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18 June 2019

VIA E-MAIL

Mr. Barry T. Sutch
Senior Engineering Manager
Greater Mid-Atlantic Market Area
Waste Management
1000 New Ford Mill Road
Morrisville, Pennsylvania 19067

Subject: **Response to Selected Comments Presented at Public Hearing**
Permit Modification Application for Vertical Expansion
Delaware Recyclable Products, Inc. Landfill
New Castle, New Castle County, Delaware

Dear Barry:

Geosyntec Consultants (Geosyntec) is pleased to present this evaluation of and response to comments presented at the 29 May 2019 public hearing for a vertical expansion to the Delaware Recyclable Products, Inc. (DRPI) Landfill in New Castle, Delaware. Specifically, Geosyntec has addressed comments presented by and on behalf of Artesian Water Company (Artesian). The public testimony and exhibits presented by and on behalf of Artesian at the public hearing are included as Attachment 1 to this letter[1]. The remainder of this letter presents: (i) discussion of the current configuration and geologic setting of the DRPI Landfill; (ii) a summary of the proposed vertical expansion; (iii) a summary of Artesian's testimony; and (iv) Geosyntec's analysis and response to Artesian's testimony.

Current Configuration and Geologic Setting of DRPI Landfill

The DRPI Landfill operates as an industrial waste landfill, which primarily accepts construction and demolition debris (CDD), that has been permitted by the Delaware Department of Natural Resources and Environmental Control (DNREC) since 1983. There have been several landfill expansions supported by subsurface investigations, including soil borings and hydrogeologic cross sections, as part of the permit modification applications. The DRPI Landfill is operated with a leachate collection system, which transmits leachate to low points within each lined cell, where the leachate is then pumped into a perimeter leachate header, which transmits the leachate to the on-site leachate pre-treatment system and, ultimately, to the New Castle County Sewer System,

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[1]Excerpted from DNREC website titled, Public Hearing: Delaware Recyclable Products, Inc. (DRPI) Industrial Waste Landfill Permit, https://dnrec.alpha.delaware.gov/events/391/public-hearing-delaware-recyclable-products-inc-drpi-industrial-waste-landfill-permit/.

where it is further treated prior to discharge. In addition, the DRPI Landfill has two lateral leachate collection toe drains, which also discharge to the leachate forcemain. These toe drains are located and function as follows: (i) the Cell 3 Toe Drain is a horizontal drain that slopes from west to east separating Cells 3 and 4, the purpose of which is to intercept liquid from Cell 3 and prevent it from migrating north under Cell 4; and (ii) the Cells 1,2,3,5 Toe Drain is a horizontal drain that slopes from south to north along the entire west side of Cells 1-3, between Cells 1-3 and Cell 5, and that intercepts westward flow from Cells 1-3 and prevents migration under Cell 5. Liquid that is collected in these toe drains is pumped into the leachate forcemain and is treated, in the same manner as leachate collected from the lined cells. Further detail on the leachate and groundwater collection and transmission systems is presented in the Permit Modification Application for Vertical Expansion for the DRPI Landfill (DRPI permit application)[2].

The DRPI Landfill is located on the Atlantic Coastal Plain Physiographic Province, near the Fall Line. Coastal Plain sediments increase in thickness, and dip, toward the southeast. Surficial sediments in the DRPI Landfill vicinity consist of the Columbia Formation sand and gravel. However, the Columbia Formation has been removed by pre-landfill sand and gravel mining operations over most of the landfill footprint except for a small area beneath the southern part of the landfill (see Attachment 2)[3]. The Potomac Formation underlies the Columbia Formation and is present beneath the landfill footprint. The Potomac Formation is divided into two zones: the Upper Potomac and the Lower Potomac, with clay aquitards and confined sand aquifers in each. A clay aquitard of the Upper Potomac Formation is present between the bottom of the landfill and the upper sand zone aquifer of the Upper Potomac Formation (see Attachment 2).

Summary of the Proposed Vertical Expansion

The vertical expansion for the DRPI Landfill is proposed over the existing footprint of Cells 1 through 6 and will increase the permitted height of the landfill from 130 feet above mean sea level (ft-msl) to 190 ft-msl.

Summary of Artesian's Testimony

There are two main portions of Artesian's testimony that are addressed in this letter, which are:

(1) Artesian identified that the proposed vertical expansion "will cause six feet of compression of the trash below" and that "what is below that is our aquifer that reaches our public supply wells."

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[2] Permit Modification Application for Vertical Expansion DRPI Industrial Landfill New Castle, Delaware, Prepared by: Geosyntec Consultants, July 2018.
[3] Blazosky Associates, Inc. Hydrogeologic Assessment Summary Narrative, DRPI Industrial Waste Landfill Proposed Disposal Cell 6 Expansion (October 13, 2004).

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(2) Artesian also noted that "the original use of the site was as a borrow pit where the top layers of soil were removed. Below the borrow pit is sand. That sand runs into the Potomac aquifer, which is like a super highway to our public supply wells."

Analysis and Response to Artesian Testimony

Artesian identified that the proposed vertical expansion will cause six feet of settlement in the existing waste. While Appendix VI-D.3 of the DRPI permit application does show a maximum of 6.13 feet of settlement (at Point 9 on Section B-B, which is in the Cells 1-3 area), not all of this settlement is due to the proposed expansion. Some of the waste placed in this area will be disposed within the limits of the current permitted landfill height. Geosyntec evaluated how much of the calculated settlement in the Cells 1-3 area is due to waste that will be placed under the current permitted maximum elevation and how much would be placed as part of the proposed vertical expansion. In comparing the calculated settlements under these two scenarios (i.e., that which is presented in Appendix VI-D.3 of the DRPI permit application as total calculated settlement due to waste overlying the Cells 1-3 overlay liner vs. that which is presented in Attachment 3 to this letter as calculated settlement due to waste that will be placed under the current permitted maximum elevation), the maximum calculated settlement due to the vertical expansion is 2.51 feet and occurs at Point 6 on Section A-A. It is noted that the settlement calculations presented in Attachment 2 are only for Sections A-A, B-B, G-G, H-H, and K-K because these sections are in the Cells 1-3 area where there is waste below the overlay liner system. The table below summarizes the average liner settlement due to waste placed as part of the proposed vertical expansion at the five sections in the Cells 1-3 overlay area.

Section	Average Liner Settlement (feet)		
	Proposed Vertical Expansion (Total)	Existing Permit (Total)	Due to Proposed Vertical Expansion (Increment)
A-A	4.6	3.1	1.5
B-B	5.3	3.5	1.8
G-G	4.7	3.0	1.6
H-H	3.8	2.4	1.4
K-K	4.8	3.4	1.4

Based on this analysis, the maximum anticipated settlement due to waste placed as part of the proposed vertical expansion is 2.51 feet and the average settlement is less than two feet, both of which are substantially less than the six feet of settlement identified in Artesian's testimony.

Additionally, the implication made in Artesian's testimony is that compression due to the additional waste loads would cause liquids to be released from the unlined waste below the Cells 1-3 overlay liner system. Geosyntec has evaluated the loading mechanisms at the DRPI Landfill during landfilling and, as subsequently described, has identified three factors that will likely reduce the leachate flow. In addition, because the area of concern has been lined, additional leachate in the waste mass underlying the overlay liner system will not be generated due to the proposed vertical expansion. Thus, the proposed vertical landfill expansion will not contribute to an increase in the total volume of leachate and may actually result in a reduction in the leachate generation rate. The three factors that will likely reduce leachate flow are as follows.

- **Reduction of hydraulic conductivity due to increased overburden stress.** The proposed vertical expansion will increase the overburden stress experienced by the existing unlined waste, which, in turn, increases the waste density. Studies by Reddy et al. (2009)[4] and Reddy et al. (2011)[5], as well as Feng et al. (2016)[6] have shown that hydraulic conductivity of waste decreases with an increase in waste density and, thus, the corresponding overburden stresses. Similarly, field studies by Jain et al. (2006)[7] and Wu et al. (2012)[8] showed waste hydraulic conductivity reduces with depth (i.e., due to increased confining stresses).
- **Waste degradation reduces hydraulic conductivity.** Reddy et al. (2009) and Reddy et al. (2011) showed that the hydraulic conductivity considerably reduces with the degradation of waste. This was attributed to the generation of fines due to degradation (Reddy et al. 2009; Hossain et al. 2009[9]). Waste in the unlined area (i.e., Cells 1-3) is relatively old and, thus, has likely undergone significant degradation, thereby reducing the hydraulic conductivity.
- **Compression of, and leachate flow into, air pockets.** Air permeability inside the landfill is very low (10^{-12} cm/s) which leads to large volumes of air entrapped inside the landfill (Jain et al. 2006). This characteristic essentially makes any leachate flow a three-phase

[4] Reddy, K.R., H. Hettiarachchi, N. Parakalla, J. Gangathulasi, J. Bogner, 2009b. Geotechnical properties of fresh municipal solid waste at Orchard Hills Landfill, USA. Waste Management 29(2), 952-959.
[5] Reddy, K. R., Hettiarachchi, H., Gangathulasi, J., and Bogner, J. E. 2011. "Geotechnical properties of municipal solid waste at different phases of biodegradation." Waste Manag., 31(11), 2275–2286
[6] Feng, S.J., Cao, B.Y., Bai, Z.B., Yin, Z.Y., 2016. Constitutive model for municipal solid waste considering the effect of biodegradation. Geotech. Lett. 6, 244–249
[7] Jain, P., Powell, J., Townsend, T. G., and Reinhart, D. R. 2006. "Estimating the hydraulic conductivity of landfilled municipal solid waste using borehole permeameter test." J. Environ. Eng., 1326, 645–653.
[8] Wu, H., Chen, T., Wang, H., Lu, W., 2012. Field air permeability and hydraulic conductivity of landfilled municipal solid waste in China. J. Environ. Manag. 98, 15–22
[9] Hossain, M.S., Penmethsa, K.K., Hoyos, L., 2009. Permeability of municipal solid waste in bioreactor landfill with degradation. Geotechnical and Geological Engineering 27(1), 43-51.

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system (Figure 1). Henrych (1979)[10] and Wang et al. (2005)[11] showed that air is highly compressible. Therefore, because of the low overall landfill permeability, an increase in overburden will cause air volume to reduce and leachate to flow into the surrounding air voids. A sketch depicting this concept is presented in Figure 1.

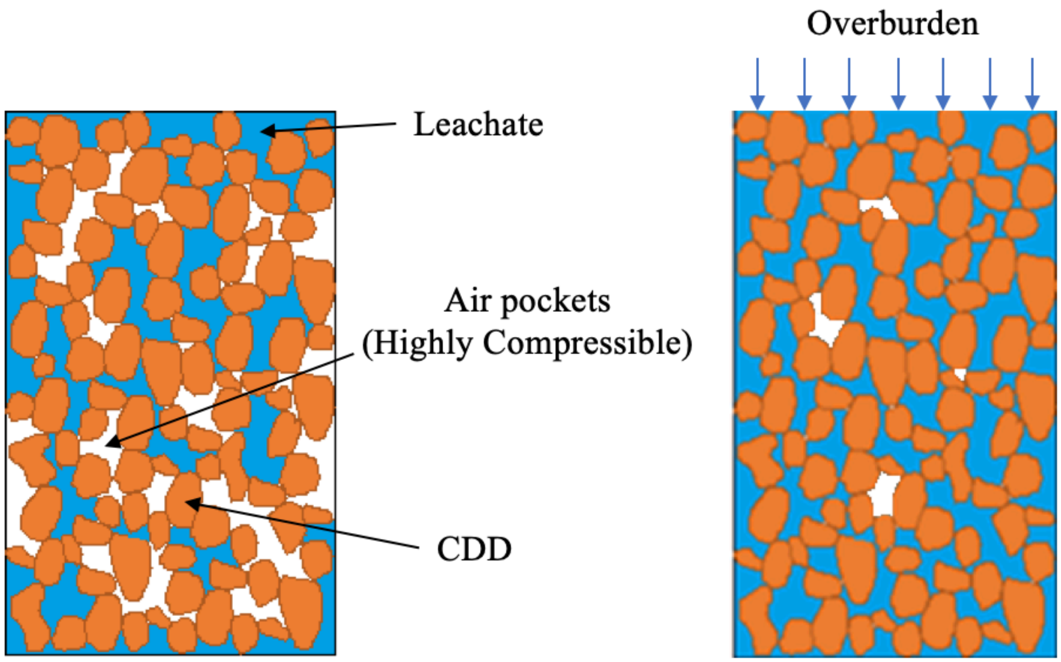

Figure 1. Three phase diagram of waste, leachate, and air without and with overburden.

In the event that liquids do flow out of the unlined waste area due to the additional compression from the increased "overburden" waste placed as part of the vertical expansion, the existing leachate toe drains (i.e., Cell 3 Toe Drain and Cells 1,2,3,5 Toe Drain) will collect this liquid for pre-treatment prior to discharge into the New Castle County Sewer System. As described previously in this letter, these toe drains were installed to collect liquids that drain out of the unlined waste in Cells 1-3 at DRPI Landfill.

Lastly, Geosyntec evaluated the potential for off-site migration of leachate to Artesian's public water supply wells. Artesian's well fields are located approximately one to two miles south of the landfill and east of the New Castle County Airport. Review of Delaware Department of Natural Resources Public Water Supply Source Assessment reports for Artesian's Collins Park[12], Castle

[10] Henrych, J. 1979. The dynamics of explosion and its use, Elsevier Science, New York, 1–562
[11] Wang Z, Lu Y, Hao H, Chong K. 2005. A full coupled numerical analysis approach for buried structures subjected to subsurface blast. Comput Struct; 83(4):339–56.

[12] Delaware Department of Natural Resources and Environmental Control, Division of Water Resources, Source Water Assessment and Protection Program, Public Water Supply Source Water Assessment for Artesian Water Company

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Hill[13], and Jefferson Farm[14] well fields indicate that some of the public wells are screened in either: (1) exclusively the upper sand zone of the Upper Potomac Formation; (2) exclusively in the lower part of the Columbia Formation; or (3) in both the lower part of the Columbia Formation aquifer and the underlying upper sand zone of the Upper Potomac Formation. A groundwater monitoring system is in place around the landfill[15] and there is also a shallow groundwater collection system beneath the landfill that induces inward gradients in shallow groundwater toward the center of the landfill, thus inhibiting potential leachate migration away from the landfill footprint[16] (see Attachment 4).

