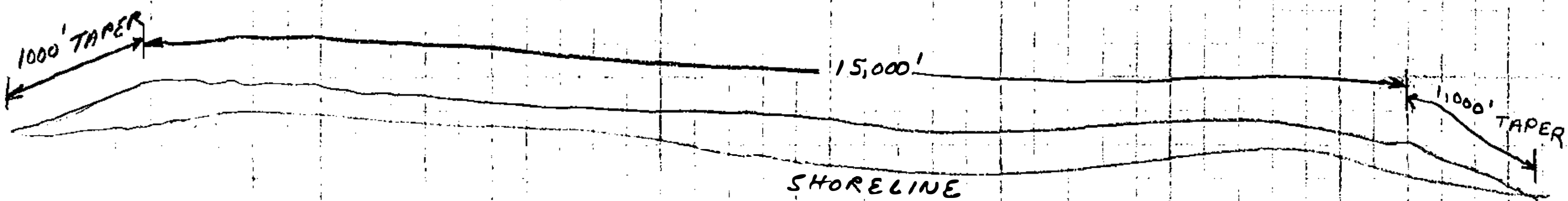
FEASIBILITY STUDY
BROADKILL BEACH
EXISTING FEATURES

FIGURE 1

CYCLE 2 ALTERNATIVES
BROADKILL BEACH

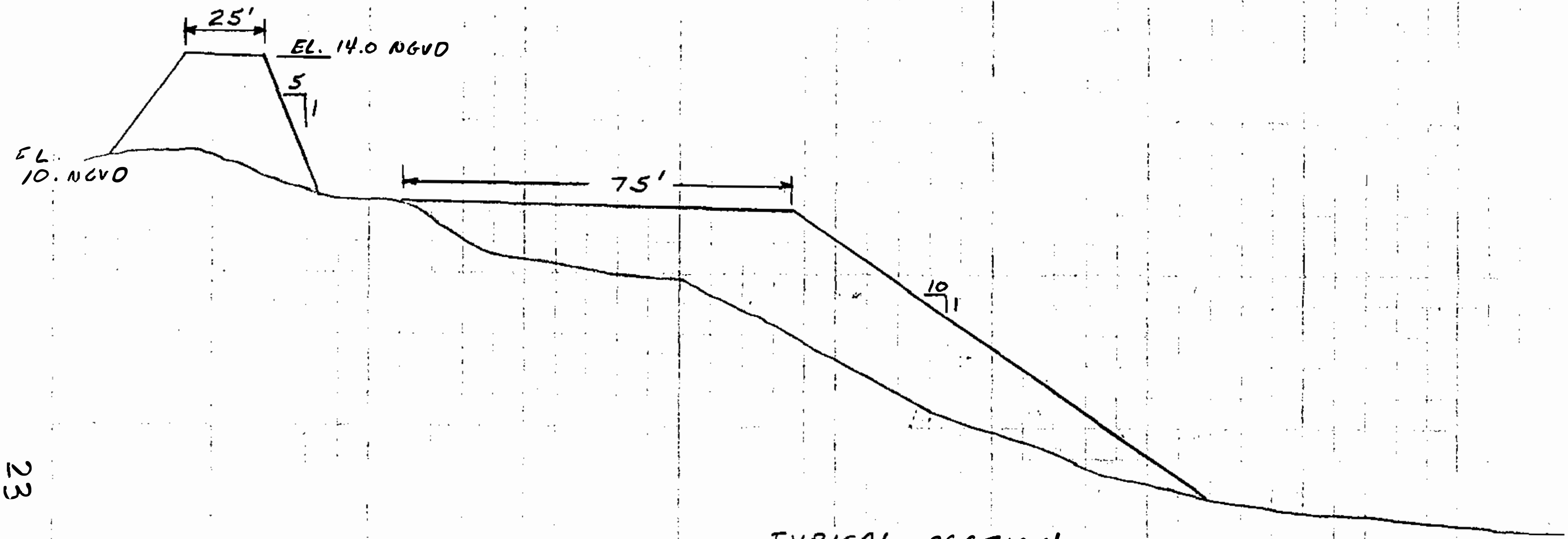


TYPICAL SECTION
BEACH RESTORATION
N.T.S.

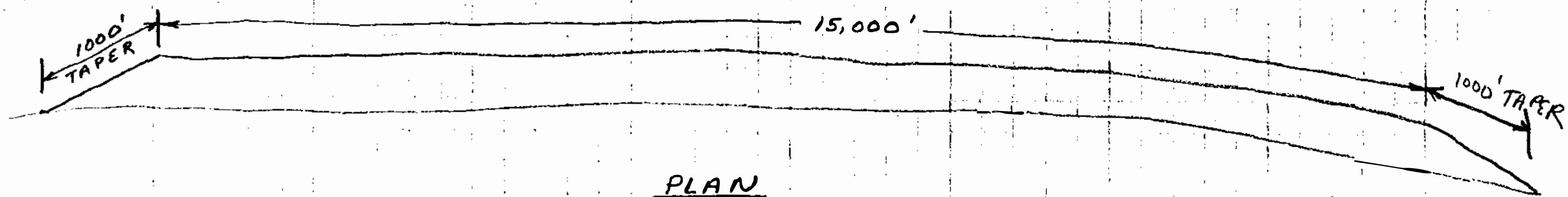


PLAN
BEACH RESTORATION
N.T.S.

FIGURE 2



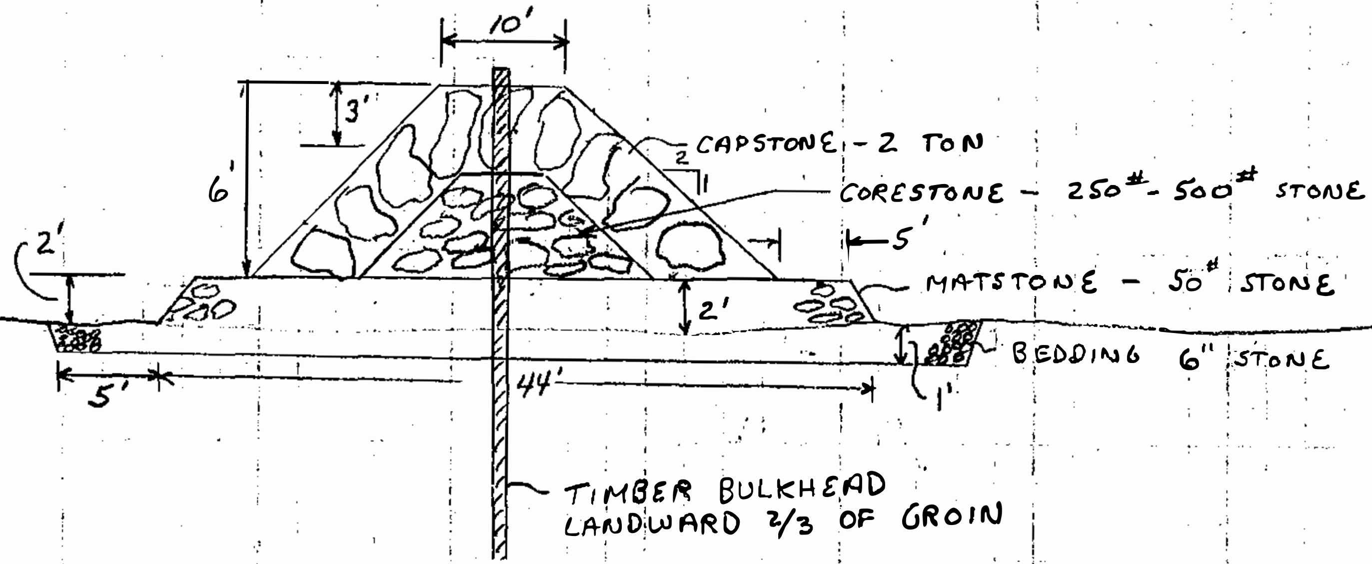
TYPICAL SECTION
BEACH RESTORATION W/ DUNE
N.T.S.



PLAN
BEACH RESTORATION W/DUNE
N.T.S

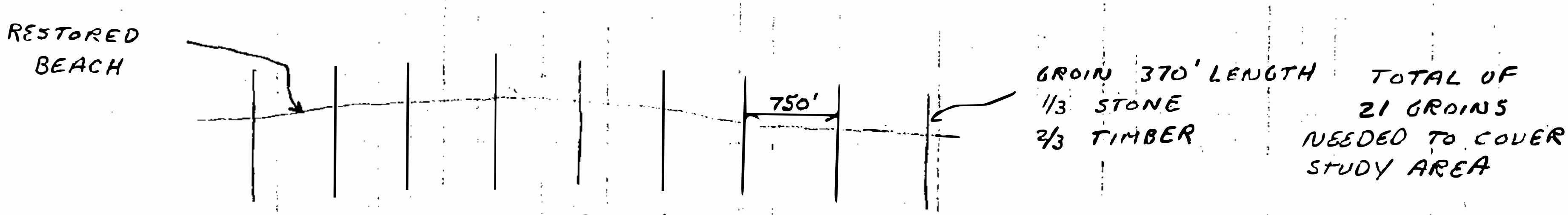
FIGURE 3

CYCLE 2 ALTERNATIVES
BROADKILL BEACH



N.T.S.

TYPICAL SECTION
GROIN



PLAN
GROIN FIELD
N.T.S.

FIGURE 4

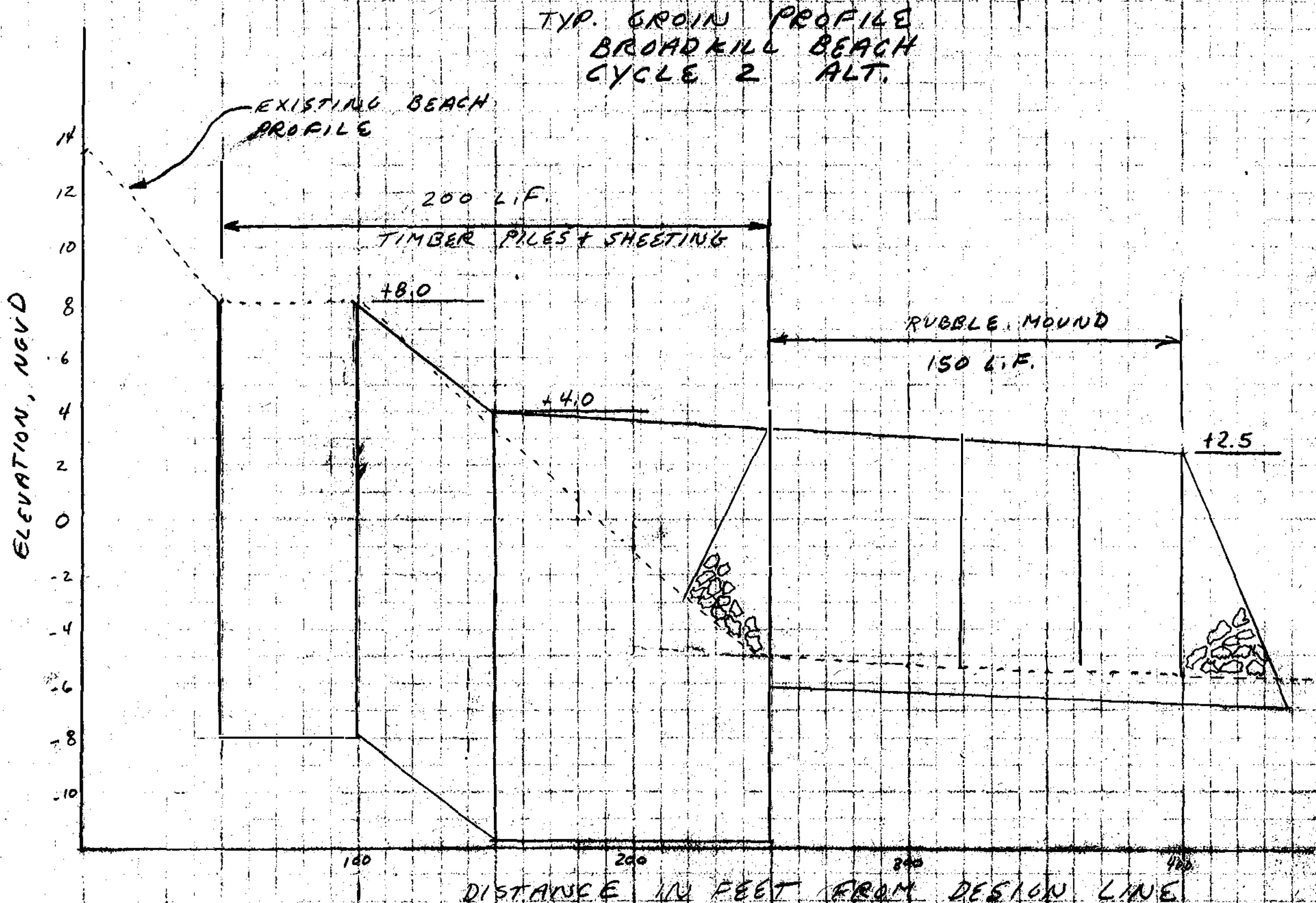

TYP. GROIN PROFILE
BROADKILL BEACH
CYCLE 2 ALT.
EXISTING BEACH PROFILE
200 L.F.
TIMBER PILES + SHEETING
RUBBLE MOUND
150 L.F.
+8.0
+4.0
+2.5
ELEVATION, NGVD
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
100
200
300
400
DISTANCE IN FEET FROM DESIGN LINE

