DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
THE DELAWARE GEOLOGICAL SURVEY
AND THE DELAWARE STATE HIGHWAY DEPARTMENT

HYDROLOGIC INVESTIGATIONS
ATLAS HA-122

Base from U.S. Geological Survey Bethany Beach quadrangle and Army Map Service Assawoman Bay quadrangle

SCALE 1:24 000

1 MILE

1 KILOMETER

CONTOUR INTERVAL 10 AND 20 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS 2.6 FEET IN INDIAN RIVER INLET AND 4 FEET ALONG THE OCEAN

Engineering soils mapped by J. K. Adams, Delaware Geological Survey, C. F. Davis and W. H. Tewelow, U.S. Geological Survey
Water-table and surface-drainage mapped by D. H. Boggess, and O. J. Coskery, U.S. Geological Survey

EXPLANATION

AM23 — Nonplastic sandy soil derived from fluvial deposits of Pleistocene age

AM3 — Nonplastic poorly graded soil derived from fluvial deposits of Pleistocene age

MB13 — Nonplastic gravelly and poorly graded sandy soil derived from marine beach sediments

MB3 — Nonplastic poorly graded sandy soil derived from marine beach sediments

MTM — Marine tidal-marsh deposits

AM2/23 — Nonplastic to slightly plastic sandy soil derived from fluvial deposits of Pleistocene age associated with AM23 soil

AM2/24 — Nonplastic to slightly plastic sandy soil associated with nonplastic to slightly plastic sandy and silty soil derived from fluvial deposits of Pleistocene age

AM23/Z — AM23 soil associated with swamp deposits

AM24/4 — Nonplastic to slightly plastic sandy and silty soil associated with slightly plastic silty and clayey soil derived from fluvial deposits of Pleistocene age

MB3/F — MB3 soil associated with fill

319 — Soil sample pit
Location and number of pit from which soil samples were obtained for laboratory analyses (See table 3). General characteristics are summarized in table 4

5B — Soil sample site
Location and number of secondary soil sample sites. Samples were collected with a one-inch-diameter long-core soil sampler. For results of laboratory analyses see table 3; for general characteristics see table 4

13 / 12-18 — Secondary observation well
Numerator is altitude of water table in October 1960. Denominator shows estimated range in altitude of water table during 1950-62 based on measurements from 1959 to 1962 and comparison with primary observation-well records

3 / 1-4 — Domestic or farm well
Numerator is altitude of water table in October 1960. Denominator, where given, shows estimated range in altitude of water table during 1950-62, based on 2 or 3 measurements and comparison with primary and secondary observation-well records

10 — Water-table contour
Number shows altitude of water table in feet above mean sea level in October 1960. Contour interval 10 feet. Relative position of water table in October 1960 is shown in hydrograph (figure 2)

Perennial stream
Bottom of stream channel almost always below water table

Intermittent stream
Bottom of stream channel above water table part of the time and below water table part of the time

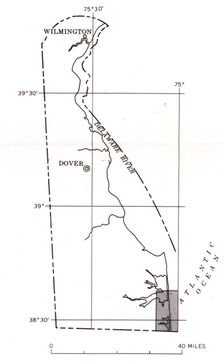

FIGURE 1.—*Index map of Delaware showing location of the Bethany Beach area*

TABLE 1.—*Explanation of letter symbols*

Symbol	Explanation
AM	Surficial alluvial mantle, Pleistocene age.
F	Fill.
MB	Marine beach.
MTM	Marine tidal marsh.
Z	Swamp deposit.

SOIL SYMBOLS

The map symbols used in this report to designate the various types of soils are a modification of the system used in the engineering soil survey of New Jersey (Rogers, 1955). The first part of the symbol is a letter, or group of letters, which identifies the parent material according to the classification developed by Lueder (1950) (see table 1). The second part of the symbols is a number which identifies the soil group according to the classification system adopted by the Highway Research Board (Allen and others, 1945) and used with some modifications by the Delaware State Highway Department (see table 2). A two-digit number indicates that two soil types are present within the same soil profile; for example, the symbol AM23 implies that both A-2 and A-3 soils are present in the same soil profile, but usually in different horizons.