The two exhibits submitted by Artesian at the 29 May 2019 public hearing include:

- 'Submission', *Diagrammatic cross-section showing stratigraphic relationships (Not to Scale)*[17] is a schematic conceptual cross section that is a portion of Sheet 4 (Structural Geology) showing generalized information on the depth and thickness of the 'upper sand zone' of the Potomac Formation, and has the approximate location of DRPI Landfill added to the figure; and

- 'Submission 2', is a portion of Sheet 3, *Structural Geology, Elevation of the Base of Sand in the Upper Part of the Potomac Formation*[18] with the approximate locations of DRPI Landfill and Artesian's well fields added to the figure.

Geosyntec evaluated the potential for migration of DRPI leachate to the upper sandy zone of the Upper Potomac Formation as well as to the Columbia Formation and discussion of both is presented herein.

(Collins Park), December 31, 2003. Table 1 shows one well, screened 100-125 feet below ground surface (bgs) in the Potomac Formation.

[13] Delaware Department of Natural Resources and Environmental Control, Division of Water Resources, Source Water Assessment and Protection Program, Public Water Supply Source Water Assessment for Artesian Water Company (Castle Hills), December 31, 2003. Table 1 shows Well 1 screened 50-73 feet bgs in Columbia Formation, Wells 2 and 3 screened 56-104 and 56-108 feet bgs, respectively, in both the Columbia Formation and Potomac Formation.

[14] Delaware Department of Natural Resources and Environmental Control, Division of Water Resources, Source Water Assessment and Protection Program, Public Water Supply Source Water Assessment for Artesian Water Company (Jefferson Farm), December 31, 2003. Table 1 shows Well 1A screened 96-140 feet bgs and Well 2 screened 127-137 feet bgs, both in the Potomac Formation.

[15] Waste Management, Updated Groundwater, Leachate, and Stormwater Monitoring and Reporting Program Plan, Cells 1, 2, 3, 4, 5, and 6, DRPI Industrial Waste Landfill, June 2009.

[16] Taylor Geoservices, DRPI 2017 Annual Report (February 28, 2018).

[17] Delaware Geological Survey Hydrologic Map Series No. 3, Geohydrology of the Wilmington Area, Kenneth D. Woodruff, 1984.

[18] Ibid.

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Potential DRPI Leachate Migration to Upper Sandy Zone of Upper Potomac Formation. It is presumed for several reasons that Artesian is concerned about potential landfill leachate migration pathways through the Upper Potomac Formation 'upper sand zone' to their supply wells. First, Artesian plotted the locations of the landfill and their wells on Submission 2 that shows structure contour information specific to the base of the upper sand zone of the Upper Potomac Formation. Second, Artesian plotted the landfill location on the schematic cross section at a location directly above the subcrop of the upper sand zone. Presumably, Artesian inferred from the conceptual cross section they submitted that there would be direct recharge of potential leachate releases from the landfill into the subcrop of the upper sand zone of the Upper Potomac Formation. The schematic cross section erroneously shows the shallow Columbia Formation aquifer in direct unconformable contact with the underlying subcrop of the upper sand zone of the Upper Potomac Formation without any intervening clay aquitard. The stratigraphy presented on the schematic cross section (Attachment 1 Submission), without any clay between the bottom of the landfill and the upper sand zone of the Upper Potomac Formation, is inconsistent with the site-specific soil boring information used to produce the subsurface stratigraphy shown in Attachment 2.

Furthermore, Artesian did not submit the more detailed cross section on Sheet 1 (B-B') from the same Delaware Geological Survey document that they consulted for their submittals (see Attachment 5). Delaware Geological Survey's cross section B-B' is drawn to scale using specific soil boring log information and passes through the landfill location. B-B' shows the presence of a substantial clay aquitard at the landfill location. The clay aquitard separates the surficial materials of the Columbia Formation (that were removed by sand and gravel quarry operations) and the upper sand zone of the Upper Potomac Formation. Sheet 1 of the Delaware Geological Survey report has text in the top right indicating for the northern area of the map (i.e. the DRPI Landfill vicinity) the upper sand zone of the Upper Potomac Formation is thin and irregular in thickness and areal extent and is therefore consistent with the site soil borings and the fence diagram in Attachment 2. The text box on the top left of Sheet 4 indicates that the upper sand zone is not always persistent along strike in the subcrop area (it is noted that the northwest portion of DRPI Landfill is located within the subcrop area). Cross Section B-B' shows that there is a clay aquitard separating the (previously quarried) Columbia Formation and the upper sand zone of the Upper Potomac Formation beneath the landfill and to the south of the landfill toward the public supply wells. Cross section B-B' goes through the site between borings Cd31-16 and Cd31-4 and shows that there is clay present above the upper sand. The schematic cross section submitted by Artesian and is, therefore, misleading because it does not show the presence of the thick clay aquitard between the landfill and the upper sand horizon. The boring logs for the landfill permit applications also show the presence of the clay aquitard between the landfill and the upper sand zone as depicted in Attachment 2[19]. Therefore, there is not a direct connection from beneath the

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[19] Geologic Fence Diagram, DRPI Industrial Waste Landfill Cell 6 Expansion Area prepared by Blazosky Associates, Inc. (BAI Drawing NO. WMI-186E001; February 18, 2004).

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DRPI Landfill to the upper sand zone of the Upper Potomac Formation and, therefore, no connection to the water supply wells.

Potential DRPI Leachate Migration to Columbia Formation. The Columbia Formation has been removed beneath most of the landfill by previous sand and gravel quarry operations. There is a small area of remaining sand and gravel in the southern end of the DRPI Landfill. However, the hydraulic gradient in the shallow groundwater is to the north toward the Christina River, and away from the Artesian well fields location to the south. This natural gradient to the north is further enhanced by the groundwater collection system beneath the center of the landfill. Therefore, there is no migration pathway for DRPI leachate to the water supply wells screened in the Columbia Formation.

Summary

In summary, based on the information reviewed, there is not a complete migration pathway from the DRPI Landfill to Artesian's public water supply wells located south of the landfill. Should you have any questions or need additional information, please do not hesitate to contact the undersigned at 410.381.4333.

Sincerely,

C.H. Pendleton

Carrie H. Pendleton, P.E.
Principal Engineer

Robert Glazier
Principal Geologist

Dave G. Sherman, P.G.
Licensed Professional Geologist

Attachments

ATTACHMENT 1

Artesian Testimony and Exhibits

failed this community for several decades.

I'm going to tell you what I am going to do: I'm a product of the sixties. And in the sixties, success was gained through litigation, demonstration, and legislation.

I am going to legislate. I'm not a lawyer, but what I do better than anything else is bring class action litigation when it's necessary and appropriate, and I'm good at it.

And third, if put to the test, we will demonstrate. And don't think for one minute this community is not capable of shutting down Route 13, shutting down Route 9 to defend our environmental rights.

Now, you all do what you want to do. I'm going to do what I have to do. (Applause)

UNIDENTIFIED SPEAKER: Woo hoo! All right! Yeah!

MS. VEST: Thank you. Next up, Karl Randall.

MR. RANDALL: Good evening, ladies and gentlemen. My name is Karl Randall. I am general counsel of Artesian Water Company. And I'm here tonight on behalf of the company to speak in opposition to this permit modification.

UNIDENTIFIED SPEAKER: All right! All right! (Applause)

MR. RANDALL: Artesian has been finding increased levels of contaminants in its wells in this area.

We know where many of them are coming from. There are other landfills that are superfund sites near here. But we do not know where all of them are coming from.

We are doing what is necessary to remove those contaminants, but doing that is expensive. And if you don't know who is responsible, those costs get passed on to our customers, and we do not want that to happen.

We have specific concerns about this permit modification.

As you heard, the original use of this site was as a borrow pit where the top layers of soil were removed. Below the borrow pit is sand. That sand runs into the Potomac aquifer, which is like a super highway to our public supply wells.

The first layers of trash brought to the dump was industrial waste, not construction demolition, and there is no liner below it.

The permit application discloses that the six stories of additional trash that they want to put on top, it will cause six feet of compression of the trash below.

That being the case, even though they intend to put liners above the old industrial waste, it will be compressed, and there is no liner below.

There is a sample leachate system over here that shows a liner underneath a pipe that would collect the water. That, to our understanding, does not exist below that old industrial waste that will be impacted by the weight of the new trash above.

And what is below that is our aquifer that reaches our public supply wells. For that reason, we think that there are -- if this was to be approved at all, there would have to be serious changes to what is being requested.

I have other experts here who will
also speak. They are professional geo --
hydrogeologists with a better understanding of
some of the technical details. (Applause)
MS. VEST: Thank you, Mr. Randall.
Christopher Whallon. Christopher Whallon?
Whallon?
MR. WHALLON: Good evening, ladies
and gentlemen. My name is Christopher Whallon.
I'm a geologist with Duffield Associates, a
local consulting company.
I would like to mention just a
couple of points about the application.
In the submission that DRPI
provided, there is a litany of questions about
siting. And by and large, the siting is
designed to evaluate things like sensitive
receptors, land use, valuable aquifers, and
natural resources.
Most of the questions about siting
were addressed by the applicant by saying, "We
are not putting new cells in, so we don't need
to do anything about it, or there is no
impact," or they said, "The studies that are

available, provided, show there is no problem."

I would like to address those few things real quickly.

The first is as to the cells, the Regulations Governing Solid Waste that were referred to by DNREC specifically define "cell" as an engineering structure designed to hold or dispose of solid waste.

Now, in this case the cells are going up, over. When they are designing cells, they are putting in new liners, they are putting in leachate control. They're putting in a new gas tank. They are building cells, building the cells up.

And so it seems to Artesian Water, who I'm speaking on behalf of tonight, that the questions about valuable aquifers, proximity to natural resources, should be addressed as to the new cells that are being installed.

The other questions about some of the natural receptors were dismissed simply by referring to hydrogeologic environmental studies, most of which date 2004 and 2005.

This modification is a substantial

one and essentially at 20 years or so to the life of the landfill.

And it seems to Artesian unwise to make technical determinations about nearby wells, nearby sensitive receptors, environmental issues that are going to remain and stand up into 2040 based on data collected in 2004. And, at least, these studies should be renewed and revised to reflect current conditions. Thank you. (Applause)

MS. VEST: Thank you, sir. Peter Demicco? Demicco? Again, I apologize if I'm saying it wrong.

MR. DEMICCO: Yes, good evening. My name is Peter Demicco. I am a geohydrologist I have been working in the State of Delaware for many years. I'm a University of Delaware graduate. I won't tell you why that was a long time ago.

And I'm going to try to describe some very specific conditions that we want to basically enter into the record to make sure DNREC reviews the information that's appropriate.

And the first one is we have all talked about the sand and gravel being removed from the area. Well, that's first and foremost.

UNIDENTIFIED SPEAKER: Louder!

MR. DEMICCO: Is that better? Sorry about that.

MS. VEST: You almost have to keep it right up against your mouth.

MR. DEMICCO: First and foremost is here is a schematic from Delaware Geological Survey publication with a reference -- I will give to DNREC that we want these added into the record formally -- that are from 1984 Geological Survey publication, and the first one is basically a schematic of the aquifers we have all been talking about.

The landfill is located on top of the Potomac aquifer. And they have excavated down into that aquifer. The problem is you couldn't pick a worse site to put a landfill if you were trying.

And the examples that we are most familiar with are Delaware Sand and Gravel superfund site and Army Creek superfund site which were being filled with trash prior to this but about the same era.

So that is first and foremost a significant problem about this site.

Second is in the Potomac aquifer -- and we have a map there which describes and locates our specific wells -- we have Collins Park, Castle Hill, Jefferson Farms -- and I will remember the name of the last one in a minute -- but three of those four wells are directly down that little dip we showed in the previous map.

And one of the other issues is their application said no new wells. Well, we have three of these locations in the last seven years put in improved wells, replacement wells. They are pumping more water. It's within the allocation limits, but we are now pumping more water. And we do not know what that impact is on their landfill, and they do not have the information available to us.

And, finally, we have the application, itself.

Surprisingly, the hydro-geo report was only put on the website at DNREC yesterday. I have had less than 24 hours to review it. I do not have details. But I have already looked at it and found some serious implications which are on this cross section. They talked about their monitor wells.

MR. SUNDE: Time.