FIGURE 5

CYCLE 2 ALTERNATIVES
BROADKILL BEACH

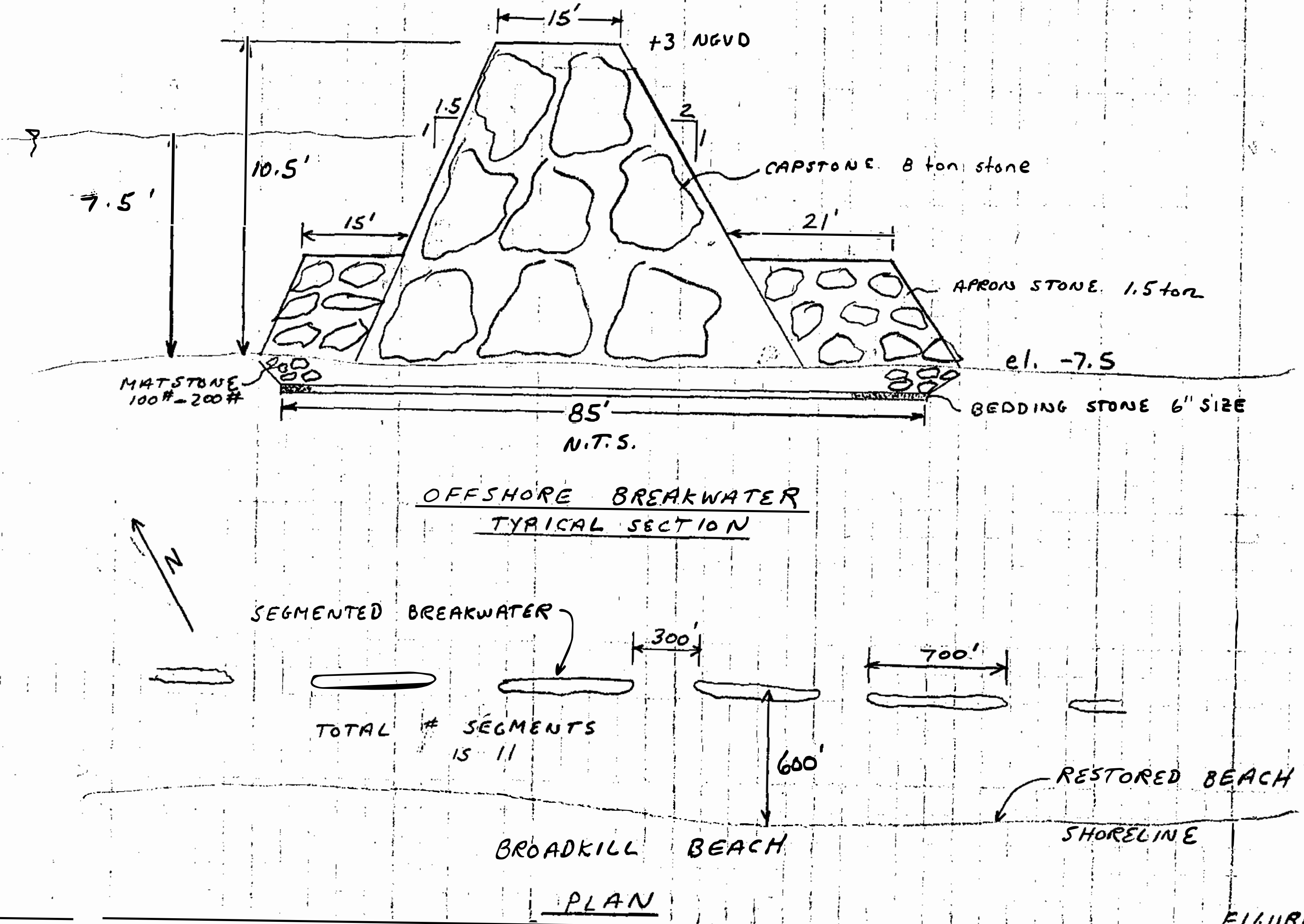
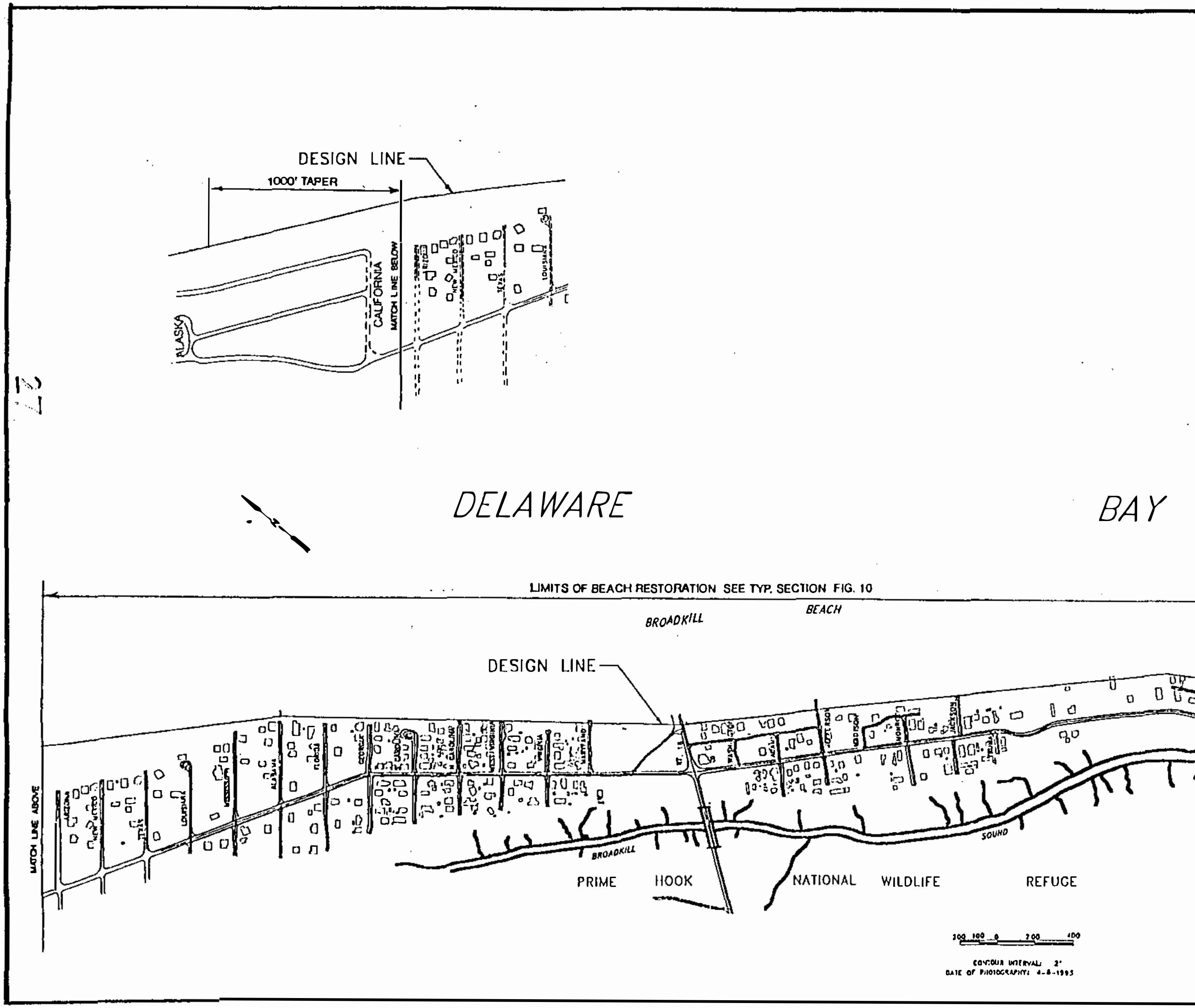
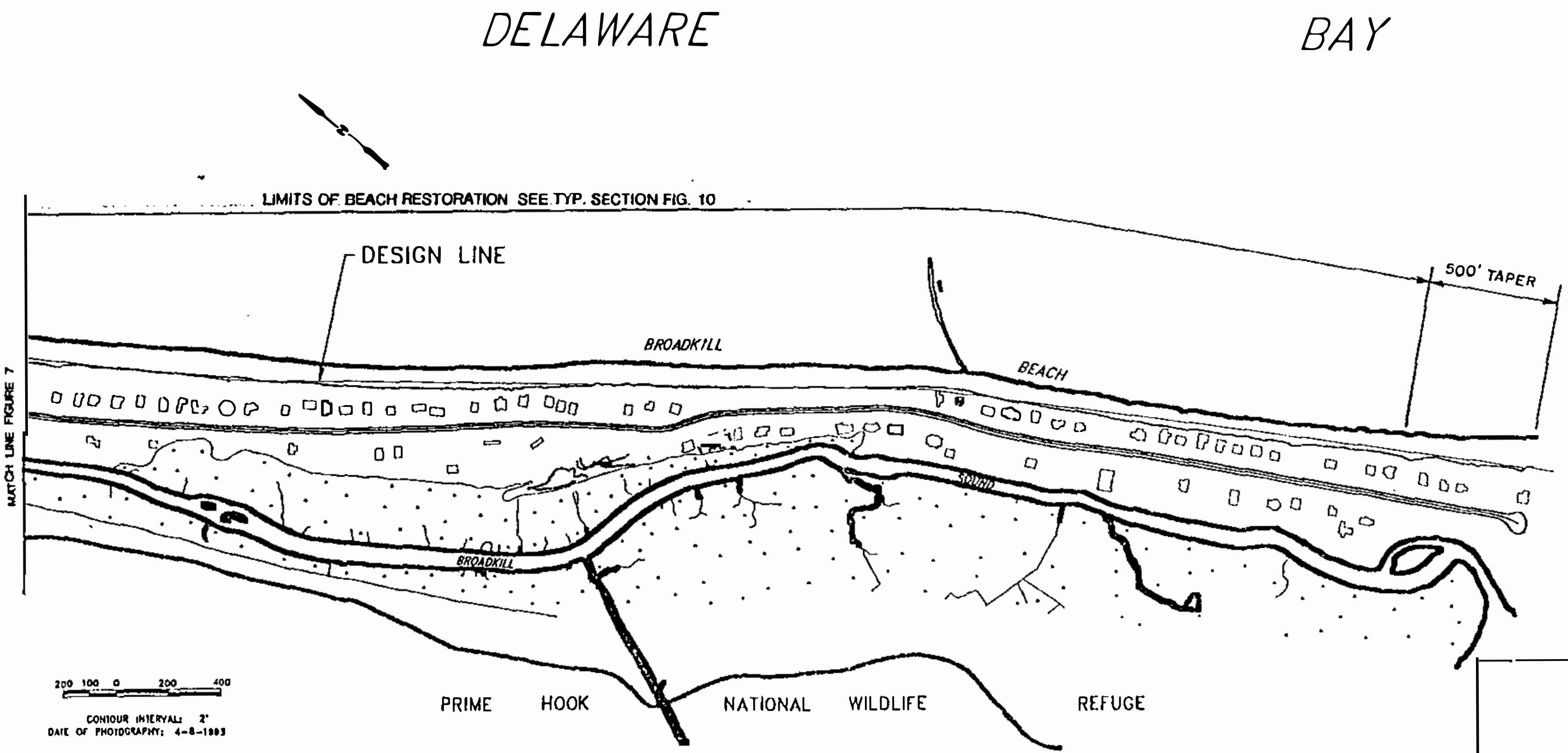


FIGURE 6



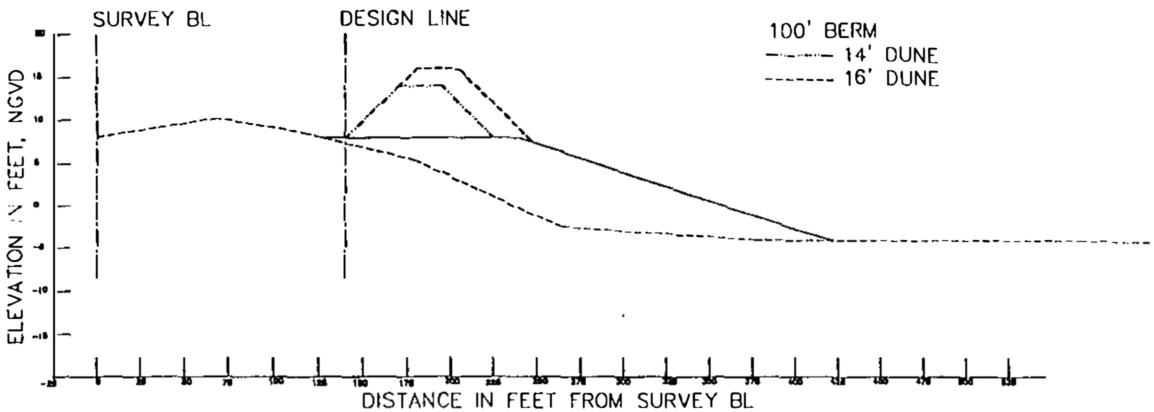
FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN

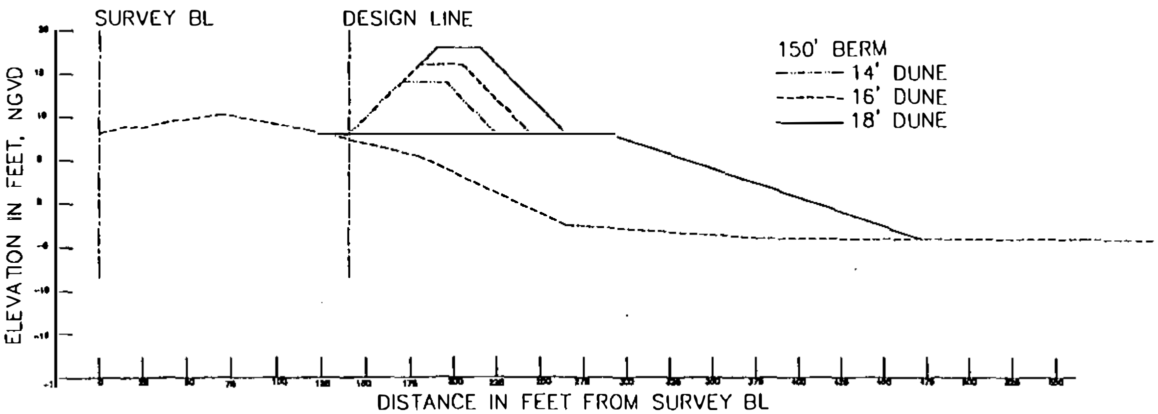
FIGURE 7



FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN

FIGURE 8

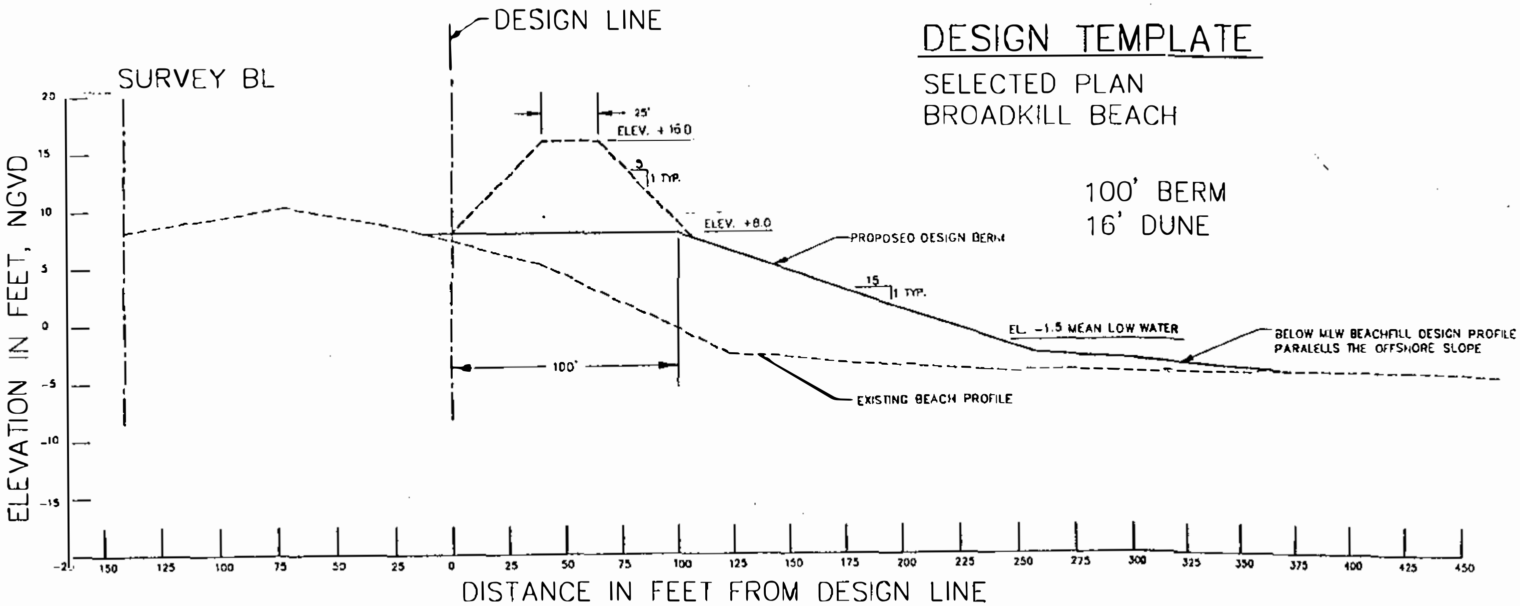




CYCLE 3 DESIGN ALTERNATIVES

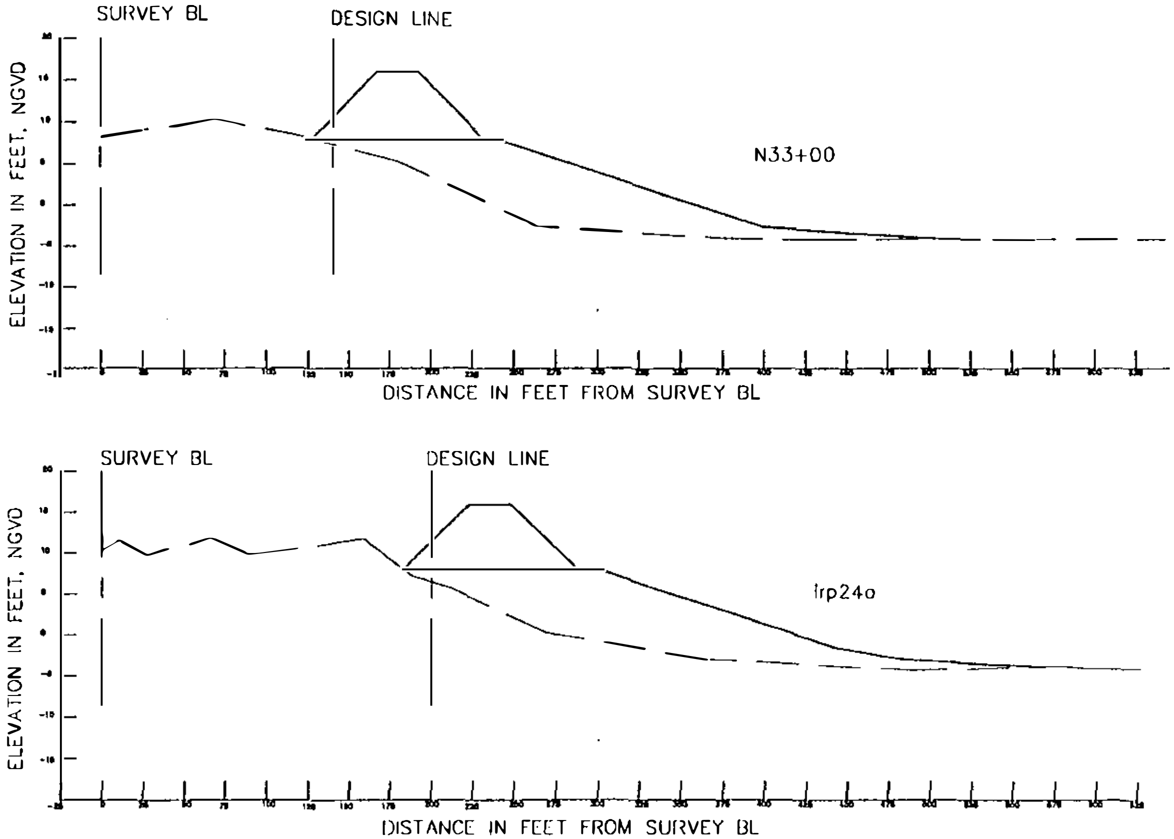
FEASIBILITY STUDY
BROADKILL BEACH

FIGURE 9



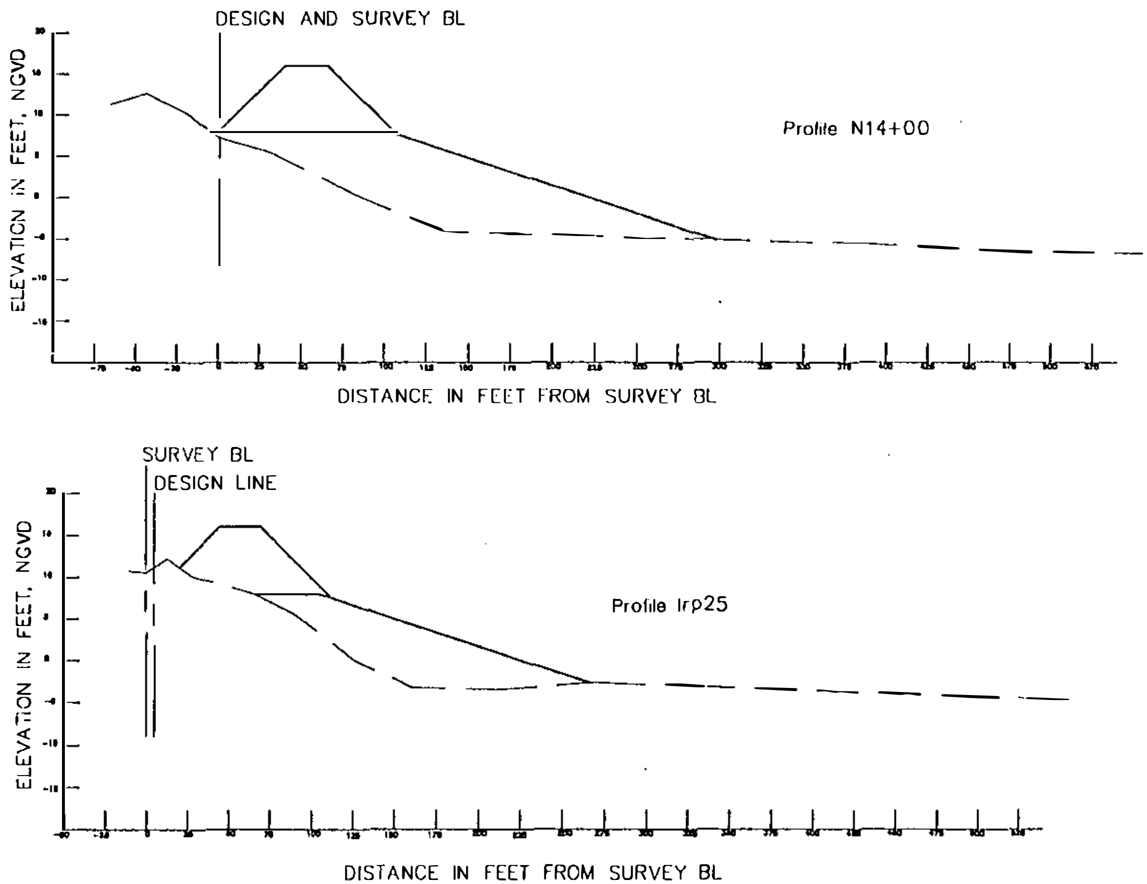
FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN
TYPICAL SECTION

FIGURE 10



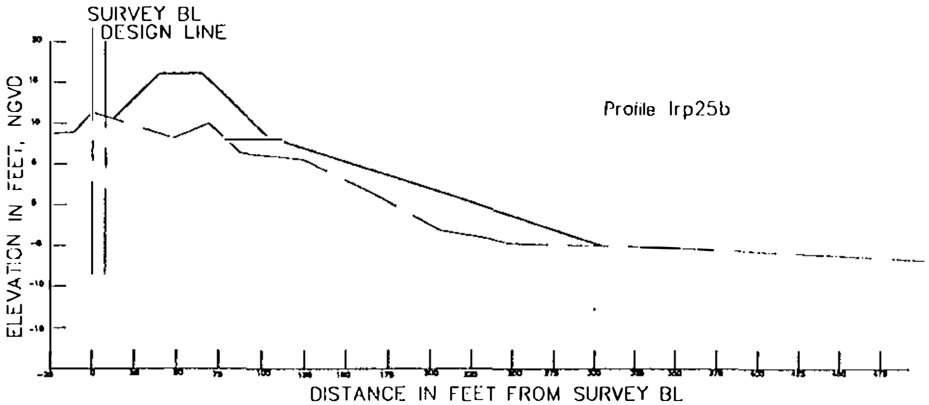
FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN
PROFILE

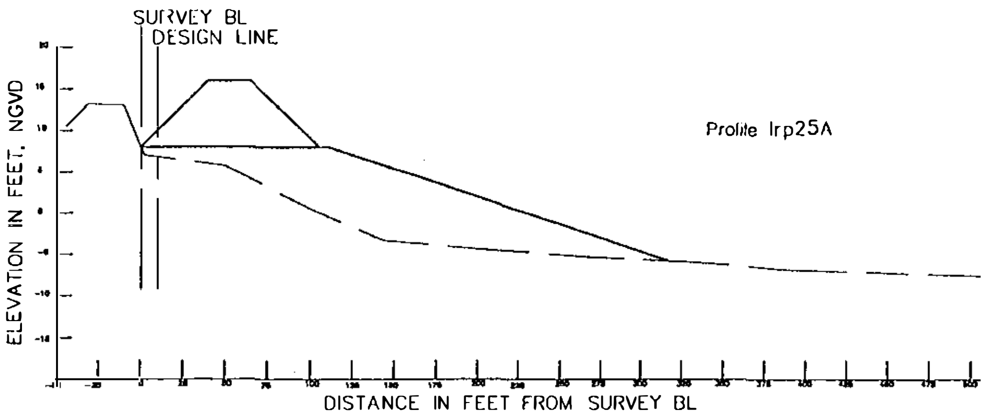
FIGURE 11



FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN
PROFILE

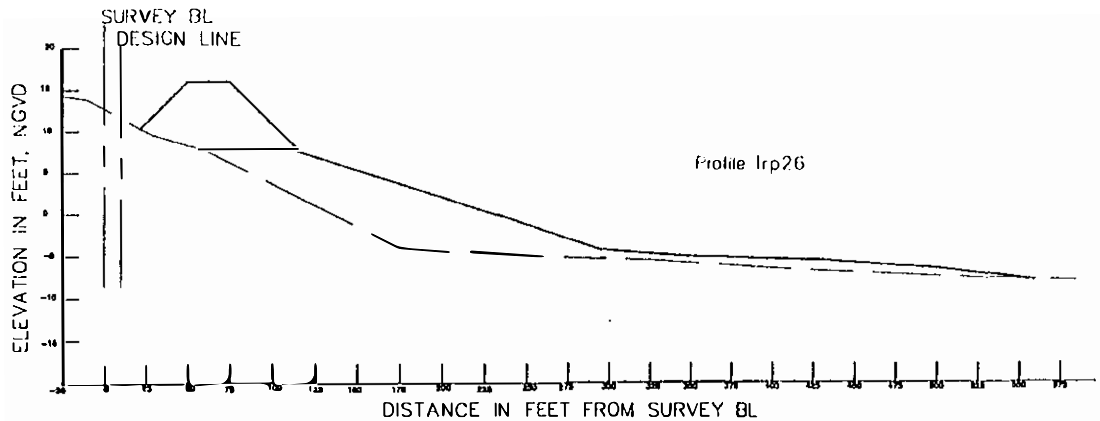
FIGURE 12

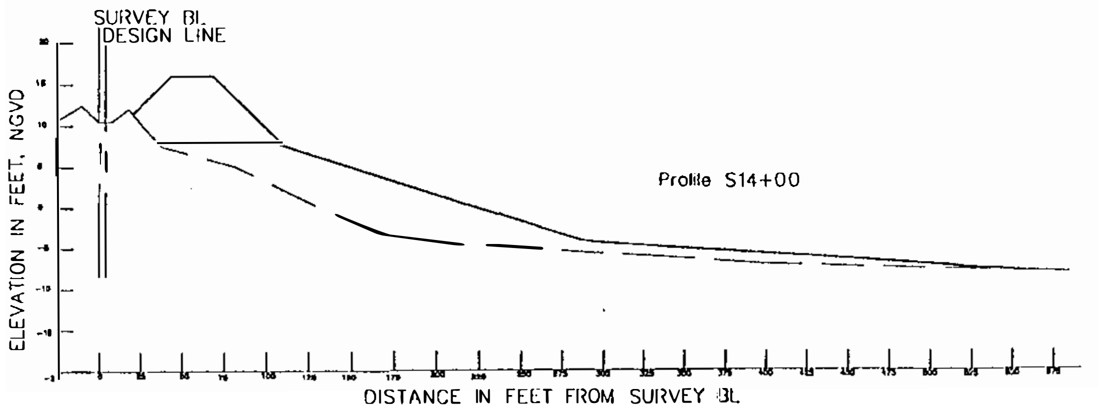




FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN
PROFILE

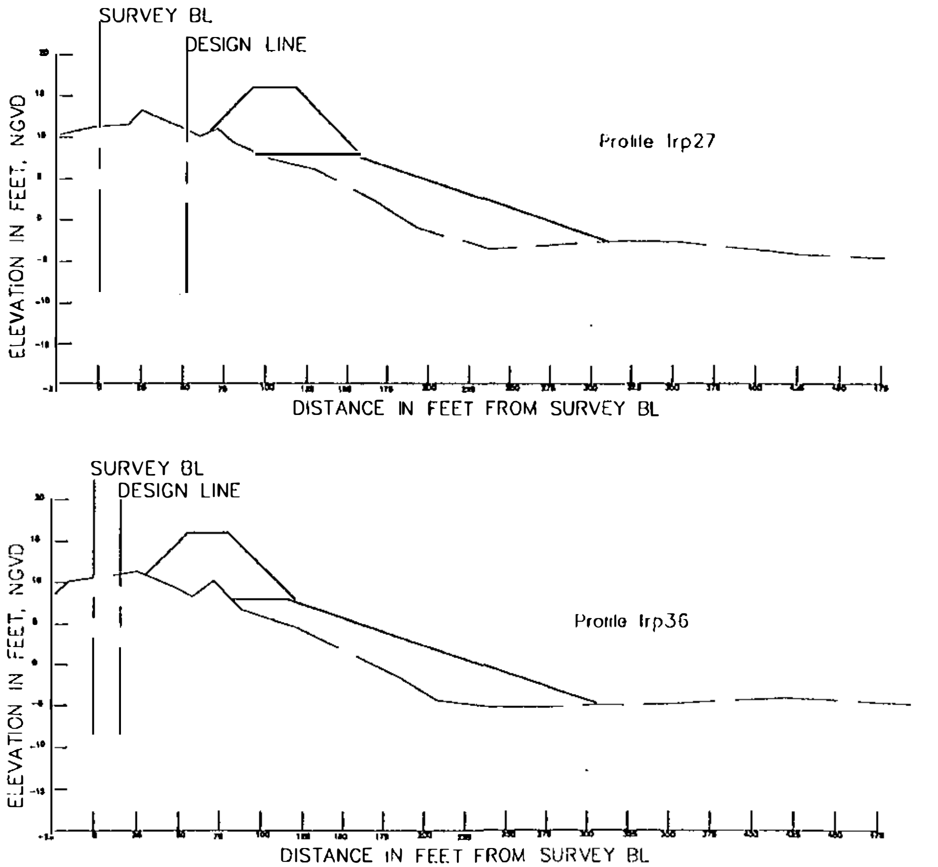
FIGURE 13





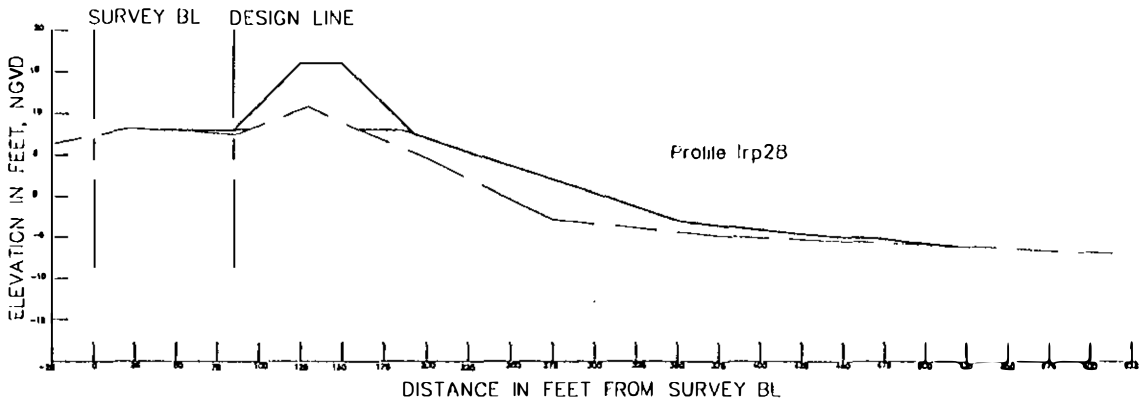
FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN
PROFILE