Two different soil symbols may be combined by a diagonal bar (AM2/24). A diagonal bar indicates that two soil types (AM2 and AM24) are present within the same area, but not necessarily within the same profile. The two soils are so finely interspersed that they cannot be mapped separately.

REFERENCES

Allen, Harold, and others, 1945, Report of committee on classification of materials for subgrades and granular type roads: Highway Research Board, 25th Ann. Mtg., Oklahoma City, 1946, Highway Research Board Proc., v. 25, p. 375-388, Washington.

Lueder, D. R., 1950, A system for designating map-units on engineering soil-maps in soil exploration and mapping: Highway Research Board Bull. 28, p. 17-35, Washington.

Rogers, F. C., 1955, Engineering soil survey of New Jersey, Report No. 1: Rutgers Univ. Eng. Research Bull. 15, 114 p., New Brunswick, N. J.

TABLE 2.—*Soils classification*

General classification	Granular materials (35 percent or less passing a No. 200 sieve)							Silt-clay materials (more than 35 percent passing a No. 200 sieve)					
Group classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7		A-8
	a	b		4	5	6	7				5[1]	6[2]	
Sieve analysis Percent passing No. 10 sieve No. 40 sieve No. 200 sieve	50 max. 30 max. 15 max.	50 max. 25 max.	51 min. 10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.	36 min.	
Characteristics of fraction passing No. 40 sieve Liquid limit Plasticity index.	6 max.	6 max.	Nonplastic	40 max. 10 max.	41 min. 10 max.	40 max. 11 min.	41 min. 11 min.	40 max. 10 max.	41 min. 10 max.	40 max. 11 min.	41 min. 11 min.	40 min. 11 min.	42-400 0-60
Group index[3]	0		0	0		4 max.		8 max.	12 max.	16 max.	20 max.		
General subgrade rating	Excellent		Good	Good		Fair		Poor	Poor	Poor	Very poor		Unsatis-factory
Material	Well-graded gravel and sand		Clean sand and gravelly sand	Poorly graded, silty or clayey sand and gravel				Silty soil	Plastic silt	Plastic clay	Expansive plastic clay		Muck-peat

[1] Plasticity index of A-7-5 subgroup is equal to or less than the liquid limit minus 30.
[2] Plasticity index of A-7-6 subgroup is greater than the liquid limit minus 30.
[3] The group index is calculated according to the following formula: Group index = 0.2a + 0.005ac + 0.01bd
in which: a = That portion of the percentage passing No. 200 sieve greater than 35 percent and not exceeding 75 percent, expressed as a positive whole number (1 to 40).
b = That portion of the percentage passing No. 200 sieve greater than 15 percent and not exceeding 55 percent, expressed as a positive whole number (1 to 40).
c = That portion of the numerical liquid limit greater than 40 and not exceeding 60, expressed as a positive whole number (1 to 20).
d = That portion of the numerical plasticity index greater than 10 and not exceeding 30, expressed as a positive whole number (1 to 20).