MR. DEMICCO: Three of the wells are in the wrong aquifers. That has to be looked at directly. (Applause)

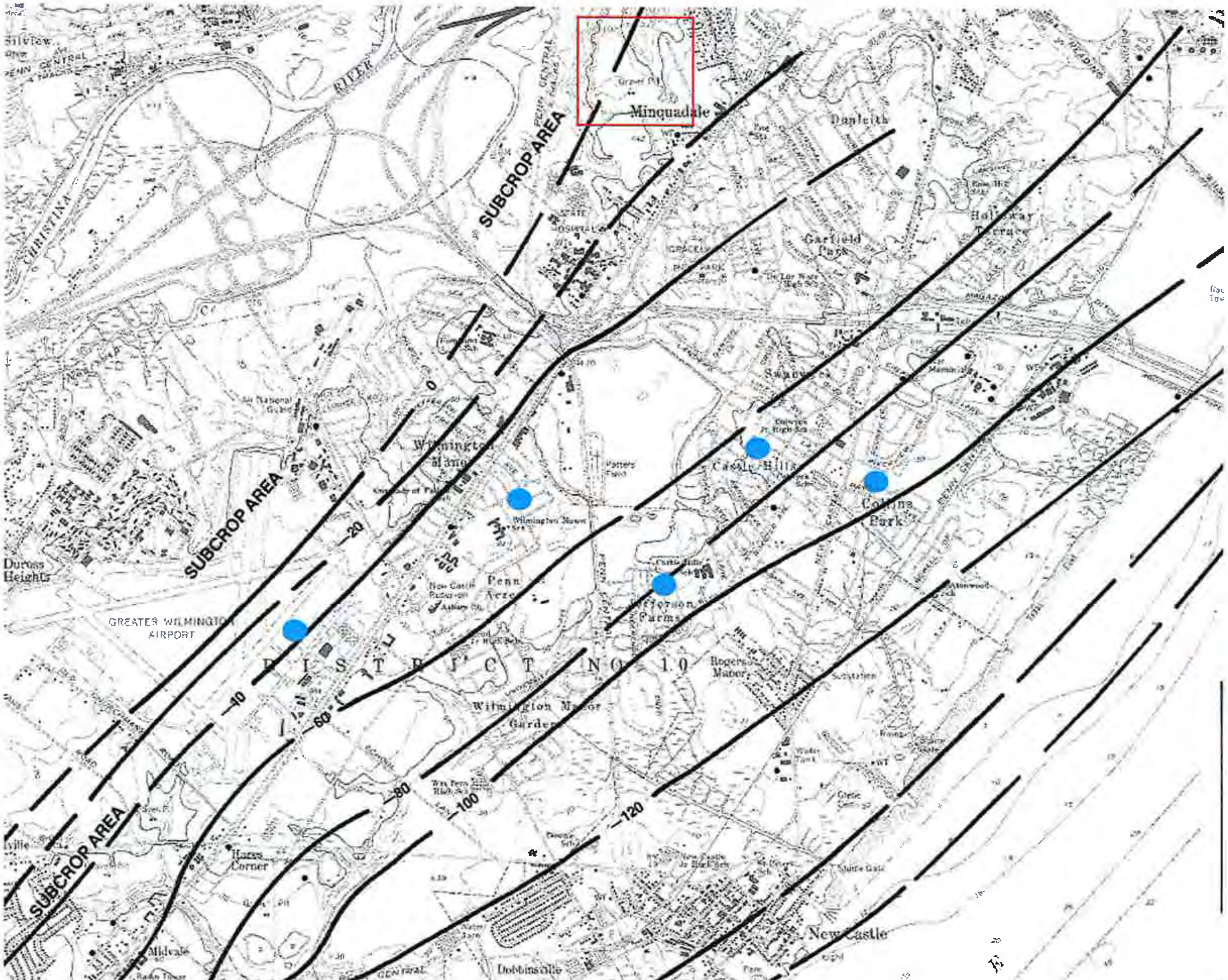
MS. VEST: Just for the benefit of the audience here, I want to make sure everybody knows that, as people are giving me these documents, I am marking them, and they are getting entered into the formal hearing record.

All of -- Mr. Randall has provided me with normal-sized copies of these blow-up pictures. I am marking all of this documentation Artesian Exhibit 1, and it will be all of them together combined.

I also want to recognize that Councilman Street's letter that he offered to

ARTESIAN WATER COMPANY, INC. SUBMISSION 2- May 29, 2019

Artesian Exh. #1

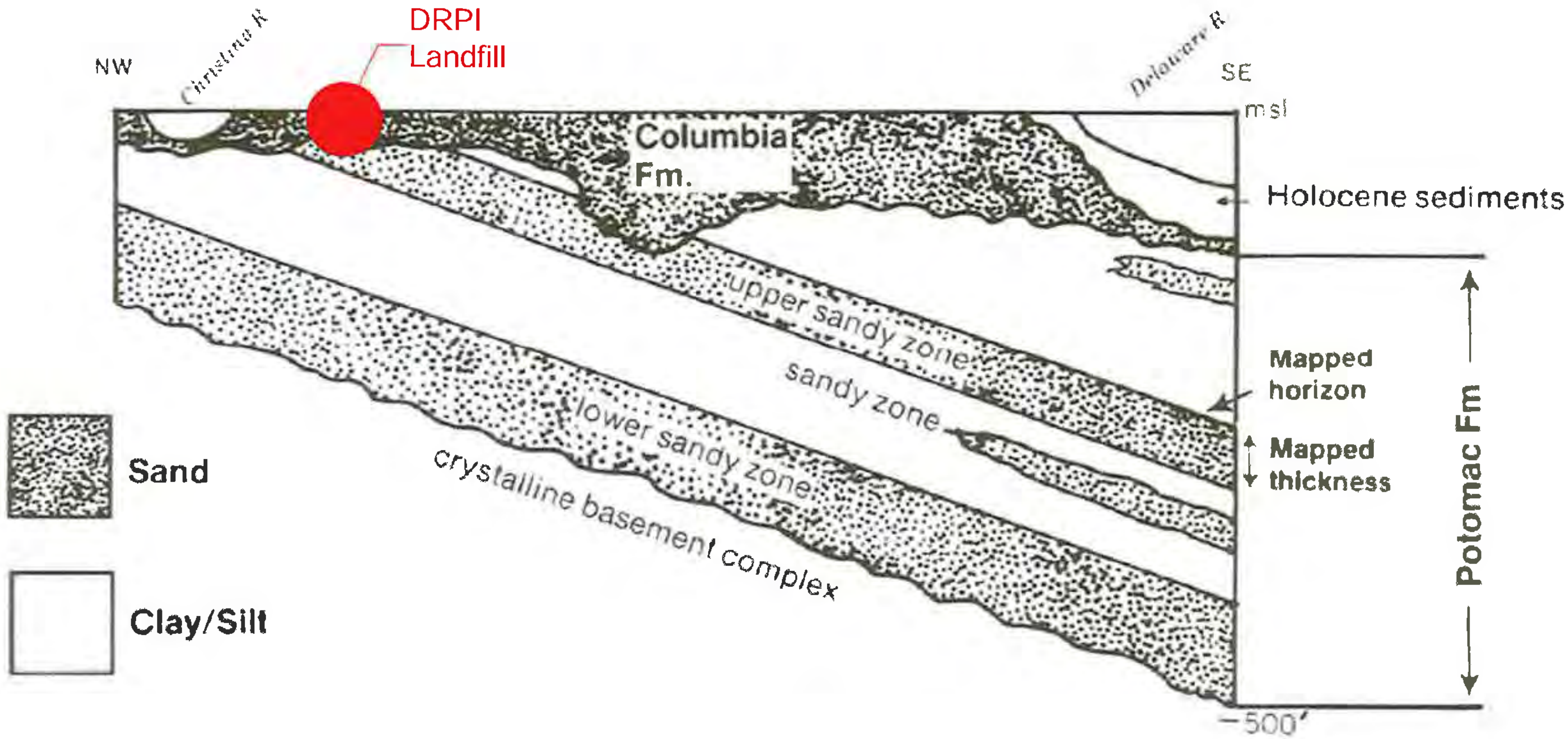


Artesian WTP

DRPI Landfill

DELAWARE GEOLOGICAL SURVEY
GEOHYDROLOGY OF THE WILMINGTON AREA
HYDROLOGIC MAP SERIES, NO. 3
SHEET 3—STRUCTURAL GEOLOGY

by Kenneth D. Wodruff, 1984



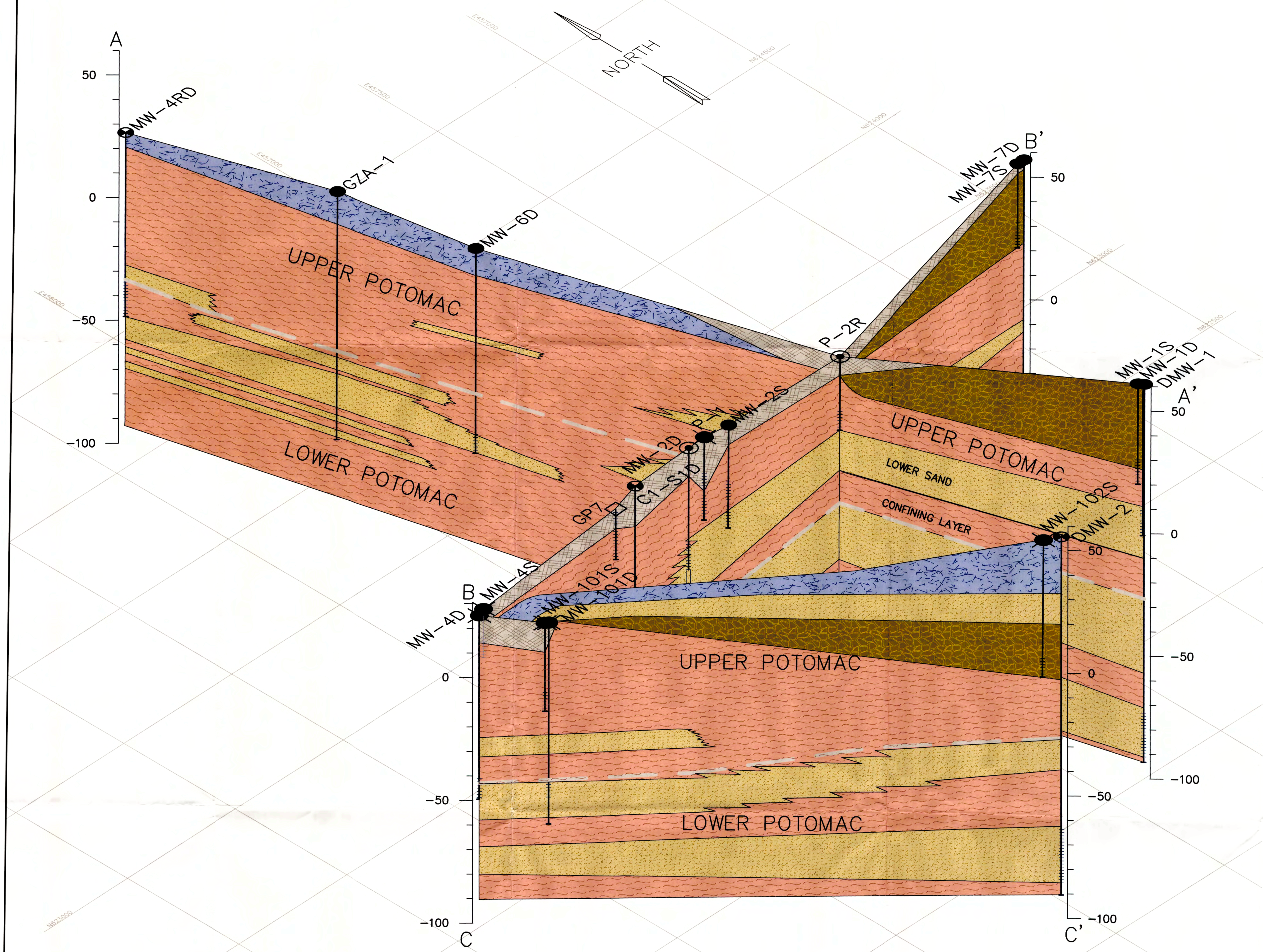
Diagrammatic cross-section showing stratigraphic relationships
(Not to Scale)

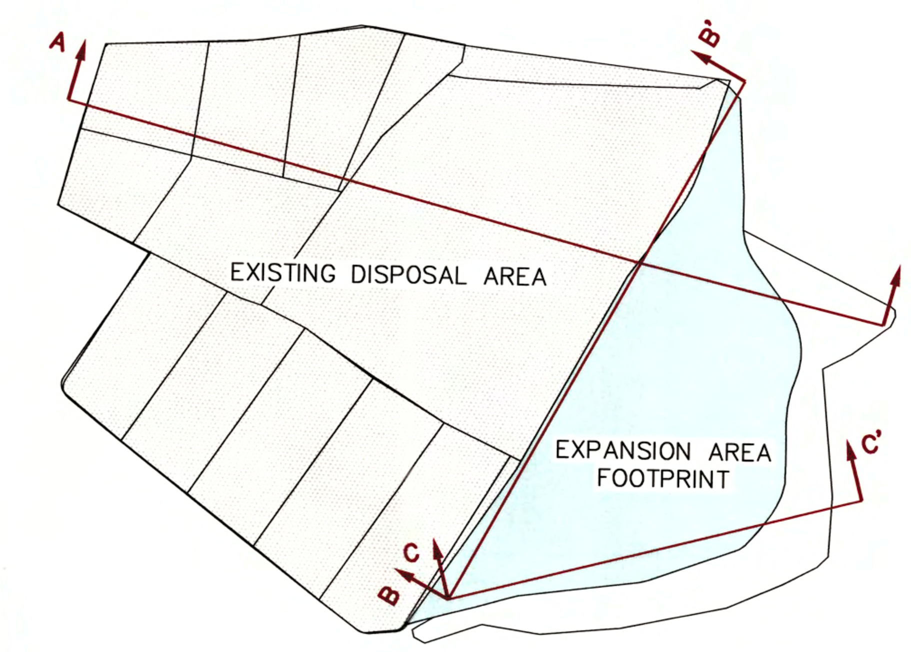
DELAWARE GEOLOGICAL SURVEY
GEOHYDROLOGY OF THE WILMINGTON AREA
HYDROLOGIC MAP SERIES, NO. 3
SHEET 4 — STRUCTURAL GEOLOGY

by Kenneth D. Woodruff, 1985

ATTACHMENT 2

Geologic Fence Diagram





CROSS SECTION LOCATION KEY

1" = 600'

NOTES

1. HORIZONTAL GRID IS DELAWARE STATE PLANE COORDINATE SYSTEM.
2. DATUM IS N.G.V.D. 1929.
3. BORINGS HAVE BEEN BROUGHT INTO CROSS SECTIONS PERPENDICULAR TO THE CROSS SECTION.
4. BORINGS ARE SHOWN AT ACTUAL ELEVATION AND TOTAL DEPTHS.
5. MW-101(S) AND MW-101(D) HAVE BEEN PROJECTED 240' NORTHEAST INTO CROSS-SECTION C-C'.
6. GP-7 HAS BEEN PROJECTED 80' SOUTH INTO CROSS-SECTION B-B'
7. MW-2D HAS BEEN PROJECTED 500' NORTH INTO CROSS-SECTION B-B'.
8. MW-7(S) AND MW-7(D) HAVE BEEN PROJECTED 260' SOUTH INTO CROSS-SECTION B-B'.

LEGEND

- CLAY
- SAND
- WASTE
- SAND AND GRAVEL
- FILL

INTERPRETED UPPER/ LOWER POTOMAC FORMATION BOUNDRY

HORIZONTAL GRAPHIC SCALE

150 0 75 150 300 600

(IN FEET)
1 inch = 150 ft.

VERTICAL GRAPHIC SCALE

20 0 10 20 40 80

(IN FEET)
1 inch = 20 ft.

... J. Sokol ... 974 DELAWARE ... PROFESSIONAL GEOLOGIST

COMMONWEALTH OF PENNSYLVANIA REGISTERED PROFESSIONAL EDWARD J. LAYTON GEOLOGIST PG003958

WASTE MANAGEMENT

REVISIONS		

BLAZOSKY Associates Inc. Balanced Environmental Solutions

DELAWARE RECYCLABLE PRODUCTS, INC.