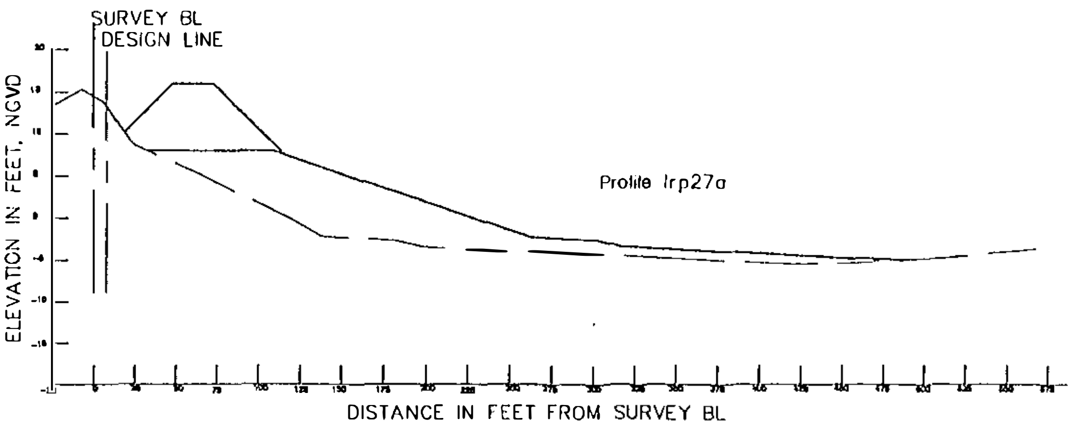
FIGURE 14



FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN
PROFILE

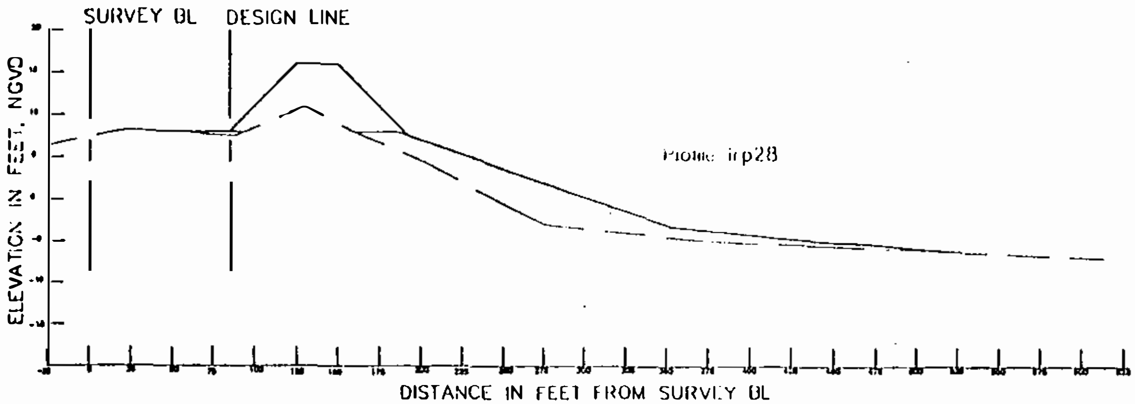
FIGURE 15

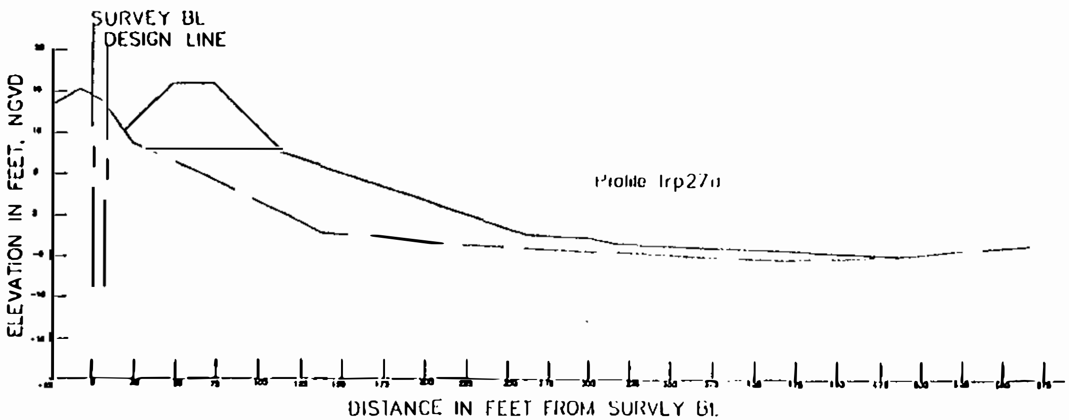




FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN
PROFILE

FIGURE 16





FEASIBILITY STUDY
BROADKILL BEACH
SELECTED PLAN
PROFILE

FIGURE 17

SECTION 7

CONSTRUCTION PROCEDURE AND WATER CONTROL PLAN

The method of construction used by the contractor is not specified beforehand in the contract specifications. However, based on previous beachfill construction in the District, it is anticipated that the contractor will use a hydraulic dredge with a cutterhead to excavate material from the offshore borrow site. The material will then be pumped from the borrow area to the beach through a submerged pipeline. Once on the beach the pipeline will run close to the landward edge of the beach.

The material will then be worked on the beach by bulldozers and front-end loaders. Pipe will be moved by front-end loaders with grapple arms. Miscellaneous equipment to be stored on the beach may include a light tower, fuel tank with containment, welding machine, and a temporary shanty for personnel.

A water quality plan is not required as only minor, temporary turbidity may result from dredging and fill operations.

SECTION 8

INITIAL RESERVOIR FILLING AND SURVEILLANCE PLAN - N/A

SECTION 9

STORM EMERGENCY PLANS

An emergency plan, Delaware Hurricane Evacuation Study, 1990, was previously completed by the District in coordination with the Delaware Division of Emergency Planning and Operations, the Federal Emergency Management Agency (FEMA) Region III, and the National Oceanic and Atmospheric Administration - National Weather Service (NOAA-NWS).

SECTION 10

CONSTRUCTION MATERIALS

The beachfill material is from an offshore borrow area and is fully compatible with the existing beach sand. The dredged material is clean sand; chemical contamination is not a concern with this type of material. No leaching is expected. For more detailed information on the borrow material, refer to SECTION 4, GEOTECHNICAL INVESTIGATION. For more detailed information on the borrow site, refer to SECTION 5, ENVIRONMENTAL AND CULTURAL INVESTIGATIONS.

SECTION 11

RESERVOIR CLEARING - N/A

SECTION 12

OPERATION AND MAINTENANCE

Operation and Maintenance (O&M) of the completed initial beachfill project is a non-Federal sponsor responsibility. The non-Federal sponsor will be furnished with an O&M Manual to assist them in carrying out their obligations under ER 1110-2-2902. Periodic nourishment of the project will be performed on an estimated 5-year cycle. As part of continuing construction, periodic nourishment will be a Federal/non-Federal cost-shared responsibility.

A Major Rehabilitation, placement of more sand than the normal periodic nourishment quantity, is scheduled for year 26 of the 50-year project. Major Rehab attempts to account for the likelihood of a major storm eroding a substantial portion of the beach once in the life of the project.

SECTION 13

ACCESS ROADS

Most of the work in conjunction with this project will be done offshore or using waterfront access to the beach. The required grading equipment will be transported via local roads in accordance with State and local regulations including a traffic control plan. Exact contractor access to the beach will be determined and coordinated during the plans and specs phase and will include the necessary easements.

For information on public access, see SECTION 15, PROJECT SECURITY.

SECTION 14

CORROSION MITIGATION - N/A

SECTION 15

PROJECT SECURITY

Initial construction and periodic nourishment of the project will necessitate a temporary (approximately one week) restriction/closure of a two-block section of beach as filling operations move along the beach. Sand ramps over the dredge pipe on the beach will be provided at public access points during construction.

For security and public safety, temporary fencing along with signage will be required around work areas. Contractor personnel will be required to insure security and public safety. In reference to the submerged pipeline, navigation will not be impeded, and a standard notification to mariners will be issued by the Coast Guard.

Typically, the District addresses project security and public access in more detail during the plans and specs phase.

SECTION 16

COST ESTIMATE

Broadkill Beach Reduction Project

APPENDIX A, SECTION 16 - COST ESTIMATES

LIST OF TABLES

APPENDIX A, SECTION 16 - COST ESTIMATE

INITIAL PROJECT CHARGES

1. General: This section presents detailed cost estimates for initial construction, nourishment, maintenance, monitoring and major rehabilitation resulting in total and annualized project costs for alternative storm damage reduction plans for the subject project. The five alternative plans developed for Broadkill Beach include: (1) Plan 1 - 100' wide berm and +14' NGVD dune; (2) Plan 2 - 100' wide berm and +16' NGVD dune; (3) Plan 3 - 150' wide berm and +14' NGVD dune; (4) Plan 4 - 150' wide berm and +16' NGVD dune; (5) Plan 5 - 150' wide berm and +18' NGVD dune. The dune for each alternative has 1 on 5 side slopes and a top width of 25'. The initial construction for each of the above plans includes design and advanced nourishment beachfill, planting dune grass, and installation of a sand fence. Also included are provisions for periodic nourishment at 3-year intervals, beach profile monitoring, and major rehabilitation to restore the design beach profile damaged by significant storm events beyond that designed for in the nourishment cycle quantity. The plan layout of the NED plan with typical improved beach sections is shown in the section of the Feasibility Study, Main Report describing the NED Plan.

2. Basis of Cost: Cost estimates presented herein are based on October 1995 price levels. Initial beachfill costs are based on beach surveys taken in September 1993. The unit prices were developed in accordance with the construction procedures outlined herein. All initial construction and nourishment costs presented in this appendix are NED costs.

3. Initial and periodic nourishment fill costs are based on the use of a 27-inch hydraulic cutterhead dredge for placement of the beachfill. The average pumping distance for the selected plan uses an average pipeline length of 13,100 l.f. Mobilization and demobilization costs are based on the assumption that beachfilling equipment located within 200 miles from the project site will be able to perform the work. The location of the borrow area is displayed in the section of the Feasibility Study, Main Report describing the NED Plan.

4. Real estate costs as shown in Table 1 are included as NED costs and reflect acquisition of easements on private beach and include surveys, appraisal, and administrative costs between the limits of beachfilling. For more information, refer to the Real Estate Appendix.

5. Alternatives Considered: Alternative plans were developed in two phases for the plan selection process. In the first phase the alternative plans were compared during the Cycle 1 and Cycle 2 screening process. For more information on these plans, refer to the section of the Feasibility Study, Main Report describing the NED Plan. Based on an analysis of these annual costs with their associated benefits, the beach restoration only plan was selected for the second phase for final plan optimization and selection.

6. The costs for the five alternative plans as described in paragraph 1 for this second phase of plan selection are displayed in Table 2.

7. Renourishment Interval Optimization: A comparative cost analysis of renourishment intervals for 3 year thru 7 year cycles was performed to obtain an optimal renourishment cycle. For more information on the renourishment interval optimization which selected the 5 year cycle, refer to the section of the Feasibility Study, Main Report describing the NED Plan.

8. Total First Cost for Selected Plan: The estimated project first cost is for the selected plan - a berm extending seaward 100' from the design line at an elevation of +8 NGVD supporting a dune with a top elevation of +16 NGVD and a top width of 25', and is based on a selected nourishment cycle of 5 years. This includes the placement of 1,305,000 c.y. of hydraulically placed design and advance nourishment beachfill, and the placement of 174,800 s.y. (36.1 acres) of dune grass and 21,800 l.f. of sand fence, NED real estate acquisition costs and pertinent contingency, engineering and design construction management costs. Details of the first cost estimate are shown in Table 1.

ANNUAL CHARGES

9. General: The estimates of annual charges for the selected plan is based on an economic project life of 50 years and an interest rate of 7.625%. The annual charges include annualized first cost and interest during construction, the annualized periodic nourishment costs, and post construction monitoring costs. It is noted that interest during construction was developed for the first cost of the project constructed over a six month period. For the selected plan, the total annualized cost is $1,303,000.

10. Periodic Nourishment: The periodic nourishment volume to be placed at 5 year cycles, subsequent to commencement of construction and throughout the 50 year economic life is 358,000 c.y. which includes overfill and tolerance. The placement of this material will follow the constructability outlines in paragraph 3. For more details on the development of the periodic nourishment quantity, refer to paragraph 7 and to the section of the Feasibility Study, Main Report describing the NED Plan. The borrow area for periodic nourishment is also shown in the section of the Feasibility Study, Main Report describing the NED Plan. Periodic nourishment costs for the selected cycle are developed in Table 3.

11. Major Rehabilitation Costs: Major rehabilitation costs are included as an additional cost for significant storm events beyond that designed for in the selected nourishment cycle to restore the design profile. The major rehabilitation losses are computed as the losses that would occur from the 50% risk event over the project life. For more detail on the development of the major rehabilitation quantity, refer to the section of the Feasibility Study, Main Report describing the NED Plan. Major rehabilitation costs are shown in Table 4.

12. Monitoring Costs: Post construction monitoring costs include coastal and environmental monitoring over the 50 year project life. Annualized monitoring costs are $60,000.

CONTINGENCIES, PRECONSTRUCTION ENGINEERING & DESIGN, AND CONSTRUCTION MANAGEMENT

13. Contingencies: The estimated cost for each major subdivision or feature of the recommended project includes an item for "contingencies". The item for "contingencies" is an allowance against some adverse or unanticipated condition not susceptible to exact evaluation from the data at hand but which must be expressed or represented in the cost estimate. The contingency allowances used in the development of the cost estimate for the selected project were estimated as an appropriate percentage. Fifteen percent was applied to beach placement work to account for concerns about pumping distances and borrow area selection, and to account for larger required beachfill quantities at the time of construction due to future preconstruction erosion. Twelve percent was applied to mobilization, demobilization, and preparatory work to account for concerns about availability of dredges and for variances in the travel distance for the dredge plant. Twenty percent was applied to dune grass and sand fencing to account for variances in the beach profile at the dune location due to preconstruction shifting and/or eroding beach conditions.