TABLE 3.—*Results of laboratory analyses of soil samples*

Sample pit and site number	Depth of interval sampled (inches)	Liquid limit: NL, nonliquid — Mechanical analyses: Cumulative percent by weight passing sieve— 3/4 in.	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	Percent by weight: Silt (0.062 to 0.0039mm.)	Clay (<0.0039mm.)	Liquid limit[1]	Plasticity index[2]	Plasticity index: NP, nonplastic — Moisture-density[3]: Maximum density (lbs. per cu. ft.)	Optimum moisture (percent by weight)	Classification: HRB[4]	Map[5] symbol
318	0-34	100	100	100	57.5	2.4			NL	NP			A-3 (0)	MB3
319	0-15	100	100	100	77.7	16.9			NL	NP			A-2-4 (0)	AM23
	15-21	100	100	100	83.3	27.3			NL	NP	119	10	A-2-4 (0)	
	21-30	100	100	100	50.8	4.9			NL	NP			A-3 (0)	
320	0-17	100	99.8	99.5	75.0	17.6			NL	NP			A-2-4 (0)	AM23
	17-37	100	99.8	98.7	78.6	16.7			NL	NP			A-2-4 (0)	
	37-60	100	100	99.9	57.2	5.8			NL	NP	113	Indefinite	A-3 (0)	
321	0-30	100	99.8	99.7	69.7	1.3			NL	NP			A-3 (0)	MB3
3A	0-7	------	------	99.6	77.7	33.4			< 40	< 10			A-2-4 (0)	AM24
	7-44	------	------	99.8	87.9	49.2			23	8			A-4 (3)	
	44-72	------	------	98.2	71.4	24.7			< 40	< 10			A-2-4 (0)	
3B	0-14	------	------	99.6	68.4	7.1			< 40	NP			A-3 (0)	AM3
	14-72	------	------	99.8	74.2	4.9			< 40	NP			A-3 (0)	
3C	0-16	------	------	99.8	83.6	11.0			< 40	< 10			A-2-4 (0)	AM23
	16-42	------	------	99.7	86.8	13.1			< 40	< 10			A-2-4 (0)	
	42-72	------	------	99.9	88.6	5.5			< 40	NP			A-3 (0)	
4A	0-6	------	------	99.3	70.7	23.2			< 40	< 10			A-2-4 (0)	AM2
	6-34	------	------	95.8	66.5	28.0			< 40	< 10			A-2-4 (0)	
	34-72	------	------	99.7	72.2	18.3			< 40	< 10			A-2-4 (0)	
4B	0-8	------	------	98.5	69.6	18.9			< 40	< 10			A-2-4 (0)	AM23
	8-32	------	------	96.0	67.4	17.3			< 40	< 10			A-2-4 (0)	
	32-72	------	------	98.1	64.0	5.6			< 40	NP			A-3 (0)	
4C	42-56	------	------	99.5	78.4	21.4			NL	NP			A-2-4 (0)	F
	56-72	------	------	100	80.9	9.8			< 40	NP			A-3 (0)	AM23
5B	0-6	------	------	99.9	77.8	22.2			< 40	< 10			A-2-4 (0)	AM23
	6-20	------	------	99.8	79.4	29.8			14	3			A-2-4 (0)	
	20-72	------	------	100	81.4	8.4			< 40	NP			A-3 (0)	
5C	0-18	------	------	99.9	84.5	31.0			< 40	< 10			A-2-4 (0)	AM2
	18-36	------	------	99.5	84.0	29.4			< 40	< 10			A-2-4 (0)	
	36-72	------	------	98.6	74.4	12.4			< 40	< 10			A-2-4 (0)	
6A	2-26	------	------	99.9	81.5	15.9			< 40	< 10			A-2-4 (0)	AM2
	26-48	------	------	100	95.5	21.6			< 40	< 10			A-2-4 (0)	
	48-72	------	------	100	96.7	12.9			< 40	< 10			A-2-4 (0)	
6B	0-8	------	------	98.0	81.5	22.4			< 40	< 10			A-2-4 (0)	AM34
	8-24	------	------	99.9	91.0	40.7			< 40	< 10			A-4 (1)	
	24-72	------	------	100	81.0	8.2			< 40	NP			A-3 (0)	
6C	0-72	------	------	100	68.7	1.0			< 40	NP			A-3 (0)	MB3
7A	0-9	------	------	99.9	84.2	9.8			< 40	NP			A-3 (0)	AM23
	9-42	------	------	99.5	82.0	15.9			< 40	< 10			A-2-4 (0)	
	42-48	------	------	56.8	22.9	3.8			< 40	< 6			A-1-b (0)	
7B	0-72	------	------	100	89.3	10.4			< 40	< 10			A-2-4 (0)	AM2
8B	0-6	------	------	100	85.9	21.4			< 40	< 10			A-2-4 (0)	AM34
	6-21	------	------	100	88.3	35.9			NL	NP			A-4 (0)	
	21-48	------	------	99.8	86.9	3.2			< 40	NP			A-3 (0)	

[1] Based on AASHO (American Association of State Highway Officials) Designation: T89-49.
[2] Based on AASHO Designation: T91-49.
[3] Based on AASHO Designation: T180-57.
[4] Highway Research Board System (see table 2); group index given in parentheses.
[5] Map symbol was determined from laboratory data and does not always agree with unit shown on map. Detailed field reconnaissance has shown that some sampling sites were not representative of the predominant soil in the area.