DRPI INDUSTRIAL WASTE LANDFILL
CELL 6 EXPANSION AREA

MINQUADALE BOROUGH NEW CASTLE COUNTY DELAWARE

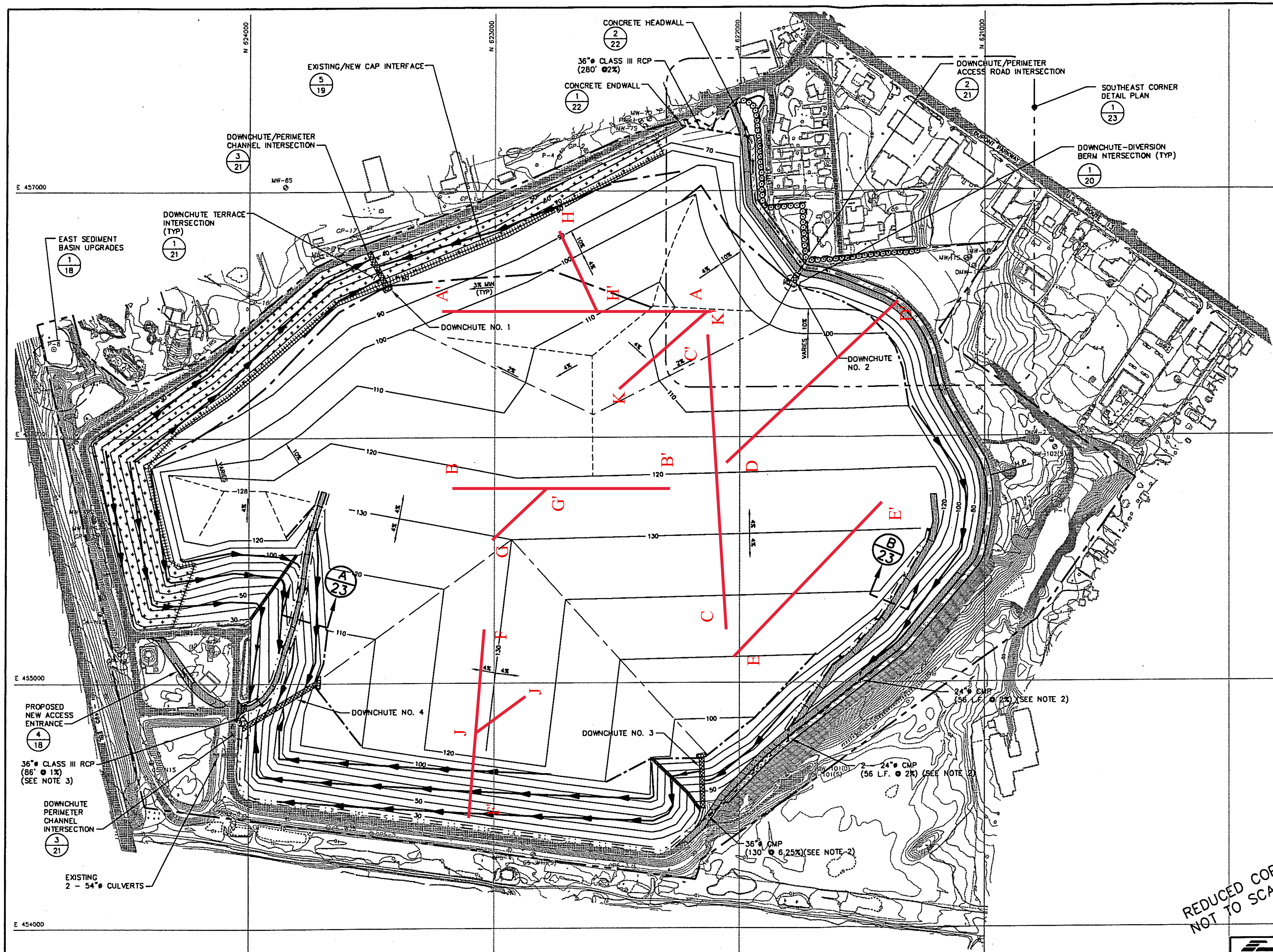
GEOLOGIC FENCE DIAGRAM

BALANCED ENVIRONMENTAL SOLUTIONS
State College, PA., Telephone: 814/238-2060; Delaware Valley, PA., Telephone: 610/783-0125

DATE: 2/18/04
DRAWN BY: DA
CHECKED: EJL
BAI DRAWING NO: WMI-186E001
SHEET NO. 3 OF 3

ATTACHMENT 3

Calculated Settlement for Current Permitted Height

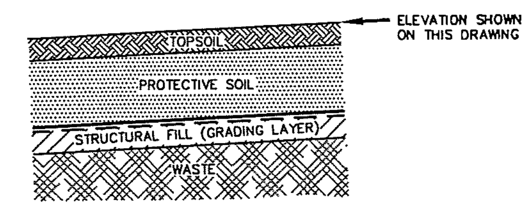


REDUCED COPY - NOT TO SCALE

NORTH

LEGEND

- PROPERTY BOUNDARY
- EXISTING GRADE CONTOUR (FEET-MSL)
- FINAL COVER GRADE CONTOUR (FEET-MSL)
- COVER TERRACE 2/19
- STORMWATER DIVERSION BERM 3/19
- EXISTING TREELINE
- DRAINAGE CHANNEL
- EXISTING ROAD
- ACCESS ROAD
- EXISTING BUILDING
- DOWNCHUTE A/20
- EROSION MAT LINER (SEE NOTE 9)
- EXISTING CLAY CAP FINAL COVER (SEE NOTE 10)



DETAIL
GRADING REFERENCE KEY
NOT TO SCALE

NOTES:

1. SEE DRAWING 2 FOR GENERAL NOTES.
2. INSTALL FLARED END SECTION AT CULVERT INLET AND OUTLET AS IDENTIFIED.
3. INSTALL STRAIGHT HEADWALL AND ENDWALL AT CULVERT INLET AND OUTLET AS IDENTIFIED.
4. TOTAL PROJECT DISTURBED AREA IS APPROXIMATELY 51.5 ACRES (LIMIT OF PROPOSED COVER SYSTEM OVER WASTE IS APPROXIMATE AND SUBJECT TO FIELD VERIFICATION).
5. THE DNREC SEDIMENT AND STORMWATER MANAGEMENT PROGRAM, MUST BE NOTIFIED IN WRITING FIVE (5) DAYS PRIOR TO COMMENCING WITH CONSTRUCTION. FAILURE TO DO SO CONSTITUTES A VIOLATION OF THE APPROVED SEDIMENT AND STORMWATER MANAGEMENT PLAN.
6. REVIEW AND/OR APPROVAL OF THE SEDIMENT AND STORMWATER MANAGEMENT PLAN SHALL NOT RELIEVE THE CONTRACTOR FROM HIS OR HER RESPONSIBILITIES FOR COMPLIANCE WITH THE REQUIREMENTS OF THE SEDIMENT AND STORMWATER REGULATIONS, NOR SHALL IT RELIEVE THE CONTRACTOR FROM ERRORS OR OMISSIONS IN THE APPROVED PLAN.
7. IF THE APPROVED PLAN NEEDS TO BE MODIFIED, ADDITIONAL SEDIMENT AND STORMWATER CONTROL MEASURES MAY BE REQUIRED AS DEEMED NECESSARY BY DNREC.
8. FOLLOWING SOIL DISTURBANCE OR REDISTURBANCE, PERMANENT OR TEMPORARY STABILIZATION SHALL BE COMPLETED IN ACCORDANCE WITH THE EROSION AND SEDIMENT CONTROL PLAN AS TO THE SURFACE OF ALL PERIMETER SEDIMENT CONTROLS, SOIL STOCKPILES, AND ALL OTHER DISTURBED OR GRADED AREAS ON THE PROJECT SITE.
9. EROSION MAT (10 FEET WIDE MINIMUM) SHALL BE INSTALLED TO MINIMIZE EROSION RILLS.
10. THE EXTENT OF THE EXISTING CLAY COVER IS PROVIDED IN A DRAWING ENTITLED "CAPPING INVENTORY" BY VANDEMARK AND LYNCH, DATED 31 AUGUST 1999.

200 100 0 200 400
SCALE: 1" = 200'

OWNER'S CERTIFICATION:
I, THE UNDERSIGNED, CERTIFY THAT ALL LAND CLEARING, CONSTRUCTION AND DEVELOPMENT SHALL BE DONE PURSUANT TO THE APPROVED PLAN

NAME:

TITLE:

NAME DATE

Final Grading Plan Under Current Permit

PERMIT DOCUMENT

GEOSYNTEC CONSULTANTS
10015 OLD COLUMBIA ROAD, SUITE A-200
COLUMBIA, MARYLAND 21046 USA
(410) 381-4333

SIGNATURE

DATE

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	FEB 05	ADDED NOTED 10 AND EXISTING CLAY CAP FINAL COVER	JOC	MFH

DATE: SEPTEMBER 2004

DES BY	RDE	JUL 04
DRN BY	JOC	JUL 04
CHK BY	CHP	AUG 04
REV BY	RDE	SEP 04
APP BY	MFH	SEP 04

PROJECT NO. ME0319 SCALE: 1" = 200'

PROJECT: PERMIT MODIFICATION APPLICATION CELL 6 EXPANSION DRPI INDUSTRIAL WASTE LANDFILL

SHEET TITLE: FINAL COVER SYSTEM AND STORMWATER MANAGEMENT SYSTEM PLAN

WASTE MANAGEMENT

FILE NO: 0319-517

DRAWING NO: 17 OF 31

Settlement Analysis Section A-A (Current Permitted Elevation - 130 ft-msl)

Delaware Recyclable Products, Inc. Landfill Vertical Expansion

New Castle, Delaware

Soil Properties	Upper Potomac	Lower Potomac	Columbia	Waste	Water	Grading Layer
Modified Compression Index	0.09	0.15	-	0.12	-	-
Modified Recompression Index	0.02	0.02		-		
Modified Secondary Compression Index	-	-		0.07		
Unit Weight, γ (pcf)	120	120	125	70	62.4	120

t_1 (years)	30
t_2 (years)	60
Distance Between Points (ft)	100

Point	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Approved waste elevation (ft.)	96.0	100.0	102.0	104.0	106.0	108.0	110.0	112.0	112.0	110.0	81.0
Base Liner Elevation (ft)	84.9	80.8	79.8	79.3	78.8	78.3	77.3	75.3	73.3	71.3	69.2
Top of Old Waste Elevation (ft)	75	75	75	75	75	75	75	75	75	75	75
Elevation of Top of Columbia (ft)	20	20	20	20	20	20	20	20	20	20	20
Elevation of Top of Upper Potomac (ft)	15	15	15	15	15	15	15	15	15	15	15
Elevation of Top of Lower Potomac (ft)	0	0	0	0	0	0	0	0	0	0	0
Elevation of bottom of Lower Potomac (ft)	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
Water Table elevation (ft-msl)	0.2	0.1	6.1	12.0	18.9	26.2	29.5	30.5	31.2	31.7	32.3
Initial Stress in old waste	3111	2625	2504	2444	2384	2324	2202	1964	1725	1481	1229
Initial Stress in Columbia (psf)	5397	5407	5031	4663	4006	3621	3413	3349	3310	3274	3240
Initial Stress in Upper Potomac (psf)	5375	5375	5375	5095	4664	4209	4002	3937	3899	3862	3829
Initial Stress in Lower Potomac (psf)	7126	7136	6759	6391	5960	5505	5298	5233	5195	5158	5125
$\Delta\sigma$ (psf)	778	1342	1552	1727	1902	2077	2289	2568	2707	2709	826
Preconsolidation Pressure Potomac (psf)	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Primary Settlement (Existing Waste) δ_P (ft)	0.64	1.18	1.38	1.53	1.68	1.83	2.04	2.40	2.70	2.98	1.47
Primary Settlement (Upper Potomac) δ_P (ft)	0.02	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.07	0.03
Primary Settlement (Lower Potomac) δ_P (ft)	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.11	0.04
Secondary Settlement (Existing Waste) δ_S (ft)	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Total Settlement δ_P (ft)	1.84	2.42	2.63	2.79	2.96	3.13	3.35	3.73	4.04	4.32	2.70
Pre-settlement Grade	-	4.1%	1.0%	0.5%	0.5%	0.5%	1.0%	2.0%	2.0%	2.0%	2.1%
Change in Grade	-	0.57%	0.21%	0.16%	0.17%	0.17%	0.23%	0.37%	0.32%	0.28%	-1.62%
Post-settlement Grade	-	4.6%	1.2%	0.7%	0.7%	0.7%	1.2%	2.4%	2.3%	2.3%	0.5%
Post-Settlement Elevation	83.0	78.4	77.2	76.5	75.9	75.2	74.0	71.6	69.3	67.0	66.5
Post-Settlement Liner-GW Seperation	82.8	78.4	71.1	64.5	57.0	49.0	44.4	41.1	38.1	35.2	34.2
Strain in Liner, ε (%)	-	0.009	0.001	0.001	0.001	0.001	0.001	0.004	0.003	0.002	0.070
Total Settlement from vertical expansion	3.266112782	4.13668169	4.56081	4.569862	4.968291178	5.441302705	5.862928497	5.69	5.161276141	4.325565	2.72396262
Total settlement with existing consition	1.84	2.42	2.63	2.79	2.96	3.13	3.35	3.73	4.04	4.32	2.70
Additional Settlement from vertical expansion	1.42	1.72	1.93	1.78	2.01	2.32	2.51	1.97	1.12	0.01	0.03

Settlement Analysis Section B-B (Current Permitted Elevation - 130 ft-msl)