14. Preconstruction Engineering & Design (P,E & D): Preconstruction Engineering and Design costs include local cooperative agreements, environmental and regulatory activities, general design memorandum, preparation of plans and specifications, engineering during construction, A/E liability actions, cost engineering, construction and supply contract award activities, project management, and the development of the PCA. P, E & D costs were estimated as lump sums of $520,000 for the initial beachfill construction and $325,000 for the nourishment cycle and are based on similar Corps of Engineers projects of the same magnitude. A contingency factor of 15% was used on all P,E & D costs.

15. Construction Management (S & A): Construction Management costs include contract administration, review of shop drawings, inspection and quality assurance, project office operation, contractor initiated claims and litigations, and government initiated claims and litigations. S & A related costs were estimated as lump sums of $400,000 for the initial beachfill construction and $250,000 for the nourishment cycle and were based on similar Corps of Engineers projects of the same magnitude. A contingency factor of 15% was used on all S & A costs.

CONSTRUCTION AND FUNDING SCHEDULE

16. General: The construction and preconstruction sequence and time schedule of the selected plan are given in Section 17 of this Engineering Technical Appendix. The schedule is based on the timeliness of the report's approval and allocation of funds by Congress, the foregoing construction procedures, and the ability of local interests to implement the necessary items of local cooperation. These items of local cooperation are principally the furnishing of offshore borrow easements by the State of Delaware, as well as required real estate easements, and the relocation of items for beach access.

Table 1 - Total First Cost - Selected Plan Price Level: Oct 95

Plan 2 (16' Dune/100' Berm - Includes 5 Yr. Nour. Cycle)

Account Code	Description of Item	Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total Project Costs
01.	Lands and Damages						
01.B	Post Authorization Planning						
01.B.2	Required Easements	1	Job	LS	$36,820	$7,885	$44,705
01.B.8	Surveys Appraisal & Admin	1	Job	LS	$22,345	$3,351	$25,696
	Total Lands and Damages				$59,165	$11,236	$70,401
17.	Beach Replacement						
17.00.01	Mobilization, Demob. and Preparatory Work	1	Job	LS	$448,616	$53,834	$502,450
17.00.16	Pipeline Dredging						
17.00.16.02	Site Work						
17.00.16.02.01	Sand Fill Placement	1,305,000	CY	$3.81	$4,972,050	$745,807	$5,717,857
17.00.99	Associated General Items						
17.00.99.02.01	Dune Grass	174,800	SY	$4.73	$826,804	$165,361	$992,165
17.00.99.02.02	Sand Fence	21,800	LF	$2.59	$56,462	$11,292	$67,754
	Total Beach Replacement				$6,303,932	$976,294	$7,280,226
30.	Planning, Engineering and Design (P,E & D)	1	Job	LS	$520,000	$78,000	$598,000
31.	Construction Management (S&A)	1	Job	LS	$400,000	$60,000	$460,000
	Total Project First Cost				$7,283,097	$1,125,530	$8,408,627
	(Rounded)				$7,283,000	$1,126,000	$8,409,000

Table 2A - Total First Cost

Plan 1 (14' Dune/100' Berm - 3 Yr. Cycle)

Account Code	Description of Item	Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total Project Costs
01.	Lands and Damages	1	Job	LS	$0	$0	$0
17.	Beach Replacement						
	Mobilization, Demob. and Preparatory Work	1	Job	LS	$439,896	$65,985	$505,881
	Pipeline Dredging	853,965	CY	$4.14	$3,535,415	$707,083	$4,242,498
	Associated General Items						
	Dune Grass	121,000	SY	$4.73	$572,330	$114,466	$686,796
	Sand Fence	18,800	LF	$2.59	$48,692	$9,738	$58,430
	Total Beach Replacement				$4,596,333	$897,272	$5,493,605
30.	Planning, Engineering and Design (P,E & D)	1	Job	LS	$520,000	$78,000	$598,000
31.	Construction Management (S&A)	1	Job	LS	$340,731	$51,110	$391,841
	Total Project First Cost				$5,457,064	$1,026,382	$6,483,446
	(Rounded)				$5,457,000	$1,026,000	$6,483,000

Table 2B - Total First Cost

Plan 2 (16' Dune/100' Berm - 3 Yr. Cycle)

Account Code	Description of Item	Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total Project Costs
01.	Lands and Damages	1	Job	LS	$0	$0	$0
17.	Beach Replacement						
	Mobilization, Demob. and Preparatory Work	1	Job	LS	$439,896	$65,985	$505,881
	Pipeline Dredging	942,679	CY	$3.88	$3,657,595	$731,518	$4,389,113
	Associated General Items						
	Dune Grass	148,000	SY	$4.73	$700,040	$140,008	$840,048
	Sand Fence	18,800	LF	$2.59	$48,692	$9,738	$58,430
	Total Beach Replacement				$4,846,223	$947,249	$5,793,472
30.	Planning, Engineering and Design (P,E & D)	1	Job	LS	$520,000	$78,000	$598,000
31.	Construction Management (S&A)	1	Job	LS	$372,824	$55,924	$428,748
	Total Project First Cost				$5,739,047	$1,081,173	$6,820,220
	(Rounded)				$5,739,000	$1,081,000	$6,820,000

Table 2C - Total First Cost

Plan 3 (14' Dune/150' Berm - 3 Yr. Cycle)

Account Code	Description of Item	Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total Project Costs
01.	Lands and Damages	1	Job	LS	$0	$0	$0
17.	Beach Replacement						
	Mobilization, Demob. and Preparatory Work	1	Job	LS	$439,896	$65,985	$505,881
	Pipeline Dredging	1,182,669	CY	$3.69	$4,364,049	$872,809	$5,236,858
	Associated General Items						
	Dune Grass	121,000	SY	$4.73	$572,330	$114,466	$686,796
	Sand Fence	18,800	LF	$2.59	$48,692	$9,738	$58,430
	Total Beach Replacement				$5,424,967	$1,062,998	$6,487,965
30.	Planning, Engineering and Design (P,E & D)	1	Job	LS	$520,000	$78,000	$598,000
31.	Construction Management (S&A)	1	Job	LS	$417,945	$62,692	$480,637
	Total Project First Cost				$6,362,912	$1,203,690	$7,566,602
	(Rounded)				$6,363,000	$1,204,000	$7,567,000

Table 2D - Total First Cost
Plan 4 (16' Dune/150' Berm - 3 Yr. Cycle)

Account Code	Description of Item	Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total Project Costs
01.	Lands and Damages	1	Job	LS	$0	$0	$0
17.	Beach Replacement						
	Mobilization, Demob. and Preparatory Work	1	Job	LS	$439,896	$65,985	$505,881
	Pipeline Dredging	1,271,383	CY	$3.52	$4,475,268	$895,053	$5,370,321
	Associated General Items						
	Dune Grass	148,000	SY	$4.73	$700,040	$140,008	$840,048
	Sand Fence	18,800	LF	$2.59	$48,692	$9,738	$58,430
	Total Beach Replacement				$5,663,896	$1,110,784	$6,774,680
30.	Planning, Engineering and Design (P,E & D)	1	Job	LS	$520,000	$78,000	$598,000
31.	Construction Management (S&A)	1	Job	LS	$449,017	$67,353	$516,370
	Total Project First Cost				$6,632,913	$1,256,137	$7,889,050
	(Rounded)				$6,633,000	$1,256,000	$7,889,000

Table 2E - Total First Cost

Plan 5 (18' Dune/150' Berm - 3 Yr. Cycle)

Account Code	Description of Item	Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total Project Costs
01.	Lands and Damages	1	Job	LS	$0	$0	$0
17.	Beach Replacement						
	Mobilization, Demob. and Preparatory Work	1	Job	LS	$439,896	$65,985	$505,881
	Pipeline Dredging	1,354,308	CY	$3.39	$4,591,104	$918,220	$5,509,324
	Associated General Items						
	Dune Grass	176,400	SY	$4.73	$834,372	$166,874	$1,001,246
	Sand Fence	18,800	LF	$2.59	$48,692	$9,738	$58,430
	Total Beach Replacement				$5,914,064	$1,160,817	$7,074,881
30.	Planning, Engineering and Design (P,E & D)	1	Job	LS	$520,000	$78,000	$598,000
31.	Construction Management (S&A)	1	Job	LS	$481,594	$72,239	$553,833
	Total Project First Cost				$6,915,658	$1,311,056	$8,226,714
	(Rounded)				$6,916,000	$1,311,000	$8,227,000

Table 3 - Periodic Nourishment Costs (5 Yr. Cycle)

Account Code	Description of Item	Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total Project Costs
17.	Beach Replacement						
17.00.01	Mobilization, Demob. and Preparatory Work	1	Job	LS	$448,616	$53,834	$502,450
17.00.16	Pipeline Dredging						
17.00.16.02	Site Work						
17.00.16.02.01	Sand Fill Placement	358,000	CY	$4.10	$1,467,800	$220,170	$1,687,970
	Total Beach Renourishment				$1,916,416	$274,004	$2,190,420
30.	Planning, Engineering and Design (P,E & D)	1	Job	LS	$325,000	$48,750	$373,750
31.	Construction Management (S&A)	1	Job	LS	$250,000	$37,500	$287,500
	Total Periodic Nourishment Cost				$2,491,416	$360,254	$2,851,670
	(Rounded)				$2,492,000	$360,000	$2,852,000

Table 4 - Major Replacement Costs

Account Code	Description of Item	Quantity	Unit	Unit Price	Estimated Amount	Contingency	Total Project Costs
17.	Beach Replacement						
17.00.01	Mobilization, Demob. and Preparatory Work	1	Job	LS	$448,616	$53,834	$502,450
17.00.16	Pipeline Dredging						
17.00.16.02	Site Work						
17.00.16.02.01	Sand Fill Placement	696,000	CY	$4.18	$2,909,280	$436,392	$3,345,672
17.00.99	Associated General Items						
17.00.99.02.01	Dune Grass	174,800	SY	$4.73	$826,804	$165,361	$992,165
17.00.99.02.02	Sand Fence	21,800	LF	$2.59	$56,462	$11,292	$67,754
	Total Beach Replacement				$4,241,162	$666,879	$4,908,041
30.	Planning, Engineering and Design (P,E & D)	1	Job	LS	$340,000	$51,000	$391,000
31.	Construction Management (S&A)	1	Job	LS	$300,000	$45,000	$345,000
	Total Major Beach Replacement Cost				$4,881,162	$762,849	$5,644,041
	(Rounded)				$4,881,000	$763,000	$5,644,000

MOB & DEMOB COST ESTIMATE
SELECTED PLAN

M MOB & DEMOB BID ITEM >

DREDGE SIZE 27 Del

	MOBILIZATION			DEMOBILIZATION		
	# DAYS	$/DAY	TOTAL	# DAYS	$/DAY	TOTAL
1. PREPARE DREDGE FOR TRANSFER	2 x	$13,119 =	$26,238	1 x	$14,083 =	$14,083
2. PREPARE PIPELINE FOR TRANSFER	2 x	$7,407 =	$14,813	1 x	$7,792 =	$7,792
3. TRANSFER ALL PLANT 200 MILES @ 55 miles/day =	3.6 x	$27,845 =	$100,244	3.6 x	$27,845 =	$100,244
4. PERMANENT PERSONNEL & MISC.	L.S.	=	$1,164	L.S.	=	$1,164
5. PREPARE DREDGE AFTER TRANSFER	2 x	$14,083 =	$28,167	1 x	$13,119 =	$13,119
6. PREPARE PIPELINE AFTER TRANSFER	2 x	$7,792 =	$15,585	1 x	$7,407 =	$7,407
7. OTHER	Travel Costs	=	$10,800	Travel Costs	=	$10,800
	SUBTOTAL MOBILIZATION		$197,011	SUBTOTAL DEMOBILIZATION		$154,609

			REMARKS
8. SUBTOTAL MOBILIZATION & DEMOBILIZATION		= $351,620	
9. OVERHEAD	12.0%	+ $42,194	
	SUBTOTAL	= $393,814	
10. PROFIT	10.0%	+ $39,381	
	SUBTOTAL	= $433,195	
11. BOND	1.0%	+ $4,332	
12. TOTAL MOBILIZATION & DEMOBILIZATION		= $437,527	+ $11,089 = $448,616

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M \ 1 MOB & DEMOB BID ITEM > ---------

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DREDGE SIZE 27 Del

1. PREPARE DREDGE FOR TRANSFER				MOBILIZATION	DEMOBILIZATION
Labor: 30 men @		8 hrs/day @	$32.88 per hour =	$7,891	$7,891
Equipment:	Dredge	$101.16 /hr (Standby)			
	Booster(s)	$37.93 /hr (Standby)			

		$139.09 /hr x 8 hrs per day =		$1,113	$1,113
Support equipment with operators				$2,415	$2,415
Supplies & small tools				$200	$200
Additional Fuel (plant idle)				$1,500	$1,500
Subsistence:	30 men @	$32.15 per day =		----	$965
				---------	---------
			COST PER DAY	$13,119	$14,083

2. PREPARE PIPELINE FOR TRANSFER				MOBILIZATION	DEMOBILIZATION
Labor: 12 men @		8 hrs/day @	$32.88 per hour =	$3,156	$3,156
Equipment:	Work Tug	$71.50 /hr			
	Crew Tug	$11.19 /hr			
	Derrick(s)	$29.59 /hr			
	Fuel Barge	$5.81 /hr			
	Work Barge	$7.56 /hr			
	Pipeline	$78.75 /hr (Standby)			

		$204.40 /hr x 8 hrs per day =		$1,635	$1,635
Support equipment with operators				$2,415	$2,415
Supplies & small tools				$200	$200
Subsistence	12 men @	$32.15 per day =		----	$386
				---------	---------
			COST PER DAY	$7,407	$7,792

M \ 2 MOB & DEMOB BID ITEM >

DREDGE SIZE 27 Del

3. TRANSFER PLANT				MOBILIZATION	DEMOBILIZATION
Labor:	21 men/shift (2-12 hr shifts) @		$32.88 per manhour =	$16,572	$16,572
Equipment:	Work Tug(s)	$71.50 /hr			
	Dredge	$101.16 /hr (Standby)			
	Booster(s)	$37.93 /hr (Standby)			
	Crew Tug	$1.19 /hr (Standby)			
	Derrick(s)	$7.82 /hr (Standby)			
	Fuel Barge	$1.98 /hr (Standby)			
	Work Barge	$2.62 /hr (Standby)			
	Unused	$0.00 /hr (Standby)			
	Pipeline	$78.75 /hr (Standby)			
		$302.95 /hr x 8 hrs per day =		$2,424	$2,424
Subsistence	42 men @	$32.15 per day =		$1,350	$1,350
Towing vessel(s):	4000 H.P. Rental Tug @				
	$5,000 per day (towing)				
	$2,500 per day (return to port)				
	$7,500 per day x 1 towing vessel(s) =			$7,500	$7,500
			COST PER DAY	$27,845	$27,845