TABLE 4.—*Characteristics of the engineering soil types in the Bethany Beach area*

Soil type[1]	Description	Origin	Engineering properties: In place — Suitability as a subgrade[3]	In place — Suitability as a wearing surface[4]	Disturbed[2] — Suitability as embankment material	Disturbed[2] — Compaction characteristics	Suitable compaction equipment
A M2	Nonplastic to slightly plastic sandy soil.	Fluvial deposits of Pleistocene age.	Good	Excellent to good depending on binder present.	Good	Good	Rubber-tired equipment.
A M23	Nonplastic, generally poorly graded sandy soil.	Fluvial deposits of Pleistocene age.	Good to fair.	Excellent to good depending on binder present if surface is A-2. Fair if surface is A-3.	Good if predominant material is A-2. Fair if predominant material is A-3.	Good if predominant material is A-2. Poor if predominant material is A-3.	Rubber-tired equipment for soil which is predominantly A-2. Vibratory equipment for soil which is predominantly A-3.
A M24	Nonplastic to slightly plastic, sandy and silty soil.	Fluvial deposits of Pleistocene age.	Good if material left after grading is predominantly A-2. Fair if material left after grading is predominantly A-4.	Excellent to good depending on binder present if surface is A-2. Fair to poor if surface is A-4.	Good if predominant material is A-2. Fair if predominant material is A-4.	Good if predominant material is A-2. Fair if predominant material is A-4.	Rubber-tired equipment.
A M3	Nonplastic, poorly graded sandy soil.	Fluvial deposits of Pleistocene age.	Fair	Fair	Fair	Poor	Vibratory equipment.
A M4	Slightly plastic, silty and clayey soil.	Fluvial and possibly eolian deposits of Pleistocene age.	Fair to poor.	Fair to poor.	Fair to poor.	Fair to poor.	Rubber-tired equipment.
MB13	Nonplastic, gravelly to poorly graded sandy soil.	Marine beach deposits.	Fair	Fair	Fair	Fair	Vibratory equipment.
MB3	Nonplastic, poorly graded sandy soil.	Marine beach deposits.	Fair	Fair	Fair	Poor	Vibratory equipment.
F	Fill. In general, nonplastic to slightly plastic, sandy soil.	Undetermined	Variable	Variable	Variable	Variable	Variable.
MTM	Soil rich in organic material and subject to inundation by high tides. No definite profile.	Tidal marsh deposits.	Variable	Variable	Variable	Variable	Variable.
Z	Soil rich in organic material and frequently poorly drained. May be underlain at shallow depths by gravel, sand, or clay.	Swamp deposits of Recent age.	Variable	Variable	Variable	Variable	Variable.

[1] Two different soils may be combined into a single map symbol (A M2/24), but the engineering characteristics of the individual soil types are described separately.
[2] For soil types designated by two-digit numbers, these columns refer to the composite soil.
[3] When not subject to frost action. Frost will affect soils that contain appreciable silt and clay and have a high moisture content.
[4] Untreated. Additives may aid in stabilization of the sandy soils and minimize dusty conditions.

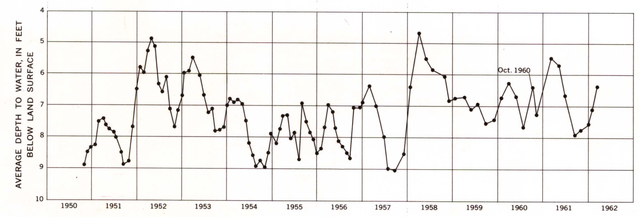

FIGURE 2.—Hydrograph showing average depth to water in 13 water-table wells in Delaware

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WATER-TABLE, SURFACE-DRAINAGE, AND ENGINEERING SOILS MAP OF THE BETHANY BEACH AREA, DELAWARE

By
Durward H. Boggess and John K. Adams

1964

HYDROLOGIC INVESTIGATIONS
ATLAS HA-122

For sale by U.S. Geological Survey, price 75 cents