Delaware Recyclable Products, Inc. Landfill Vertical Expansion

New Castle, Delaware

Soil Properties	Upper Potomac	Lower Potomac	Columbia	Waste	Water	Grading Layer			
Modified Compression Index	0.09	0.15	-	0.12	-	-		t_1 (years)	30
Modified Recompression Index	0.02	0.02		-				t_2 (years)	60
Modified Secondary Compression Index	-	-		0.07			Distance Between Points (ft)		100
Unit Weight, γ (pcf)	120	120	125	70	62.4	120			
Point	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Approved waste elevation (ft.)	124.0	124.0	124.0	124.0	124.0	124.0	124.0	124.0	124.0
Base Liner Elevation (ft)	87.1	84.7	83.2	81.7	80.2	78.7	77.2	75.8	74.4
Top of Old Waste Elevation (ft)	74	74	74	74	74	74	74	74	74
Elevation of Top of Columbia (ft)	20	20	20	20	20	20	20	20	20
Elevation of Top of Upper Potomac (ft)	15	15	15	15	15	15	15	15	15
Elevation of Top of Lower Potomac (ft)	0	0	0	0	0	0	0	0	0
Elevation of bottom of Lower Potomac (ft)	-30	-30	-30	-30	-30	-30	-30	-30	-30
Water Table elevation (ft-msl)	0.6	0.3	0.1	2.7	6.6	10.3	14.2	21.3	25.6
Initial Stress in old waste	3463	3178	2998	2818	2638	2458	2278	2101	1936
Initial Stress in Columbia (psf)	5304	5320	5335	5170	4932	4695	4457	3856	3588
Initial Stress in Upper Potomac (psf)	5305	5305	5305	5305	5305	5127	4890	4444	4177
Initial Stress in Lower Potomac (psf)	7033	7048	7064	6899	6660	6423	6186	5740	5473
$\Delta\sigma$ (psf)	2583	2748	2854	2959	3064	3169	3273	3377	3473
Preconsolidation Pressure Potomac (psf)	20000	20000	20000	20000	20000	20000	20000	20000	20000
Primary Settlement (Existing Waste) δ_P (ft)	1.57	1.75	1.88	2.02	2.17	2.33	2.51	2.70	2.89
Primary Settlement (Upper Potomac) δ_P (ft)	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.08
Primary Settlement (Lower Potomac) δ_P (ft)	0.08	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.13
Secondary Settlement (Existing Waste) δ_S (ft)	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Total Settlement δ_P (ft)	2.84	3.03	3.16	3.31	3.46	3.64	3.82	4.03	4.24
Pre-settlement Grade	-	2.4%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.4%
Change in Grade	-	0.19%	0.13%	0.14%	0.16%	0.17%	0.19%	0.21%	0.21%
Post-settlement Grade	-	2.6%	1.6%	1.6%	1.7%	1.7%	1.7%	1.7%	1.6%
Post-Settlement Elevation	84.3	81.7	80.1	78.4	76.8	75.1	73.4	71.7	70.1
Post-Settlement Liner-GW Seperation	83.7	81.4	80.0	75.7	70.2	64.8	59.3	50.4	44.6
Strain in Liner, ε (%)	-	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Total Settlement from vertical expansion	4.6	4.777	4.955	5.081	5.292	5.471	5.684	5.897	6.128
Total settlement with existing consition	2.8	3.0	3.2	3.3	3.5	3.6	3.8	4.0	4.2
Additional Settlement from vertical expansion	1.7	1.7	1.8	1.8	1.8	1.8	1.9	1.9	1.9

Settlement Analysis Section G-G (Current Permitted Elevation - 130 ft-msl)

Delaware Recyclable Products, Inc. Landfill Vertical Expansion

New Castle, Delaware

Soil Properties	Upper Potomac	Lower Potomac	Columbia	Waste	Water	Grading Layer
Modified Compression Index	0.09	0.15	-	0.12	-	-
Modified Recompression Index	0.02	0.02		-		
Modified Secondary Compression Index	-	-		0.07		
Unit Weight, γ (pcf)	120	120	125	70	62.4	120

t_1 (years)	30
t_2 (years)	60
Distance Between Points (ft)	98

Point	**0**	**1**	**2**	**3**
Approved waste elevation (ft.)	128.0	130.0	128.0	125.0
Base Liner Elevation (ft)	90.0	87.6	85.1	82.7
Top of Old Waste Elevation (ft)	74	74	74	74
Elevation of Top of Columbia (ft)	20	20	20	20
Elevation of Top of Upper Potomac (ft)	15	15	15	15
Elevation of Top of Lower Potomac (ft)	0	0	0	0
Elevation of bottom of Lower Potomac (ft)	-30	-30	-30	-30
Water Table elevation (ft-msl)	1.0	0.6	0.3	0.2
Initial Stress in old waste	3810	3516	3222	2928
Initial Stress in Columbia (psf)	5281	5301	5321	5330
Initial Stress in Upper Potomac (psf)	5305	5305	5305	5305
Initial Stress in Lower Potomac (psf)	7010	7030	7050	7058
$\Delta\sigma$ (psf)	2660	2971	3003	2964
Preconsolidation Pressure Potomac (psf)	20000	20000	20000	20000
Primary Settlement (Existing Waste) δ_P (ft)	1.49	1.72	1.85	1.97
Primary Settlement (Upper Potomac) δ_P (ft)	0.05	0.06	0.06	0.06
Primary Settlement (Lower Potomac) δ_P (ft)	0.08	0.09	0.09	0.09
Secondary Settlement (Existing Waste) δ_S (ft)	1.14	1.14	1.14	1.14
Total Settlement δ_P (ft)	2.76	3.01	3.14	3.26
Pre-settlement Grade	-	2.5%	2.5%	2.5%
Change in Grade	-	0.25%	0.13%	0.12%
Post-settlement Grade	-	2.8%	2.6%	2.6%
Post-Settlement Elevation	87.2	84.5	82.0	79.4
Post-Settlement Liner-GW Seperation	86.3	83.9	81.7	79.2
Strain in Liner, ε (%)	-	0.002	0.000	0.000
Total Settlement from vertical expansion	4.4	4.549	4.764	4.999
Total settlement with existing consition	2.8	3.0	3.1	3.3
Additional Settlement from vertical expansion	1.6	1.5	1.6	1.7

Settlement Analysis Section H-H (Current Permitted Elevation - 130 ft-msl)

Delaware Recyclable Products, Inc. Landfill Vertical Expansion

New Castle, Delaware

Soil Properties	Upper Potomac	Lower Potomac	Columbia	Waste	Water	Grading Layer
Modified Compression Index	0.09	0.15		0.12		
Modified Recompression Index	0.02	0.02	-	-	-	-
Modified Secondary Compression Index	-	-		0.07		
Unit Weight, γ (pcf)	120	120	125	70	62.4	120

t_1 (years)	30
t_2 (years)	60
Distance Between Points (ft)	81

Point	**0**	**1**	**2**	**3**	**4**
Approved waste elevation (ft.)	97.9	95.0	100.0	105.0	109.0
Base Liner Elevation (ft)	86.0	83.1	81.5	79.9	78.3
Top of Old Waste Elevation (ft)	75	75	75	75	75
Elevation of Top of Columbia (ft)	20	20	20	20	20
Elevation of Top of Upper Potomac (ft)	15	15	15	15	15
Elevation of Top of Lower Potomac (ft)	0	0	0	0	0
Elevation of bottom of Lower Potomac (ft)	-30	-30	-30	-30	-30
Water Table elevation (ft-msl)	30.0	28.8	27.7	26.9	26.3
Initial Stress in old waste	3244	2900	2705	2512	2322
Initial Stress in Columbia (psf)	3380	3458	3528	3575	3615
Initial Stress in Upper Potomac (psf)	3968	4046	4117	4164	4203
Initial Stress in Lower Potomac (psf)	5264	5342	5413	5460	5499
$\Delta\sigma$ (psf)	833	831	1295	1758	2148
Preconsolidation Pressure Potomac (psf)	20000	20000	20000	20000	20001
Primary Settlement (Existing Waste) δ_P (ft)	0.65	0.72	1.12	1.52	1.88
Primary Settlement (Upper Potomac) δ_P (ft)	0.02	0.02	0.04	0.05	0.05
Primary Settlement (Lower Potomac) δ_P (ft)	0.04	0.04	0.06	0.07	0.09
Secondary Settlement (Existing Waste) δ_S (ft)	1.16	1.16	1.16	1.16	1.16
Total Settlement δ_P (ft)	1.88	1.94	2.37	2.80	3.18
Pre-settlement Grade	-	3.6%	2.0%	2.0%	2.0%
Change in Grade	-	0.08%	0.53%	0.53%	0.47%
Post-settlement Grade	-	3.6%	2.5%	2.5%	2.4%
Post-Settlement Elevation	84.1	81.2	79.1	77.1	75.1
Post-Settlement Liner-GW Seperation	54.1	52.4	51.5	50.2	48.9
Strain in Liner, ε (%)	-	0.000	0.007	0.007	0.006
Total Settlement from vertical expansion	1.9	3.298	3.785	4.661	5.453
Total settlement with existing consition	1.9	1.9	2.4	2.8	3.2
Additional Settlement from vertical expansion	0.0	1.4	1.4	1.9	2.3

Settlement Analysis Section K-K (Current Permitted Elevation - 130 ft-msl)
Delaware Recyclable Products, Inc. Landfill Vertical Expansion
New Castle, Delaware

Soil Properties	Upper Potomac	Lower Potomac	Columbia	Waste	Water	Grading Layer
Modified Compression Index	0.09	0.15	-	0.12	-	-
Modified Recompression Index	0.02	0.02		-		
Modified Secondary Compression Index	-	-		0.07		
Unit Weight, γ (pcf)	120	120	125	70	62.4	120

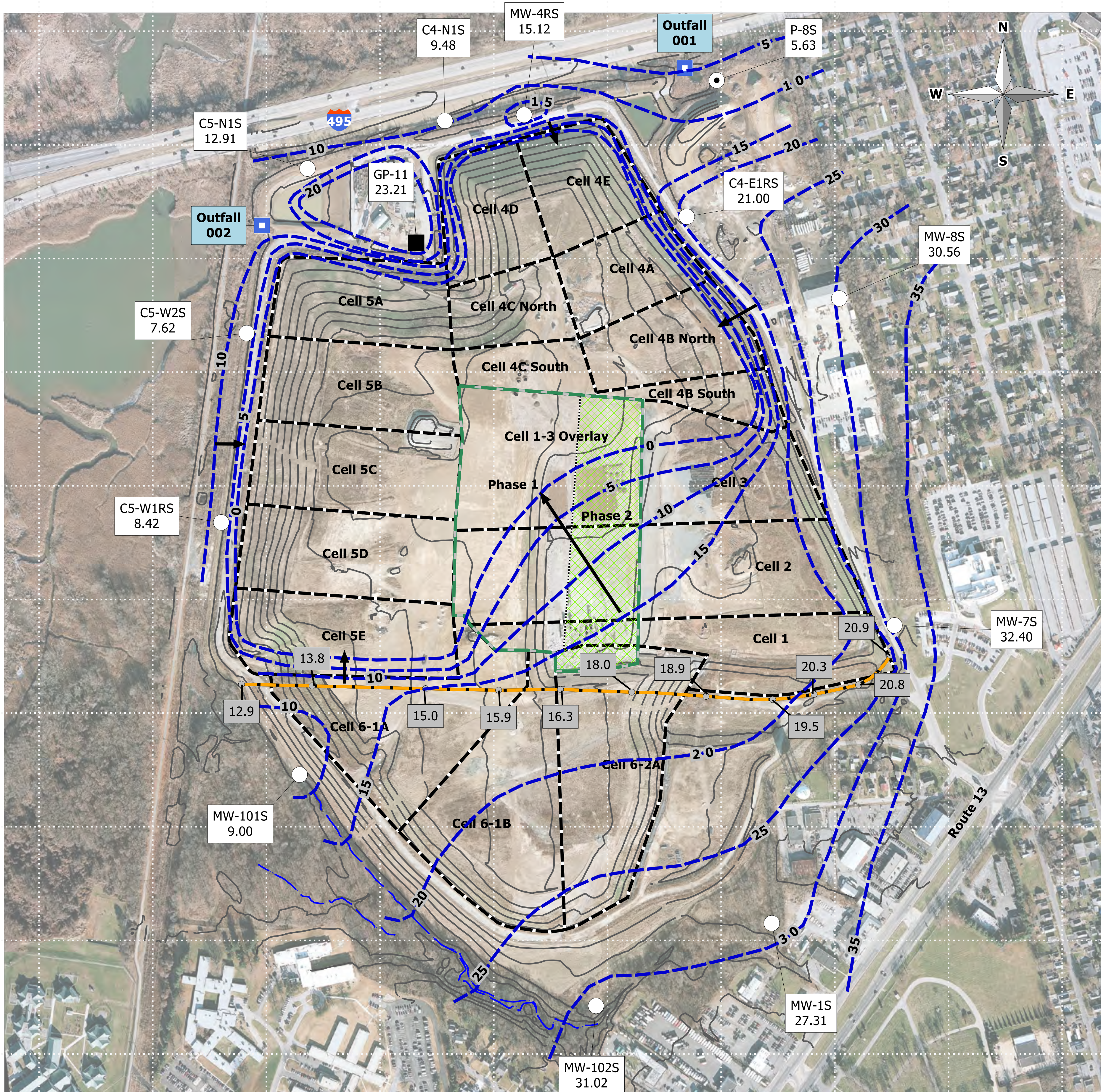
t_1 (years)	30
t_2 (years)	60
Distance Between Points (ft)	84