4. PERMANENT PERSONNEL & MISC.			MOBILIZATION	DEMOBILIZATION
3 men @	8 hrs/day @ $32.88 per hour @ 1 DAY		$789	$789
Travel Expenses	$125 per man		$375	$375
Local hire			$0	----
		TOTAL	$1,164	$1,164

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M \ 3 MOB & DEMOB BID ITEM >

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DREDGE SIZE 27 Del

5. PREPARE DREDGE AFTER TRANSFER

				MOBILIZATION	DEMOBILIZATION
Labor:	30 men @	8 hrs/day @	$32.88 per hour =	$7,891	$7,891
Equipment:	Dredge	$101.16 /hr (Standby)			
	Booster(s)	$37.93 /hr (Standby)			

		$139.09 /hr x 8 hrs per day =		$1,113	$1,113
Support equipment with operators				$2,415	$2,415
Supplies & small tools				$200	$200
Additional Fuel (plant idle)				$1,500	$1,500
Subsistence	30 men @	$32.15 per day =		$965	----
				---------	---------
			COST PER DAY	$14,083	$13,119

6. PREPARE PIPELINE AFTER TRANSFER

Labor:	12 men @	8 hrs/day @	$32.88 per hour =	$3,156	$3,156
Equipment:	Work Tug	$71.50 /hr			
	Crew Tug	$11.19 /hr			
	Derrick(s)	$29.59 /hr			
	Fuel Barge	$5.81 /hr			
	Work Barge	$7.56 /hr			
	Pipeline	$78.75 /hr (Standby)			

		$204.40 /hr x 8 hrs per day =		$1,635	$1,635
Support equipment with operators				$2,415	$2,415
Supplies & small tools				$200	$200
Subsistence	12 men @	$32.15 per day =		$386	----
				---------	---------
			COST PER DAY	$7,792	$7,407

M \ 4 MOB & DEMOB BID ITEM >

DREDGE SIZE 27 Del

		REMARKS
1 EQUIPMENT COSTS - WORKING RATES		RATES TAKEN FROM SHEET D
A. WORK TUG(S)	$71.50 /HR	$25,526 /MO DIVIDED BY 357 HRS/MO
B. CREW/SURVEY TUG	$11.19 /HR	$3,994 /MO DIVIDED BY 357 HRS/MO
C. DERRICK(S)	$29.59 /HR	$10,563 /MO DIVIDED BY 357 HRS/MO
D. FUEL/WATER BARGE	$5.81 /HR	$2,076 /MO DIVIDED BY 357 HRS/MO
E. WORK BARGE	$7.56 /HR	$2,698 /MO DIVIDED BY 357 HRS/MO
2 LABOR COSTS	$32.88 /MHR	FROM SHEET D \ 1
3 EQUIPMENT COSTS - STANDBY RATES		RATES TAKEN FROM SHEET D \ 2
A. DREDGE	$101.16 /HR	1 EA @ $101.16 /HR
B. BOOSTER(S)	$37.93 /HR	1 EA @ $ 37.93 /HR
C. CREW/SURVEY TUG	$1.19 /HR	1 EA @ $ 1.19 /HR
D. DERRICK(S)	$7.82 /HR	2 EA @ $ 3.91 /HR
E. FUEL/WATER BARGE	$1.98 /HR	1 EA @ $ 1.98 /HR
F. WORK BARGE	$2.62 /HR	2 EA @ $ 1.31 /HR
G. ***Unused***	$0.00 /HR	0 EA @ $ 0.00 /HR
3 PIPELINE COSTS - STANDBY RATES		RATES TAKEN FROM SHEET D \ 3
A. FLOATING PIPELINE	$24.00 /HR	2,000 LF @ $0.012 /HR
B. SUBMERGED PIPELINE	+ $24.75 /HR	4,950 LF @ $0.005 /HR
C. SHORELINE	+ $30.00 /HR	15,000 LF @ $0.002 /HR
D. TOTAL PIPELINE COSTS	= $78.75 /HR	21,950 LF (ON JOB)

INITIAL CONSTRUCTION COST ESTIMATE
SELECTED PLAN

A DESCRIPTION AND QUANTITY SUMMARY

1 PROJECT	Delaware Coast Planning	DATE OF ESTIMATE	29 Aug 96
2 LOCATION	Broadkill River, w/Dune	INVIT. OR CONTR. NO.	>
3 ESTIMATED BY	Bill Welk	CHECKED BY	
4 TYPE OF DREDGE	27 Del Cutter-Suction Dredge	TYPE OF ESTIMATE	Planning Estimate
5 DESCRIPTION OF WORK	Initial Construction (16' Dune, 100' Berm, Includes 5 Yr. Nour. Cycle)		

6 EXCAVATION

			REMARKS
A. REQUIRED		1,305,000 CY	4,893,750 s.f. of Dredging Area
B. PAY OVERDEPTH	+	0 CY	
C. MAX. PAY YARDAGE	=	1,305,000 CY	(YARDAGE USED ON BID FORM)
D. O.D. NOT DREDGED	-	0 CY	
E. NET PAY YARDAGE	=	1,305,000 CY	(YARDAGE USED TO FIGURE UNIT PRICE PER C.Y.)
F. NON-PAY YARDAGE	+	326,300 CY	1.8 Feet Average Overdigging Outside of Prism
G. GROSS YARDAGE	=	1,631,300 CY	(YARDAGE USED TO FIGURE PRODUCTION TIME & COST)

B	DREDGING COST		BID ITEM # >
			REMARKS
1 GROSS YARDAGE		1,631,300 CY	FROM SHEET A, ITEM 6 G.
2 PRODUCTION RATE	/	412,560 CY/MO	FROM SHEET C, ITEM 8.
3 DREDGING TIME	=	3.95 MONTHS	1,305,000 Net Pay CY / 3.95 MO = 330,380 Pay CY/MO
4 TOTAL MONTHLY COST	x	$1,010,628	FROM SHEET D, ITEM 5.
SUBTOTAL............	=	$3,991,980	
5 FIXED COSTS	+	$0	FROM SHEET E, ITEM 15.
SUBTOTAL..............	=	$3,991,980	
6 OVERHEAD 12.0%	+	$479,038	
SUBTOTAL............	=	$4,471,018	
7 PROFIT 10.0%	+	$447,102	
SUBTOTAL..............	=	$4,918,120	
8 BOND 1.0%	+	$49,181	
9 GROSS PRODUCTION COSTS	=	$4,967,301	
10 NET PAY YARDAGE	/	1,305,000 CY	FROM SHEET A, ITEM 6 E.
11 UNIT COST	=	$3.81 /CY	
12 MAX PAY YARDAGE	x	1,305,000 CY	FROM SHEET A, ITEM 6 C.
13 DREDGING COST	=	$4,972,050	

C MONTHLY PRODUCTION SUMMARY BID ITEM # >

Item	Value	REMARKS
1 SIZE OF DREDGE....PIPELINE.........>	27 Del	
2 POWER OUTPUT......MAIN PUMP........>	5,000 HP	
3 NUMBER OF BOOSTERS IN LINE.........>	1	
4 POWER OUTPUT......EACH BOOSTER.....>	4,000 HP	
5 PUMPING DISTANCES		
A. MAXIMUM PIPELINE NEEDED.........>	21,950 LF	
B. AVERAGE PIPELINE................>	13,450 LF	
C. EQUIVALENT ADDITIONAL PIPELINE +	2,750 LF	
D. PRODUCTION BASED ON =	16,200 LF	
6 GROSS PRODUCTION	1146 CY/HR	SEE SHEET C \ 1, ITEM 4 F.
7 OPERATING TIME x	360 HRS/MO	SEE SHEET C \ 1, ITEM 5 E. (360 Operating Hrs per Mo / 730 Hrs per Mo of Dredging = 49.3% Effective Time)
8 PRODUCTION RATE =	412,560 CY/MO	

GROSS PRODUCTION

C \ 1 BID ITEM # >

OPERATING TIME

			REMARKS
1 SIZE OF DREDGE....PIPELINE.........>		27 Del	
2 POWER OUTPUT......MAIN PUMP........>		5,000 HP	
3 NUMBER OF BOOSTERS IN LINE		1	Each Booster is 4000 Horsepower.
4 PRODUCTION.........(BASED ON)......>		16,200 LF	FROM SHEET C \ 2, ITEM 13.
A. ADJUSTED CHART PRODUCTION		1,339 CY/HR	FROM SHEET C \ 2, ITEM 14.
B. MATERIAL FACTOR	x	0.90	FROM SHEET C \ 3, ITEM 1 B.
C. BANK FACTOR	x	1.10	FROM SHEET C \ 3, ITEM 2 D.
D. OTHER FACTOR	x	0.95	Wave action.
E. CLEANUP FACTOR	x	0.91	10% ADDITIONAL DREDGING TIME
F. GROSS PRODUCTION	=	1,146 CY/HR	

			REMARKS
5 OPERATING TIME:			
A. BOOSTER FACTOR		0.90	10% LOSS IN PUMPING TIME PER BOOSTER
B. TIME EFFICIENCY	x	54.8%	% OF EFFECTIVE WORKING TIME WITHOUT BOOSTERS
C. NET EFFICIENCY	=	49.3%	% OF EFFECTIVE WORKING TIME INCLUDING BOOSTER LOSSES
D. MAX DREDGE TIME	x	730 HRS/MO	
E. OPERATING TIME	=	360 HRS/MO	

C \ 2 ADJUSTED CHART PRODUCTION BID ITEM # >

		REMARKS
1 SIZE OF DREDGE....PIPELINE.........>	27 Del	
2 CHART HORSEPOWER...................>	5,000 HP	
3 STANDARD PRODUCTION CHART:		

STANDARD DREDGE PRODUCTION BASED ON CHART HORSEPOWER

UP TO	6,875 L.F. OF PIPE	1500 CY/HR
AT	13,750 L.F. OF PIPE	980 CY/HR
AT	19,375 L.F. OF PIPE	420 CY/HR

		REMARKS
4 POWER OUTPUT....USED FOR DREDGE....>	5,000 HP	Chart Adjustment Factor = (Available Dredge Horsepower +
5 NUMBER OF BOOSTERS USED............>	1	Number of Boosters x Booster H.P.) / Chart H.P.
6 POWER OUTPUT......EACH BOOSTER.....>	4,000 HP	
7 TOTAL POWER APPLIED TO PIPELINE....>	9,000 HP	= (5000 H.P. + 1 Booster(s) x 4000 HP/Booster)
8 CHART ADJUSTMENT FACTOR (C.A.F)....>	1.80	= (9000 HP / 5000 HP)
9 ADJUSTED PRODUCTION CHART:		

ADJUSTED DREDGE PRODUCTION CHART BASED ON C.A.F.

UP TO	12,375 L.F. OF PIPE	1500 CY/HR
AT	24,750 L.F. OF PIPE	980 CY/HR
AT	34,875 L.F. OF PIPE	420 CY/HR

		REMARKS
10 MAXIMUM LINE LENGTH...............>	21,950 LF	
11 AVERAGE LINE LENGTH...............>	13,450 LF	Actual Pipeline
12 EQUIVALENT ADDITIONAL PIPELINE +	2,750 LF	>
13 PIPE USED FOR PRODUCTION =	16,200 LF	Actual Pipeline + Equivalent Feet of Pipe
14 ADJUSTED CHART PRODUCTION	1,339 CY/HR	Interpolated from Chart

MATERIAL FACTOR CALCULATION

C \ 3 BID ITEM # >

BANK FACTOR CALCULATION

1 MATERIAL FACTOR COMPUTATION:

A. MATERIAL FACTOR CHART:

DESCRIPTION	INPLACE DENSITY		FACTOR	%	QUANTITIES
MUD & SILT	1200	GR/L	3	0%	0 c.y.
MUD & SILT	1300	GR/L	2.5	0%	0 c.y.
MUD & SILT	1400	GR/L	2	0%	0 c.y.
LOOSE SAND	1700	GR/L	1.1	0%	0 c.y.
LOOSE SAND	1900	GR/L	1	0%	0 c.y.
COMP. SAND	2000	GR/L	0.9	0%	0 c.y.
STIFF CLAY	2000	GR/L	0.6	0%	0 c.y.
COMP. SHELL	2300	GR/L	0.5	0%	0 c.y.
SOFT ROCK	2400	GR/L	0.4	0%	0 c.y.
BLAST. ROCK	2000	GR/L	0.25	0%	0 c.y.

B. MATERIAL FACTOR.................> 0.90 100% 1,631,300 c.y. (Chart was not used)

2 BANK FACTOR COMPUTATION:

REMARKS

A. SIZE OF DREDGE....PIPELINE......> 27 Del

B. AVERAGE BANK HEIGHT.............> 9 FT

C. BANK FACTOR CHART:

BANK HEIGHT	1	2	3	4	5	6	7	8	9
FACTOR	NA	0.43	0.55	0.65	0.78	0.9	1	1.1	1.1

D. BANK FACTOR.....................> 1.10 Interpolated from chart

>

D MONTHLY COST SUMMARY BID ITEM # >

DREDGE SIZE 27 Del

			REMARKS
1 LABOR COSTS		$426,571 /MO	FROM SHEET D \ 1
2 EQUIPMENT COSTS			FROM SHEET D \ 2
A. DREDGE	+	$226,060 /MO	1 EA @ $226,060 /MO
B. WORK TUG(S)	+	$25,731 /MO	2 EA @ $12,866 /MO
C. CREW/SURVEY TUG	+	$4,026 /MO	1 EA @ $4,026 /MO
D. DERRICK(S)	+	$10,640 /MO	2 EA @ $5,320 /MO
E. FUEL/WATER BARGE	+	$2,090 /MO	1 EA @ $2,090 /MO
F. WORK BARGE	+	$2,717 /MO	2 EA @ $1,358 /MO
H. BOOSTER(S)	+	$113,478 /MO	1 EA @ $113,478 /MO
G. ***Unused***	+	$0 /MO	0 EA @ $0 /MO
3 PIPELINE COSTS BASED ON PUMPING SAND			21,950 LF (ON JOB) - RATES TAKEN FROM SHEET D \ 3
A. (1) FLOATING PIPE (AVERAGE)	+	$17,280 /MO	2,000 LF @ $8.64 /MO
(2) FLOATING PIPE (REMAINING)	+	$0 /MO	0 LF @ $0.012 /HR X 360 HRS/MO
B. (1) SUBMERGED PIPE (AVERAGE)	+	$11,250 /MO	2,841 LF @ $3.96 /MO
(2) SUBMERGED PIPE (REMAINING)	+	$3,796 /MO	2,109 LF @ $0.005 /HR X 360 HRS/MO
C. (1) SHORE PIPE (AVERAGE)	+	$12,139 /MO	8,609 LF @ $1.41 /MO
(2) SHORE PIPE (REMAINING)	+	$4,602 /MO	6,391 LF @ $0.002 /HR X 360 HRS/MO
4 OTHER MONTHLY COSTS	+	$150,247 /MO	FROM SHEET D \ 4
5 TOTAL MONTHLY COST	=	$1,010,628	

D \ 1 LABOR COSTS BID ITEM # >

DREDGE SIZE 27 Del

SALARIED PERSONNEL:	NO.	RATE	AMOUNT
CAPTAIN	1	per month	$3,000
CHIEF ENGR.	1	"	$2,800
CIVIL ENGR.			
OFFICE MGR			
OFFICE PERSONNEL	1	"	$1,800
SUBTOTAL....			$7,600
TAXES,INS.,FRINGES......		44.8%	$3,406
SALARIED PAYROLL.......>			$11,006 /MO

CREW LABOR	NO.	RATE	AMOUNT
LEVERMAN	3	$23.35	$70.05
WATCH ENGINEER	3	$21.51	$64.53
DREDGE MATES	2	$19.65	$39.30
TUG MASTERS	2	$20.71	$41.42
LAUNCHMEN	3	$16.36	$49.08
MAINTENANCE ENGINEERS	0	$21.04	$0.00
EQUIPMENT OPERATORS	3	$20.71	$62.13
WELDERS	2	$20.71	$41.42
OILERS	2	$16.77	$33.54
DECKHANDS	12	$16.15	$193.80
ELECTRICIAN	1	$20.87	$20.87
GENERAL DUMP FOREMAN	1	$21.20	$21.20
DUMP FOREMAN	3	$19.47	$58.41
YARD AND SHORE MEN	12	$16.15	$193.80
ENGINEERS FOR BOOSTERS	3	$21.51	$64.53
CREW TOTAL (3 SHIFTS)	52 MEN		$954.08 /HR

WAGES

WORK 56 HRS /WK		
PAY 64 HRS /WK @ 4.34WKS/WMO		$265,005
TAXES,INS.,FRINGES......	56.8%	$150,560
CREW PAYROLL..........>		$415,565 /MO

Taxes, insurance and fringes on labor:
Based on General Decision No. NY- 930002
Publication Date:1/Oct/93 to 30/Sep/94

Social Security		7.65%
Workman's Compensation (State)		11.30%
State Unemployment Comp.		6.50%
Federal Unemployment Comp.		1.00%
Fringes...	$4.45 per hour	21.21%
(Not based	9 paid hol.	2.16%
on O.T.)	8.00%vacation	7.00%
TAXES,INS.,FRINGES......CREW...		56.8%
-(BENEFIT DIFFERENTIAL)		12.0%
TAXES,INS.,FRINGES......MANAGEMENT..		44.8%

MONTHLY CREW PAYROLL	$415,565
+ MONTHLY SALARIED PAYROLL	$11,006
MONTHLY LABOR COSTS:	$426,571

(ave. gross crew wage = $32.88 per manhour)

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D \ 2 EQUIPMENT COSTS BID ITEM # >

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				2a. LAF.................	1.060
DREDGE SIZE	27 Del	1g. Pres Year...........	1993	2b. Fuel Cost per Gal...	$0.85
		1h. Cost of Money Rate..	6.375%	3b. Ec Index <for 1993>.	5028
		1i. Disc Money Rate:	5.100%	5a. Mos Available/Year..	9
		1j. Hrs Worked/Mo.......	360	5b. Hrs Available/Yr:	3,240

	--DREDGE--	----TUGS & TENDERS-----		------BARGES------			--BOOSTER--	---OTHER---
1a. Plant Description......	HYDRAULIC	WORK TUG	CREW/SURVEY	DERRICK	FUEL/WATER	WORK	FLOATING	***Unused***
1c. Prime Eng HP...........	5,000	250	100	200	0	0	4,000	0
1d. (1) Dredge El Gen HP...	830	--	--	--	--	--	--	--
1d. Total 2nd Eng HP.......	3,310	50	40	40	10	0	200	0
1e. Plant Value............	$4,431,000	$250,000	$42,000	$190,000	$95,000	$63,000	$2,200,000	$0
1f. Acquis Year............	1980	1982	1987	1980	1980	1980	1980	0
3a. Ec Index <for Acq Yr>..	2922	3391	3886	2922	2922	2922	2922	0
4a. Life (in Hours)........	60,000	35,000	25,000	40,000	40,000	40,000	55,000	0
4b. SLV Factor.............	0.10	0.05	0.05	0.10	0.05	0.05	0.15	0.00
4c. Pr Eng Fuel Factor.....	0.045	0.045	0.045	0.011	0.011	0.011	0.045	0
4d. 2nd Eng Fuel Factor....	0.039	0.039	0.039	0.011	0.011	0.011	0.039	0
4e. WLS Factor.............	0.24	0.38	0.38	0.20	0.20	0.20	0.22	0.00
4f. RPR Factor.............	1.10	1.00	0.90	0.70	0.60	0.60	0.90	0.00
5c. N (Life in Years):	18.52	10.80	7.72	12.35	12.35	12.35	16.98	0.00
6a. Depreciation:	4.86%	8.80%	12.31%	7.29%	7.69%	7.69%	5.01%	0.00%
6b. FCCM:	2.93%	2.90%	2.99%	2.99%	2.87%	2.87%	3.06%	0.00%
6c. Total Ownership/Year:	7.79%	11.70%	15.30%	10.28%	10.56%	10.56%	8.07%	0.00%
7a. Yearly Ownership:	$345,175	$29,250	$6,426	$19,532	$10,032	$6,653	$177,540	$0
7b. Monthly Ownership:	$38,353	$3,250	$714	$2,170	$1,115	$739	$19,727	$0
8a. (1) Hrly Pr Eng Fuel:	$191.25	$9.56	$3.83	$1.87	$0.00	$0.00	$153.00	$0.00
8a. (2) Hrly 2nd Eng Fuel:	$109.73	$1.66	$1.33	$0.37	$0.09	$0.00	$6.63	$0.00
8b. (1) Hrly Pr Eng WLS:	$45.90	$3.63	$1.46	$0.37	$0.00	$0.00	$33.66	$0.00
8b. (2) Hrly 2nd Eng WLS:	$26.34	$0.63	$0.51	$0.07	$0.02	$0.00	$1.46	$0.00
8c. (1) EAF:	1.721	1.483	1.294	1.721	1.721	1.721	1.721	0.000
8c. (2) Hrly Repair:	$148.19	$11.23	$2.07	$6.07	$2.60	$1.72	$65.67	$0.00
8d. Total Hrly Operating:	$521.41	$26.71	$9.20	$8.75	$2.71	$1.72	$260.42	$0.00
8e. Monthly Operating:	$187,708	$9,616	$3,312	$3,150	$976	$619	$93,751	$0
11. MONTHLY RATE:	$226,060	$12,866	$4,026	$5,320	$2,090	$1,358	$113,478	$0
12a. Yearly Standby:	$237,502	$18,250	$3,841	$12,607	$6,379	$4,230	$122,430	$0
12b. Monthly Standby:	$26,389	$2,028	$427	$1,401	$709	$470	$13,603	$0
12c. STANDARD HRLY STANDBY:	$73.30	$5.63	$1.19	$3.89	$1.97	$1.31	$37.79	$0.00
12d. Gener Fuel Allowance:	$27.52	--	--	--	--	--	--	--
12e. DREDGE HOURLY STANDBY:	$100.82	--	--	--	--	--	--	--

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D \ 3 PIPELINE COSTS BID ITEM # >

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PIPELINE SIZE:	27 Del	1g. Pres Year...........	1993	2a. LAF.................	1.060
		1h. Cost of Money Rate..	6.375%	3b. Ec Index <for 1993>.	5028
MATERIAL PUMPED:	SAND	1i. Disc Money Rate:	5.100%	5a. Mos Available/Year..	9
		1j. Hrs Worked/Mo.......	360	5b. Hrs Available/Yr:	3,240

	--------FLOATING PIPELINE---------			--SUBMERGED PIPELINE--		-SHOREPIPE-
1a. Plant Description......	Pipeline	Joints	Pontoons	Pipeline	Joints	Pipeline
Quantity...............	100	1	2	400	1	40
Fixed Units Per Item..>	LF	Set	Each	LF	Set	LF
Unit Price.............	$50.00	$12,000.00	$7,000.00	$50.00	$12,000.00	$25.00
1e. Plant Value:	$5,000.00	$12,000.00	$14,000.00	$20,000.00	$12,000.00	$1,000.00
1f. Acquis Year............	1992	1992	1992	1992	1992	1992
3a. Ec Index <for Acq Yr>..	4611	4611	4611	4611	4611	4611
4a. Life (in Hours)........	6,000	12,000	60,000	6,000	12,000	6,000
4b. SLV Factor.............	0.20	0.20	0.20	0.20	0.20	0.20
4f. RPR Factor.............	0.05	0.30	0.05	0.05	0.30	0.05
5c. N (Life in Years):	1.85	3.70	18.52	1.85	3.70	1.85
6a. Depreciation:	43.24%	21.62%	4.32%	43.24%	21.62%	43.24%
6b. FCCM:	4.16%	3.61%	3.17%	4.16%	3.61%	4 16%
6c. Total Ownership/Year:	47.40%	25.23%	7.49%	47.40%	25.23%	[illegible]
7a. Yearly Ownership:	$2,370	$3,028	$1,049	$9,480	$3,028	$4?4
7b. Monthly Ownership:	$263.33	$336.44	$116.56	$1,053.33	$336.44	$52.67
8c. (1) EAF:	1.090	1.090	1.090	1.090	1.090	1.090
8c. (2) Hrly Repair:	$0.05	$0.35	$0.01	$0.19	$0.35	$0.01
8e. Monthly Operating:	$18.00	$126.00	$3.60	$68.40	$126.00	$3.60
11. Monthly Rate (EA Item):	$281.33	$462.44	$120.16	$1,121.73	$462.44	$56.27
Monthly Rate Per Section (Sum Of Items):			$863.93		$1,584.17	$56.27
/ Section Length (In Linear Feet):			100		400	40
MONTHLY RATES PER LF OF PIPELINE:			$8.64		$3.96	$1.41

	--------FLOATING PIPELINE---------			--SUBMERGED PIPELINE--		-SHOREPIPE-
1a. Plant Description:	Pipeline	Joints	Pontoons	Pipeline	Joints	Pipeline
4a. Life* (in Hours).......	6,000	12,000	60,000	6,000	12,000	6,000
5c. N (Life in Years):	1.85	3.70	18.52	1.85	3.70	1.85
6a. Depreciation:	43.24%	21.62%	4.32%	43.24%	21.62%	43.24%
6b. FCCM:	4.16%	3.61%	3.17%	4.16%	3.61%	4.16%
12a. Yearly Standby:	$1,289	$1,730	$746	$5,156	$1,730	$258
12b. Monthly Standby:	$143	$192	$83	$573	$192	$29
12c. Hrly Standby per Item:	$0.398	$0.534	$0.230	$1.591	$0.534	$0.080
Hrly Standby Rate Per Section (Sum Of Items):			$1.162		$2.125	$0.080
/ Section Length (In Linear Feet):			100		400	40
HOURLY STANDBY RATES PER LF OF PIPELINE:			$0.012		$0.005	$0

*Life of Pipe for Standby is based on pumping Sand.

D \ 4 OTHER MONTHLY COSTS BID ITEM # >

DREDGE SIZE 27 Del

			REMARKS
1 Beach Rehandling w/Dune		$150,247 /MO	
2 >	+	$0 /MO	
3 >	+	$0 /MO	
4 >	+	$0 /MO	
5 >	+	$0 /MO	
6 >	+	$0 /MO	
7 >	+	$0 /MO	
8 >	+	$0 /MO	
9 >	+	$0 /MO	
10 >	+	$0 /MO	
11 >	+	$0 /MO	
12 >	+	$0 /MO	
13 >	+	$0 /MO	
14 >	+	$0 /MO	
15 TOTAL OTHER MONTHLY COSTS	=	$150,247 /MO	

BACKUP DATA

Delaware Coast Study:Beachfill
- W/Dune

-

Designed By: Tom Heary, CENAP-En-CS
Estimated By: Bill Welk, CENAP-EN-EC

Prepared By:

Preparation Date: 08/22/96
Effective Date of Pricing: 11/15/95

Sales Tax: 0.00%

1 - Material delivery is contingent on access to the project. Contingency includes an allowance for additional transportation requirements. Also, material availability might become a concern.
2 - Material availability is fairly stable although access might be a problem.
3 - Material availability is stable and access should not be a problem.
4 - Normal construction contingencies expected.
5 - Material availability might become a concern although access should not be a problem.
6 - Material availability might become a concern and access might be a problem.
7 - Material availability is stable although access might be a problem.
8 - Site requirements are subject to change.

** CONTRACTOR SETTINGS **

		AMOUNT	PCT	PCT S	RISK	DIFF	SIZE	PERIOD	INVEST	ASSIST	SUBCON
AA Prime Contractor											
OVERHEAD	P		13.00								
HOME OFFICE	P		3.00								
PROFIT	P		9.00								
BOND	P		1.00								

SUMMARY REPORTS SUMMARY PAGE

DETAILED ESTIMATE DETAIL PAGE

BACKUP REPORTS BACKUP PAGE

* * * END TABLE OF CONTENTS * * *

	QUANTITY	UOM	CONTRACT	CONTINGN	P,E & D	SIOH	TOTAL COST	UNIT COST	NOTES
6 Beachfill w/Dune									
6/ 1 Beachfill w/Dune									
6/ 1.1 Beachfill w/Dune	1.00	MO	150,247	30,049	10,818	17,066	208,180	208180.16	4
6/ 1.2 Mob & Demob (one time cost)	1.00	EA	11,089	2,218	798	1,260	15,365	15365.43	4
6/ 1.4 Beachfill w/Dune:Sand Fence	21800.00	LF	56,503	11,301	4,068	6,418	78,290	3.59	8
6/ 1.6 Beachfill w/Dune:Dune Grass	174800.00	SY	827,329	165,466	59,568	93,976	1,146,339	6.56	8
TOTAL Beachfill w/Dune	1.00	MO	1,045,168	209,034	75,252	118,720	1,448,175	1448175	8
TOTAL Beachfill w/Dune	1.00	MO	1,045,168	209,034	75,252	118,720	1,448,175	1448175	
TOTAL Delaware Coast Study:Beachfill	1.00	EA	1,045,168	209,034	75,252	118,720	1,448,175	1448175	

Sand fence - $56,503/21800 lf = $2.59/lf

Dune grass - $827,329/174800 lf = $4.73/sy

6/ 1. Beachfill w/Dune	QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMNT	MATERIAL	TOTAL COST
6. Beachfill w/Dune									
6/ 1. Beachfill w/Dune									
6/ 1.1. Beachfill w/Dune									
[01380 40020 Surveying Data]									
USR AA Surveying Crew (3) men					24.00	739.63	0.00	0.00	739.63
	21.00	DAY	USRYA	0.13	504	15,532	0	0	15,532
[02101 0000 Structure Moving] [Note - One Day Move, Up To 24 Ft Wide. Reset On New Foun- Dations,] [Patch And Hook Up]									
USR AA Move Shore Pipe -					16.00	516.93	194.33	0.00	711.27
	21.00	DAY	COEMC1	0.13	336	10,856	4,081	0	14,937
[02226 1000 Excavation By Dozer Moved 150 Ft (45M) And] [Stockpiled Measured In Bank Cy Avg. Oper 50 Min Hr + 5> Grade]									
L USR AA Berm Fill, (4) D-9H Dozer					32.00	1033.86	3098.94	0.00	4132.80
w/U-Blade 410 HP, Move 150' and Stockpile	21.00	DAY	CODTN_3	0.13	672	21,711	65,078	0	86,78
TOTAL Beachfill w/Dune					1,512	48,099	69,159	0	117,258
6/ 1.2. Mob & Demob (one time cost)									
[01630 0000 Equipment: MOB and DEMOB]									
L USR AA Mob and Demob					32.00	768.18	674.25	0.00	1442.43
	2.00	DAY	UTDHA5	0.13	64	1,536	1,349	0	2,885
L USR AA Mob and Demob					32.00	768.18	674.25	0.00	1442.43
	2.00	DAY	UTDHA5	0.13	64	1,536	1,349	0	2,885
L USR AA Mob and Demob					32.00	768.18	674.25	0.00	1442.43
	2.00	DAY	UTDHA5	0.13	64	1,536	1,349	0	2,885
TOTAL Mob & Demob (one time cost)					192	4,609	4,046	0	8,655
6/ 1.4. Beachfill w/Dune:Sand Fence									
[02712 6200 Snow Fence On Steel Posts]									
L CIV AA Stl Post, 10'OC f/4' Sand Fence					0.05	1.16	0.02	0.84	2.0
	21800	LF	XLABC	62.12	1,173	25,277	508	18,312	44,09