Point	0	1	2	3	4	5
Approved waste elevation (ft.)	115.0	113.0	112.0	110.0	102.0	95.9
Base Liner Elevation (ft)	82.0	79.9	77.7	75.6	73.1	70.6
Top of Old Waste Elevation (ft)	75	75	75	75	75	76
Elevation of Top of Columbia (ft)	20	20	20	20	20	21
Elevation of Top of Upper Potomac (ft)	15	15	15	15	15	16
Elevation of Top of Lower Potomac (ft)	0	0	0	0	0	1
Elevation of bottom of Lower Potomac (ft)	-30	-30	-30	-30	-30	-30
Water Table elevation (ft-msl)	25.7	28.0	30.1	30.7	31.3	32.0
Initial Stress in old waste	2766	2518	2253	1995	1693	1279
Initial Stress in Columbia (psf)	3648	3507	3378	3339	3298	3321
Initial Stress in Upper Potomac (psf)	4236	4096	3967	3927	3887	3909
Initial Stress in Lower Potomac (psf)	5532	5392	5263	5223	5183	5234
$\Delta\sigma$ (psf)	2309	2314	2399	2409	2025	1767
Preconsolidation Pressure Potomac (psf)	20000	20000	20000	20000	20001	20002
Primary Settlement (Existing Waste) δ_P (ft)	1.74	1.87	2.08	2.27	2.25	2.49
Primary Settlement (Upper Potomac) δ_P (ft)	0.06	0.06	0.06	0.06	0.05	0.05
Primary Settlement (Lower Potomac) δ_P (ft)	0.09	0.09	0.10	0.10	0.09	0.08
Secondary Settlement (Existing Waste) δ_S (ft)	1.16	1.16	1.16	1.16	1.16	1.16
Total Settlement δ_P (ft)	3.05	3.18	3.40	3.59	3.55	3.77
Pre-settlement Grade	-	2.5%	2.6%	2.6%	3.0%	2.9%
Change in Grade	-	0.16%	0.26%	0.23%	-0.04%	0.26%
Post-settlement Grade	-	2.6%	2.9%	2.8%	3.0%	3.2%
Post-Settlement Elevation	79.0	76.8	74.3	72.0	69.5	66.8
Post-Settlement Liner-GW Seperation	53.2	48.8	44.3	41.3	38.2	34.9
Strain in Liner, ε (%)	-	0.001	0.002	0.001	0.000	0.002

Total Settlement from vertical expansion	5.28	5.50	5.23	4.86	4.35	3.77
Total settlement with existing consition	3.05	3.18	3.40	3.59	3.55	3.77
Additional Settlement from vertical expansion	2.24	2.32	1.83	1.26	0.80	0.00

ATTACHMENT 4

Potentiometric Surface Maps



NOTES

1. Base Aerial from Quantum Spatial flown 12/27/2017
2. Horizontal Grid is Delaware State Plane NAD 27
3. Vertical Datum is NGVD 1929
4. Water elevation data collected on October 2, 2018

LEGEND

- Shallow Zone Monitoring Well
- Piezometer
- Gas Monitoring Probe
- Groundwater Contour (C.I. = 5')
- Stormwater Monitoring Points (Outfall 001 and 002)
- As-Built Invert Elevation (Cell 6 GWCD)
- Cell 6 Groundwater Control Drain (GWCD)
- Disposal Cell Limit
- Cell 1-3 Overlay Limit
- Active Disposal Areas
- Limit of Landfill
- Property Boundary
- Groundwater Flow Direction
- State Plane Grid Line
- Stream
- Topographic Contour (C.I. = 10')

Hydraulic Gradient Calculation

(MW-7S to C4-N1S)
L= 3,000 ft
H1= 32.40 ft
H2= 9.48 ft
I = ((H1-H2)/L)x100
I = 0.76%

Taylor GEOSERVICES
38 Bishop Hollow Road, Suite 200, Newtown Square, PA 19073 Phone: (610) 325-5570 www.taylorgeoservices.com

11/19/2018

Drawn by: MI

Checked by: AJS

DELAWARE RECYCLABLE PRODUCTS, INC.
DRPI INDUSTRIAL WASTE LANDFILL
Shallow Zone Groundwater Contour Map
October 2, 2018

Minquadale Borough New Castle County Delaware

WM WASTE MANAGEMENT

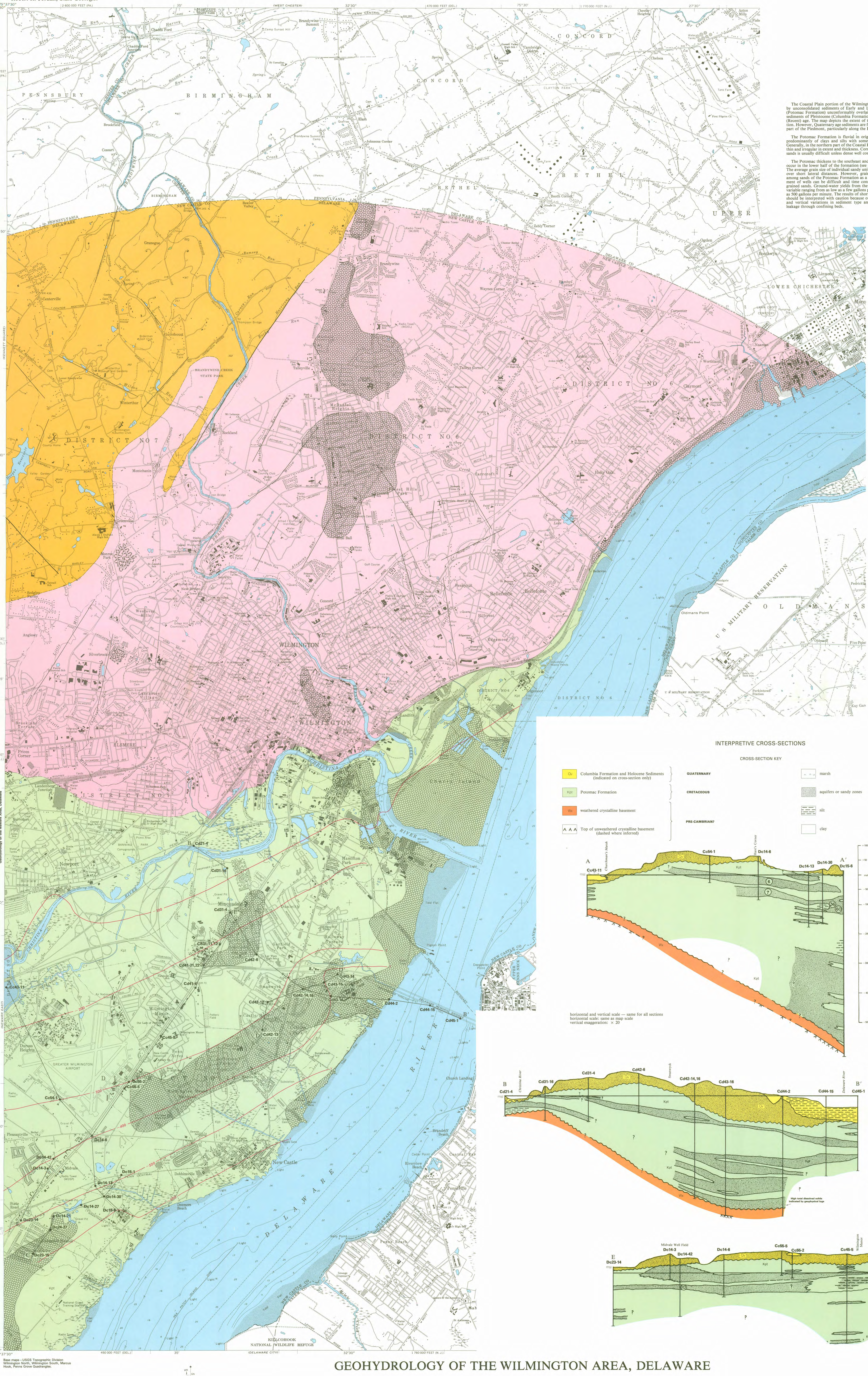
0 500 ft US

Figure 1

ATTACHMENT 5

Delaware Geological Survey Maps

DELAWARE GEOLOGICAL SURVEY
UNIVERSITY OF DELAWARE, NEWARK
Robert R. Jordan, State Geologist



MAP KEY AND DISCUSSION

Kpt

Sediments of the Coastal Plain Province:

The Coastal Plain portion of the Wilmington area is underlain by unconsolidated sediments of Early and Late Cretaceous age (Potomac Formation) unconformably overlain in most places by sediments of Pleistocene (Columbia Formation) and/or Holocene (Recent) age. The map depicts the extent of the Potomac Formation. However, Quaternary age sediments are found in the southern part of the Piedmont, particularly along the Fall Zone.

The Potomac Formation is fluvial in origin and is composed predominantly of clays and silts with some interbedded sands. Generally, in the northern part of the Coastal Plain, these sands are thin and irregular in extent and thickness. Correlation of individual sands is usually difficult unless dense well control exists.

The Potomac thickens to the southeast and sandy units tend to occur in the lower half of the formation (see cross-section A-A′). The average grain size of individual sandy units is usually constant over short lateral distances. However, grain size varies widely among sands of the Potomac Formation as a whole, and development of wells can be difficult and time consuming in the finer-grained sands. Ground-water yields from the Potomac are highly variable ranging from as low as a few gallons per minute to as high as 500 gallons per minute. The results of short-term pumping tests should be interpreted with caution because of the extreme lateral and vertical variations in sediment type and the possibility of leakage through confining beds.

The Columbia Formation is composed primarily of poorly sorted fluvial sands with some interbedded gravels, silts, and clays. Thick sections of the Columbia Formation (paleochannels) may yield up to several hundred gallons per minute to individual wells. The thickness of the Columbia Formation is shown in detail on Delaware Geological Survey Geologic Map, Series No. 4 (Woodruff and Thompson, 1975). A northeast-southwest trending paleochannel occurs in the vicinity of the developments of Castle Hills and Collins Park (see well Cd43-16 on cross-section B-B′) and is a major source of ground water. The Delaware River has truncated the Columbia and older formations along the course of the river and has deposited in turn mostly fine-grained material (see cross-section B-B′) within the present channel. The Columbia Formation is usually the source of recharge for aquifers within the Potomac Formation. In some cases sands of the Potomac Formation and the Columbia Formation may act as a single hydrologic unit.

Quaternary age sediments of the Coastal Plain greater than 40 feet thick.

Immediately adjacent to the Delaware River and in areas such as Cherry Island and Pigeon Point these sediments include the Columbia Formation of Pleistocene age, overlying sediments of Recent age deposited by the Delaware River, and possibly hydraulic fill. In other areas only the Columbia Formation is present.

Wg wc

Crystalline rocks of the Piedmont Province:

Gneisses and schists of the Wissahickon Formation Wg with some interlayered amphibolites underlie the western half of the map area. Ground-water yields are variable but average about 10 gallons per minute (gpm) for wells drilled at random. Wells drilled in highly fractured areas may, in rare cases, yield up to about 300 to 400 gpm initially. The overburden or weathered rock may be up to several tens of feet thick and often is a source of shallow ground water. This latter water is often of questionable quality and is generally not used if water is available from deeper zones.

Igneous and altered igneous rocks of the Wilmington Complex (wc) predominate in the eastern part of the map area. These rocks generally have less secondary permeability than the Wissahickon Formation and yields are usually low. The yield of the average house well is about 1 gpm and dry holes are fairly common. Some improvement in yield is usually possible by using terrain and linear features as guidelines in exploration. Aquifer tests on new wells in the Piedmont must be interpreted with caution. Initial yields may decline with time by as much as 50 percent due to water being removed from storage within the rocks. Aquifer characteristics derived from short-term tests could be highly directional.

Sediments of the Piedmont Province greater than 10 feet thick (excluding weathered rock):

In scattered areas throughout the Piedmont the crystalline rock is overlain by thin patches of predominately sandy or gravelly sediments. These sediments include the Bryn Mawr Formation (age uncertain) to the north of Wilmington and Quaternary age sediments within Wilmington and along the Fall Zone. The thickness of these deposits does not exceed about 50 feet and, because of their limited extent, they do not yield large amounts of ground water.

200

Altitude in feet of weathered basement beneath Coastal Plain sediments (sea level datum). The top of weathered basement usually defines the maximum depth of drilling for ground-water exploration in the Coastal Plain. Locally, little ground-water has been found in the basement (crystalline) rocks beneath the Coastal Plain sediments.

minor **major**

Fracture traces or lineaments postulated from study of conventional air photos, topographic maps, and satellite photos. Such traces often indicate zones of fractured rock where ground-water yields may be higher than average.

• Db11-28

Well or test hole number

A ——— A′

Location of cross-section

Geologic contact, dashed where inferred or concealed

Geologic mapping in the Piedmont is under revision by A. M. Thompson (unpublished manuscript). Geologic contacts within the Piedmont are taken from the revised work and may differ from those shown on previous publications.

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INTERPRETIVE CROSS-SECTIONS

CROSS-SECTION KEY

Qv	Columbia Formation and Holocene Sediments (indicated on cross-section only)	QUATERNARY
Kpt	Potomac Formation	CRETACEOUS
Wx	weathered crystalline basement	PRE-CAMBRIAN?
ʌ ʌ ʌ	Top of unweathered crystalline basement (dashed where inferred)	PRE-CAMBRIAN?

marsh
aquifers or sandy zones
silt
clay

(20) Transmissivity, ft²/day × 100
unconformity
? correlation uncertain

A
Cc43-11
Churchman's Marsh
Cc54-1
Hare's Corner
Dc14-6
Dc14-13
Dc14-30
A′
Dc15-6
Kpt
Qv
msl
C
Llangollen Well Field
Dc23-15
Dc24-27
Dc14-21
Dc14-27
Dc14-30
Dc15-1
C′
B
Cd21-4
Cd31-16
Cd31-4
Cd42-6
Cd42-14,16
Cd43-16
Cd44-2
Dc44-15
Dc45-1
B′
D
Collins Park-Castle Hills Well Fields
Cd42-13
Cd42-12
Cd42-14,16
Cd43-15
Cd43-14
D′
E
Dc23-14
Midvale Well Field
Dc14-3
Dc14-42
Dc14-6
Cc56-6
Cc56-2
Cc45-5
Cd41-4
Cd41-21,22
Cd31-11,12
Cd21-4
E′
horizontal and vertical scale — same for all sections
horizontal scale: same as map scale
vertical exaggeration: × 20

Base maps—USGS Topographic Division
Wilmington North, Wilmington South, Marcus Hook, Penns Grove Quadrangles.

UTM GRID AND 1967 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

GEOHYDROLOGY OF THE WILMINGTON AREA, DELAWARE

by
Kenneth D. Woodruff

1981

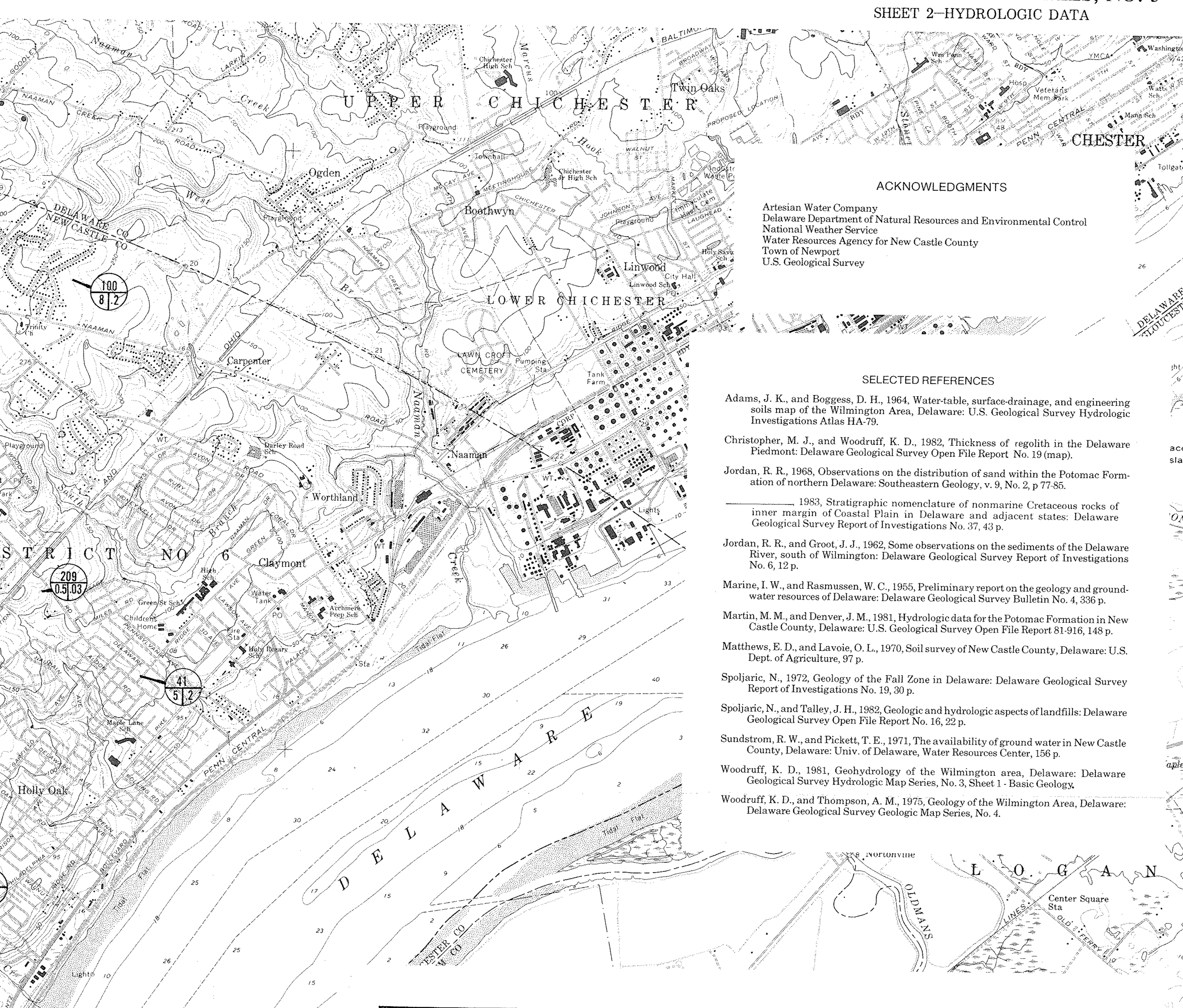
SCALE 1:24 000

CONTOUR INTERVAL 10 FEET (APPROX. 3 METERS)

QUADRANGLE LOCATION

Williams & Heintz Map Corporation, Capitol Heights, Md. 20743

DELAWARE GEOLOGICAL SURVEY
UNIVERSITY OF DELAWARE, NEWARK
Robert R. Jordan, State Geologist



ACKNOWLEDGMENTS

Artesian Water Company
Delaware Department of Natural Resources and Environmental Control
National Weather Service
Water Resources Agency for New Castle County
Town of Newport
U.S. Geological Survey

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MAP KEY

RECORDING STREAM GAGE
U.S.G.S. Gage No.
Drainage area: (sq. miles) | Years of record
Flow extremes (CFS) | max. | min.

- Observation or test well
- Production well, public supply
- N Production well, industrial
- Abandoned well
- Dc31-10: Well number
  - Kp : Potomac Formation
  - Qc : Columbia Formation

WELL IN CRYSTALLINE ROCK
Yield; Depth of well (ft.); Specific capacity (gpm/ft)

SPRING

GROUND-WATER QUALITY
Total Iron — mg/L
pH — units

SEWAGE TREATMENT PLANT
S — Maximum discharge capacity, MGD; Average discharge, MGD (1982)

WATER TREATMENT PLANT
W — Capacity, MGD; Ave. daily use, MGD

Probable recharge area of the Potomac Formation before start of major withdrawals.
U: upper sands
L: lower sands

LANDFILL
active, 1982
abandoned

C = chemical
D = dredge material
F = construction debris and /or fill
M = mixed waste

DISCUSSION

This is a companion map to Geohydrology of the Wilmington Area, Sheet 1, Basic Geology (Woodruff, 1981) that presents additional hydrologic data useful in assessing water supply possibilities.

In the map area both surface and ground-water supplies are used extensively. The City of Wilmington withdraws an average of about 27 million gallons per day (mgd) from Brandywine Creek with an additional 2 billion gallons of storage available from Hoopes Reservoir located in the Red Clay Creek Watershed. During periods of severe drought, instantaneous flows in Brandywine Creek have occasionally just equalled the daily average demand. Surface water quality varies generally with time of year. During low flows quality problems can arise from discharges or accidental spills originating in the upper reaches of the watershed. Spring flows sometimes create treatment problems due apparently to turnover of bottom sediments. Private suppliers using surface water serve the northeast portion of the map area.

Major ground-water extraction is located south of the Fall Zone from sands of both the Columbia Formation and underlying Potomac Formation (see Sheet 1). The Fall Zone marks the boundary between the crystalline rocks of the Piedmont and the unconsolidated sediments of the Coastal Plain physiographic province. Columbia sands comprise the water-table aquifer and are capable of providing high yields where sufficiently thick, that is greater than about 40 feet, and saturated. However, their most important hydrologic function in this area is to provide recharge to deeper underlying units of the Potomac Formation.

Several major well fields located in the southern half of the map area tap the upper portion of the Potomac Formation (upper hydrologic zone of Sundstrom and Pickett, 1967). Some industrial wells are constructed in the lower portion of the Potomac Formation (lower hydrologic zone) where sands are generally thick (Jordan, 1968). The two zones seem to be separated hydrologically as evidenced by differences in both historic and present water levels.

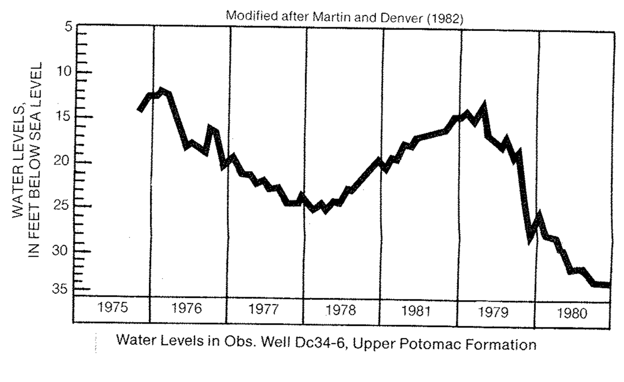
Total ground-water use in the map area from Coastal Plain formations is about 8.5 mgd derived from nine well fields used for public supply plus some additional industrial withdrawals. Domestic withdrawals are small as public or private water purveyors serve most of the area. The recharge areas of the Potomac Formation, before heavy ground-water development, are indicated on the map and were deduced from historic water levels. These areas still function as recharge sources but because of local withdrawals no excess water remains to flow to adjoining areas. Presently, about 4.0 to 4.5 mgd is provided through the recharge areas leaving a shortage of about 4.0 mgd that must come from cones of depression now reaching into nearby areas and possibly from storage in the finer-grained sediments. The exception is the Newport area where excess water in the Potomac Formation appears to be discharging to the Christina River. Calculations and extrapolation of a limited number of water level measurements indicate that withdrawal effects extend beneath the Delaware River. Analyses of cores, samples, and geologic cross-sections suggest that south of about the Delaware Memorial Bridge the Potomac sands are largely isolated from direct infiltration of brackish river water (Marine and Rasmussen, 1955; Sheet 1 - this report; Talley - unpublished data). Nevertheless the exact degree of interconnection is unknown and should be quantified in future studies.

The lowest pumping water levels in the upper Potomac sands are about 50 feet below sea level in the Collins Park-Castle Hills area. Total withdrawals from the lower part of the Potomac Formation are less than from the upper sands. However, near the Delaware Bridge levels in the lower sands are about 135 feet below sea level. In general, water levels in the Potomac fluctuate widely in response to varying withdrawals.

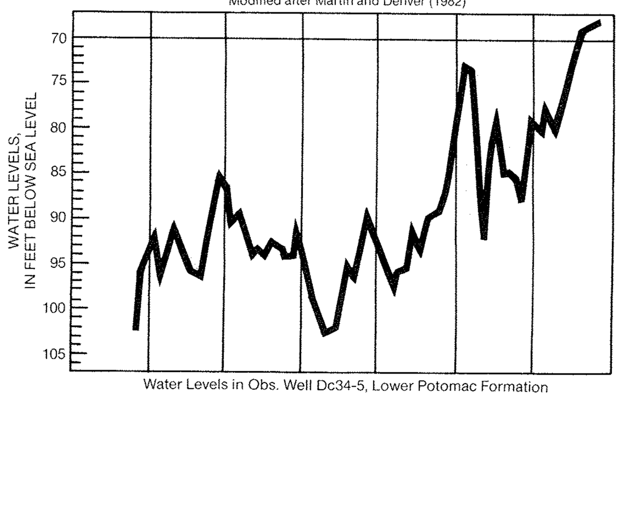
Numerous landfills are located in the Coastal Plain portion of the map area. Some of these are small with relatively inert waste and present no major threat to ground-water supplies. Others have presented major problems to ground-water supplies and have come under intensive investigation. Large active landfills are located at Pigeon Point, just north of the Delaware Memorial Bridge, and at Cherry Island. Cherry Island is predominantly a dredge spoils site but is scheduled for development as a major landfill for domestic waste.

In the Piedmont portion of the map area data on crystalline rock wells are indicated as a guide for predicting yields, particularly for installation of ground-water heat pumps. (Individual well numbers are not shown for these wells.) Many wells with higher yields and specific capacities can be correlated with linear features plotted on Sheet 1 and are usually located in topographic lows. Yields of Piedmont wells vary widely but, in general, sustained yields of over about 20 gpm are not usually obtainable unless well sites are selected with care. Ground-water temperature at about 100 feet ranges from about 53° to 55°F with a gradient of approximately 1°F/100 feet. In many cases adequate yields for heat pumps can be obtained from shallow wells drilled just through the overburden and into the top of unweathered rock. Quality for domestic purposes however may be poor due to pollution from surface sources.

Most ground water has a pH less than 7.0 (neutral) except in an area centered around the intersection of U.S. Route 13 and Interstate Route 295. Water from the Columbia Formation and upper Potomac sands in this latter area tends to have a pH between about 7 and 8. The reason for this is unclear at the moment. Total dissolved iron is usually high in ground water throughout the map area (up to several parts per million) and can be troublesome to treat in both domestic wells, and higher yielding public supply and industrial wells.

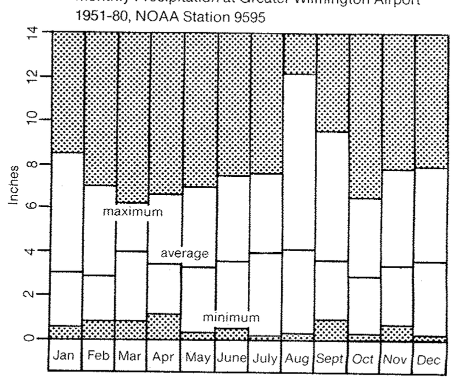


Water Levels in Obs. Well Dc34-6, Upper Potomac Formation

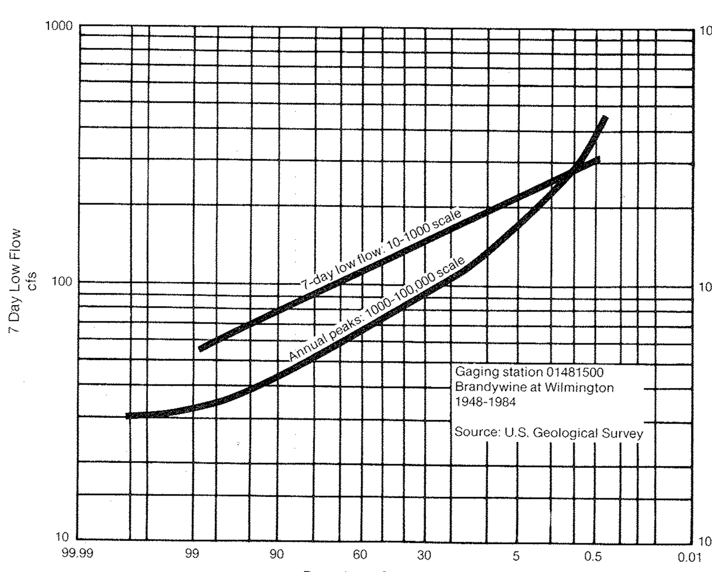


Water Levels in Obs. Well Dc34-5, Lower Potomac Formation

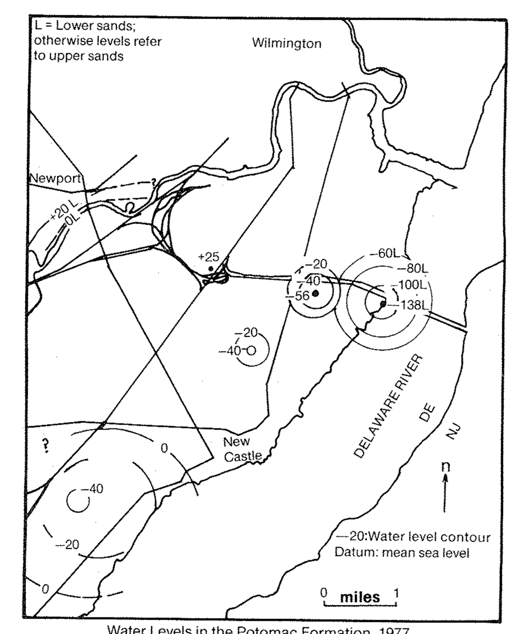
Monthly Precipitation at Greater Wilmington Airport
1951-80, NOAA Station 9595