6/ 1. Beachfill w/Dune	QUANTY	UOM	CREW ID	OUTPUT	MANHRS	LABOR	EQUIPMNT	MATERIAL	TOTAL COST
TOTAL Beachfill w/Dune:Sand Fence					1,173	25,277	508	18,312	44,097
6/ 1.6. Beachfill w/Dune:Dune Grass									
[02810 2000 By Hand]									
L USR AA Dune Grass Seedlings					0.01	0.18	0.01	3.50	3.69
	174800	SY	XLABEB	500.00	1,398	31,394	2,482	611,800	645,676
TOTAL Beachfill w/Dune:Dune Grass					1,398	31,394	2,482	611,800	645,676
TOTAL Beachfill w/Dune					4,275	109,379	76,194	630,112	815,686
TOTAL Beachfill w/Dune					4,275	109,379	76,194	630,112	815,686
TOTAL Delaware Coast Study:Beachfill					4,275	109,379	76,194	630,112	815,686

** CREW BACKUP **

SRC	ITEM ID	DESCRIPTION	NO.	UOM	RATE	**** LABOR **** HOURS	COST	**** EQUIP **** HOURS	COST	TOTAL COST
	* CODTN_3	4 B-eqoprmed + 4 Dozer, Cat D-9l, 460 Hp			PROD =	100%			CREW HOURS =	168
MIL	* B-EQOPRCRNL	Eq Oper, Crane/Shovl	4.00	HR	32.31	4.00	129.23			129.23
MIL	* XMIXX020	E Small Tools	4.00	HR	1.45			4.00	5.80	5.80
MIL	* T10CA022	E BLADE, UNIVERSAL,HYDR,FOR D9	4.00	HR	9.22			4.00	36.88	36.88
MIL	* T15CA017	E DOZER,CWLR,CAT D-9N, (ADD BLADE	4.00	HR	86.17			4.00	344.69	344.69
	TOTAL					4.00	129.23	12.00	387.37	516.60
	COEMC1	1 B-eqoprmed + Forklift			PROD =	100%			CREW HOURS =	168
MIL	* B-EQOPRMEDL	Eq Oper, Medium (ENGI0825B	2.00	HR	32.31	2.00	64.62			64.62
MIL	* F10CA023	E FKLFT 6000#@24"LC ROUGH TERRAIN	2.00	HR	10.70			2.00	21.39	21.39
MIL	* XMIXX020	E Small Tools	2.00	HR	1.45			2.00	2.90	2.90
	TOTAL					2.00	64.62	4.00	24.29	88.91
	USRYA	Means A-7, Chief, Instru. & Rdmn			PROD =	100%			CREW HOURS =	168
USR	* X-CHFPARTYL	Chief of Party	1.00	HR	34.51	1.00	34.51			34.51
USR	* X-INSTRUMNL	Instrument Man	1.00	HR	30.79	1.00	30.79			30.79
USR	X-RODMEN	L Rodmen/Chainman	1.00	HR	27.15	1.00	27.15			27.15
	TOTAL					3.00	92.45	0.00	0.00	92.45
	* UTDHA5	2 Trck Drivr + 2 Tractor & Lowbed Trailer, 40 To			PROD =	100%			CREW HOURS =	48
MIL	* B-LABORER	L Laborer (Semi-Skilled)	2.00	HR	22.94	2.00	45.87			45.87
MIL	* B-TRKDVRHVL	Truck Drivers, Heavy	2.00	HR	25.07	2.00	50.15			50.15
MIL	* XMIXX020	E Small Tools	2.00	HR	1.45			2.00	2.90	2.90
MIL	* T45XX019	E TRK TRLR,LOWBOY, 75 TON, 3 AXLE	2.00	HR	8.66			2.00	17.31	17.31
MIL	* T50KE004	E TRK,HWY,3AXLE,50000GVW, 85000GC	2.00	HR	32.04			2.00	64.07	64.07
	TOTAL					4.00	96.02	6.00	84.28	180.30
	XLABC	3 X-laborer + Small Tools			PROD =	100%			CREW HOURS =	351
MIL	XMIXX020	E Small Tools	1.00	HR	1.45			1.00	1.45	1.45
MIL	X-LABORER	L Outside Laborer	3.00	HR	21.51	3.00	64.54			64.54
MIL	X-LABORER	F Outside Laborer	0.34	HR	22.01	0.34	7.49			7.49
	TOTAL					3.34	72.03	1.00	1.45	73.48
	* XLABEB	2 + 1 X-Lab + Dvr + Pkup			PROD =	100%			CREW HOURS =	350
MIL	* X-LABORER	F Outside Laborer (Semi-Skilled)	1.00	HR	22.01	1.00	22.01			22.01
MIL	* X-LABORER	L Outside Laborer (Semi-Skilled)	2.00	HR	21.51	2.00	43.03			43.03
MIL	* X-TRKDVRLTL	Outside Truck Dr. Light	1.00	HR	24.75	1.00	24.75			24.75
MIL	T50F0004	E TRK,HWY,4X4,F250,3/4T,8800 GVW	1.00	HR	7.11			1.00	7.11	7.11
	TOTAL					4.00	89.79	1.00	7.11	96.90

** LABOR BACKUP **

SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	**** TOTAL **** DEFAULT	HOURS
MIL	B-EQOPRCRN	Eq Oper, Crane/Shovl	19.59	0.0%	29.7%	6.90	0.00	32.31	HR	10/13/95	33.06	672
MIL	B-EQOPRMED	Eq Oper, Medium	19.59	0.0%	29.7%	6.90	0.00	32.31	HR	10/13/95	30.73	336
MIL	B-LABORER	Laborer/Helper - Kent	13.29	0.0%	29.7%	5.70	0.00	22.94	HR	10/13/95	27.33	96
MIL	B-TRKDVRHV	Truck Drivers, Heavy	14.66	0.0%	29.7%	6.06	0.00	25.07	HR	06/07/95	27.58	96
USR	X-CHFPARTY	Chief of Party	22.30	0.0%	29.7%	5.60	0.00	34.51	HR	02/27/95	0.00	168
USR	X-INSTRUMN	Instrument Man	19.90	0.0%	29.7%	4.99	0.00	30.79	HR	02/27/95	0.00	168
MIL	X-LABORER	Outside Laborer	12.07	0.0%	29.7%	5.86	0.00	21.51	HR	06/07/95	27.33	2221
USR	X-RODMEN	Rodmen/Chainman	17.55	0.0%	29.7%	4.40	0.00	27.15	HR	02/27/95	0.00	168
TWT	X-TRKDVRLT	Outside Truck Dr. Light	14.41	0.0%	29.7%	6.06	0.00	24.75	HR	06/07/95	27.71	350

** EQUIPMENT BACKUP **

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
MIL	F10CA023	FORK LIFT,R/T 6,000#,20.00'L-HT	3.49	1.01	2.20	0.48	0.29	0.04	3.19	10.70 HR	336
UPB	T10CA022	BLADE, UNIVERSAL, HYDR (FOR D9	4.02	1.12		0.19			3.89	9.22 HR	672
UPB	T15CA017	DOZER,CWLR, D-9N,PS (ADD BLADE)	28.09	7.80	12.99	3.31			33.99	86.17 HR	672
UPB	T45XX019	TRLR,LOWBOY, 75T, 3 AXLE(ADD TRK	3.35	1.29		0.13	1.30	0.18	2.41	8.66 HR	96
UPB	T50FO004	TRK,HWY, 8,800GVW,4X4, 3/4T-PKUP	1.60	0.37	2.65	0.68	0.30	0.04	1.47	7.11 HR	350
UPB	T50KE004	TRK,HWY, 50,000 GVW, 6X4, 3 AXLE	9.65	2.22	9.60	2.45	0.43	0.06	7.63	32.04 HR	96
UPB	XMIXX020	SMALL TOOLS	0.46	0.20	0.15	0.06			0.58	1.45 HR	1455

No errors detected...

* * * END OF ERROR REPORT * * *

SECTION 17

SCHEDULE FOR DESIGN AND CONSTRUCTION

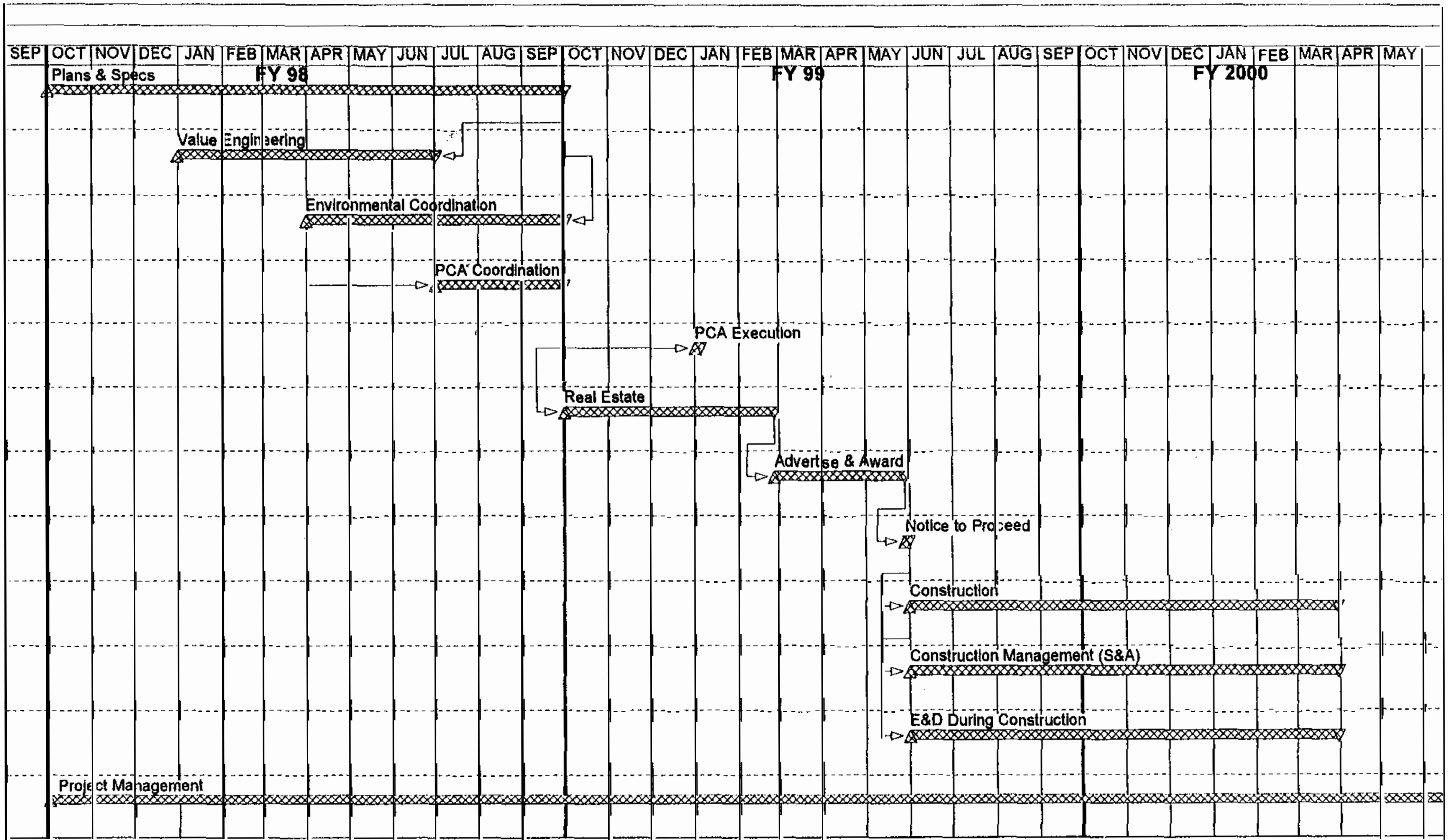
The plans and specs (P&S) phase is scheduled to take place over a 12-month period in FY 98 from additional geotechnical sampling (see SECTION 18, SPECIAL STUDIES) to P&S completion. The PCA coordination will start in FY 98 with execution occurring in FY 99. The Real Estate work will occupy the first half of FY 99. Approximately ten months (bridging FY 99 and FY 00) will be allotted for initial construction from contract award to contract closeout.

The project funding schedule and CPM (from P&S to initial construction completion) follows on the next two pages.

FIGURE F-1

BROADKILL BEACH, DELAWARE FUNDING SCHEDULE BY TASK
INITIAL CONSTRUCTION
OCTOBER 1995 PRICE LEVEL

	FY 98	FY 99	FY 00	FY 01	FY 02	TOTALS BY TASK
	O N D J F M A M J J A S	O N D J F M A M J J A S	O N D J F M A M J J A S	O N D J F M A M J J A S	O N D J F M A M J J A S O	
Plans & Specs	|=====================| $304,750					$304,750
Value Engineering	|===========| $80,500					$80,500
Environmentl Coord	|===========| $5,750					$5,750
PCA	|=====| $23,000	X Execution				$23,000
Real Estate		|=======| $70,401				$70,401
Cert of RE		|=|				
Advertise & Award		|=====X NTP $5,750				$5,750
Construction		|====== $2,080,227	======| $5,200,000			$7,280,227
Constr Mgmt (S&A)		|====== $140,000	======| $320,000			$460,000
E&D During Constr		|====== $17,500	======| $40,000			$57,500
Project Management	|====== $36,000	====== $44,750	======| $40,000			$120,750
TOTALS BY FY	FY 98 = $450,000	FY 99 = $2,358,628	FY 00 = $5,600,000	FY 01 = $000,000	FY 02 = $000,000	INITIAL CONSTR TOTAL = $8,408,628



Broadkill Beach, Delaware CPM
Initial Construction

US Army Corps of Engineers
Philadelphia District

SECTION 18

SPECIAL STUDIES

The borrow area limits have been well defined, and the more than ample quantity of material available has been established during this Feasibility Study. Additional borrow area borings will be required in the plans and specs (P&S) phase for final quantity determination and exact site location of dredging area(s) within the already identified borrow area limits.

Final environmental coordination with various resource agencies will be completed during the P&S phase. An updated Section 7 Endangered Species Act consultation will be necessary during P&S for initial construction and for each periodic nourishment. A Water Quality Certificate will be required from the State of Delaware for initial construction and for each periodic nourishment. Consistency with the Delaware Coastal Zone Management Program must be assured. No compensatory mitigation is required with the project.