Source: National Weather Service



Annual Peaks and 7-Day Low Flows for
Brandywine Creek at Wilmington, Period of Record



Water Levels in the Potomac Formation, 1977

Base maps—USGS
Wilmington North, Wilmington South,
Marcus Hook

UTM GRID AND 1967 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

GEOHYDROLOGY OF THE WILMINGTON AREA, DELAWARE

by
Kenneth D. Woodruff

1984

QUADRANGLE LOCATION

SCALE 1:24000

CONTOUR INTERVAL 10 FEET (APPROX. 3 METERS)

DELAWARE GEOLOGICAL SURVEY
UNIVERSITY OF DELAWARE, NEWARK
Robert R. Jordan, State Geologist

DELAWARE GEOLOGICAL SURVEY
GEOHYDROLOGY OF THE WILMINGTON AREA
HYDROLOGIC MAP SERIES, NO. 3
SHEET 3 — STRUCTURAL GEOLOGY

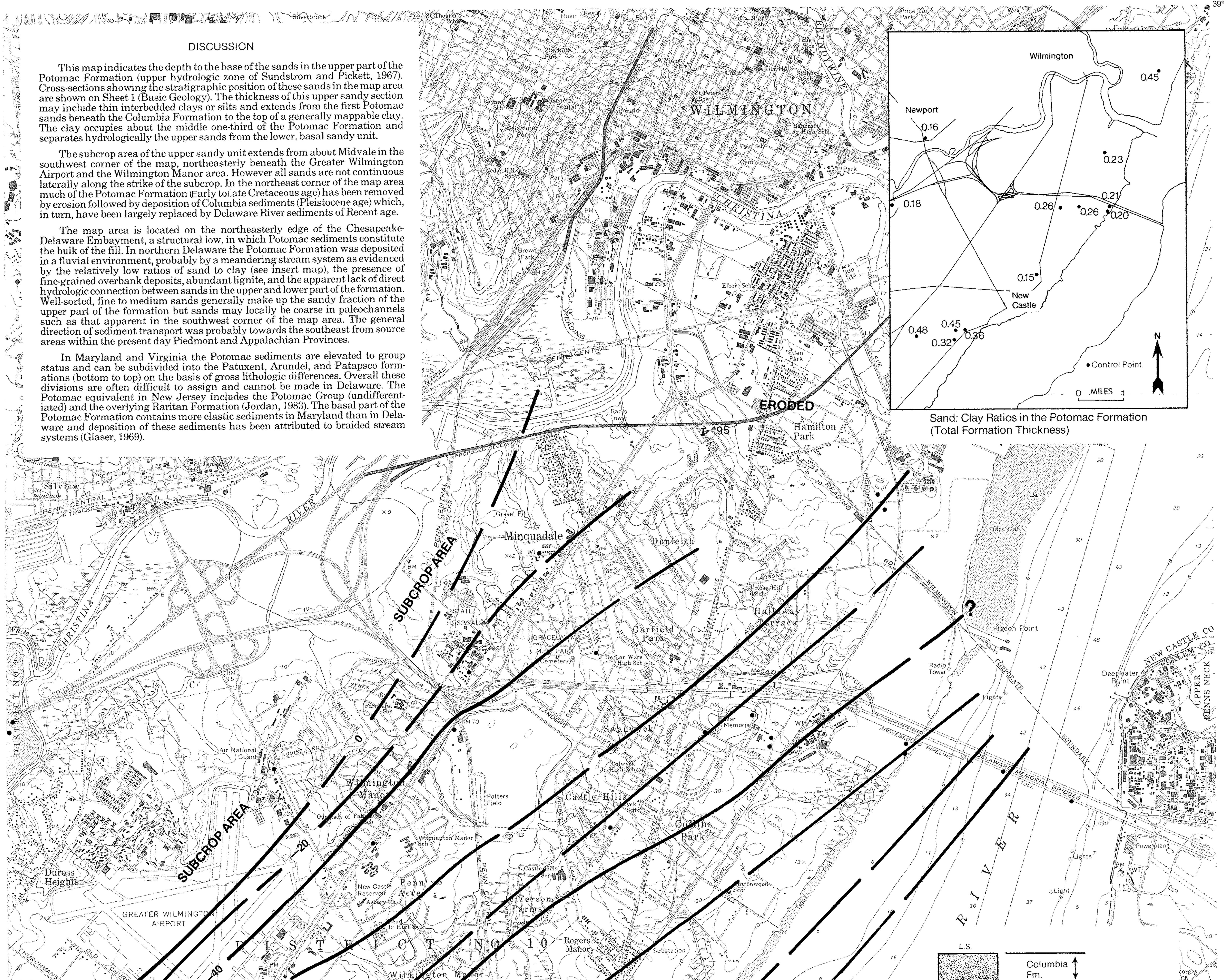
DISCUSSION

This map indicates the depth to the base of the sands in the upper part of the Potomac Formation (upper hydrologic zone of Sundstrom and Pickett, 1967). Cross-sections showing the stratigraphic position of these sands in the map area are shown on Sheet 1 (Basic Geology). The thickness of this upper sandy section may include thin interbedded clays or silts and extends from the first Potomac sands beneath the Columbia Formation to the top of a generally mappable clay. The clay occupies about the middle one-third of the Potomac Formation and separates hydrologically the upper sands from the lower, basal sandy unit.

The subcrop area of the upper sandy unit extends from about Midvale in the southwest corner of the map, northeasterly beneath the Greater Wilmington Airport and the Wilmington Manor area. However all sands are not continuous laterally along the strike of the subcrop. In the northeast corner of the map area much of the Potomac Formation (Early to Late Cretaceous age) has been removed by erosion followed by deposition of Columbia sediments (Pleistocene age) which, in turn, have been largely replaced by Delaware River sediments of Recent age.

The map area is located on the northeasterly edge of the Chesapeake-Delaware Embayment, a structural low, in which Potomac sediments constitute the bulk of the fill. In northern Delaware the Potomac Formation was deposited in a fluvial environment, probably by a meandering stream system as evidenced by the relatively low ratios of sand to clay (see insert map), the presence of fine-grained overbank deposits, abundant lignite, and the apparent lack of direct hydrologic connection between sands in the upper and lower part of the formation. Well-sorted, fine to medium sands generally make up the sandy fraction of the upper part of the formation but sands may locally be coarse in paleochannels such as that apparent in the southwest corner of the map area. The general direction of sediment transport was probably towards the southeast from source areas within the present day Piedmont and Appalachian Provinces.

In Maryland and Virginia the Potomac sediments are elevated to group status and can be subdivided into the Patuxent, Arundel, and Patapsco formations (bottom to top) on the basis of gross lithologic differences. Overall these divisions are often difficult to assign and cannot be made in Delaware. The Potomac equivalent in New Jersey includes the Potomac Group (undifferentiated) and the overlying Raritan Formation (Jordan, 1983). The basal part of the Potomac Formation contains more clastic sediments in Maryland than in Delaware and deposition of these sediments has been attributed to braided stream systems (Glaser, 1969).



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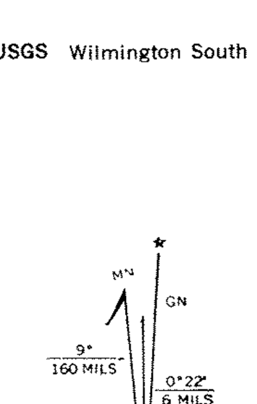
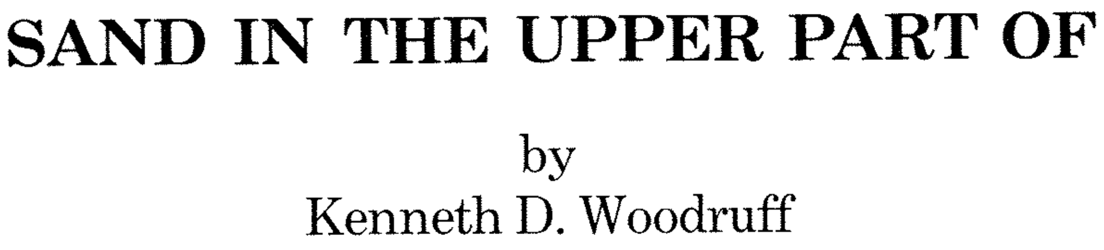
ELEVATION OF THE BASE OF SAND IN THE UPPER PART OF THE POTOMAC FORMATION

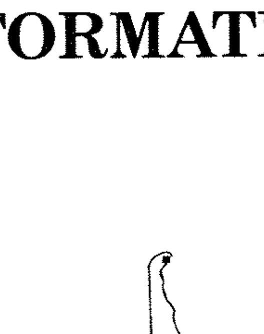
by
Kenneth D. Woodruff
1984

Base map—USGS Wilmington South Quadrangle





CONTOUR INTERVAL 10 FEET



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DELAWARE GEOLOGICAL SURVEY
GEOHYDROLOGY OF THE WILMINGTON AREA
HYDROLOGIC MAP SERIES, NO. 3
SHEET 4 — STRUCTURAL GEOLOGY

DISCUSSION

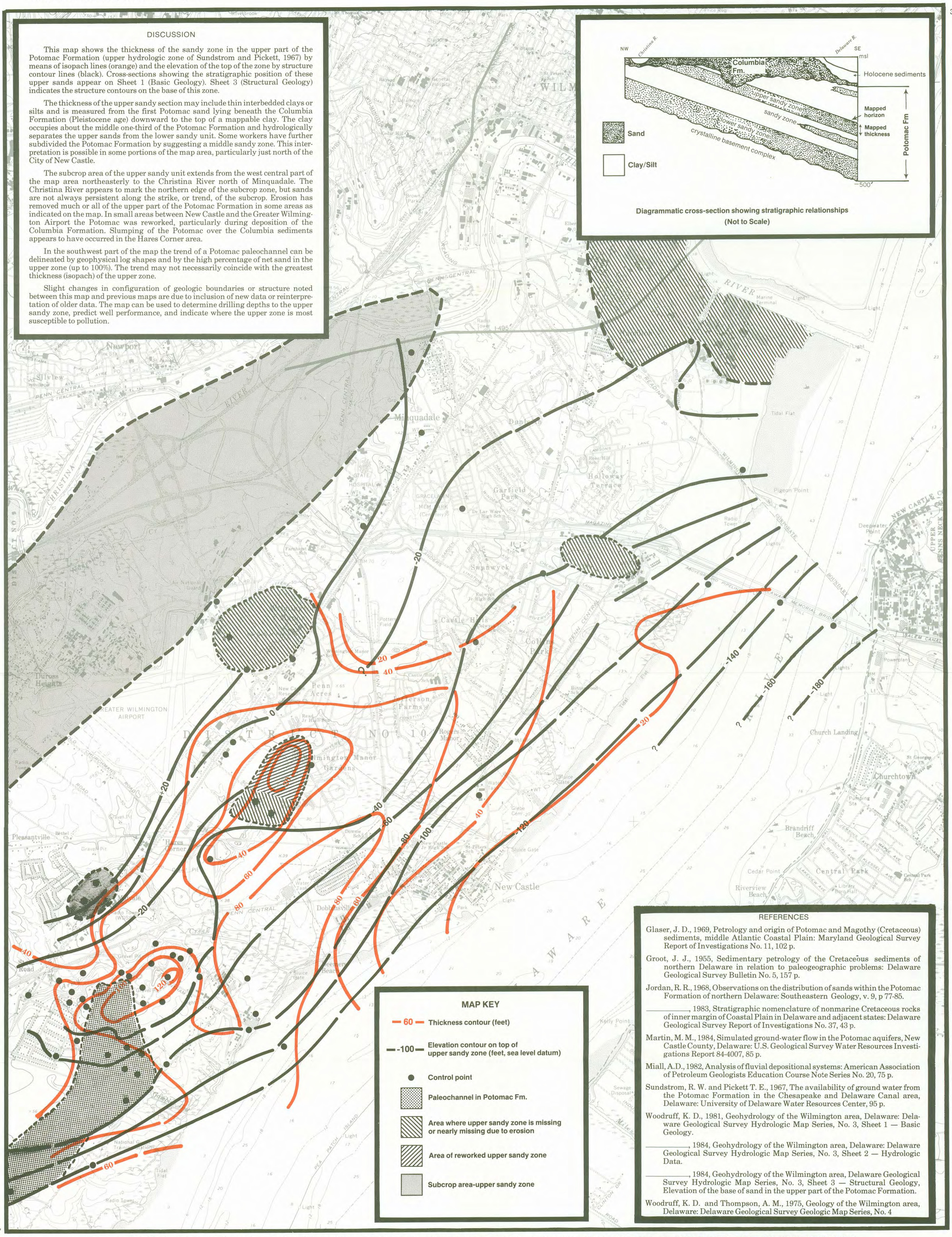
This map shows the thickness of the sandy zone in the upper part of the Potomac Formation (upper hydrologic zone of Sundstrom and Pickett, 1967) by means of isopach lines (orange) and the elevation of the top of the zone by structure contour lines (black). Cross-sections showing the stratigraphic position of these upper sands appear on Sheet 1 (Basic Geology). Sheet 3 (Structural Geology) indicates the structure contours on the base of this zone.

The thickness of the upper sandy section may include thin interbedded clays or silts and is measured from the first Potomac sand lying beneath the Columbia Formation (Pleistocene age) downward to the top of a mappable clay. The clay occupies about the middle one-third of the Potomac Formation and hydrologically separates the upper sands from the lower sandy unit. Some workers have further subdivided the Potomac Formation by suggesting a middle sandy zone. This interpretation is possible in some portions of the map area, particularly just north of the City of New Castle.

The subcrop area of the upper sandy unit extends from the west central part of the map area northeasterly to the Christina River north of Minquadale. The Christina River appears to mark the northern edge of the subcrop zone, but sands are not always persistent along the strike, or trend, of the subcrop. Erosion has removed much or all of the upper part of the Potomac Formation in some areas as indicated on the map. In small areas between New Castle and the Greater Wilmington Airport the Potomac was reworked, particularly during deposition of the Columbia Formation. Slumping of the Potomac over the Columbia sediments appears to have occurred in the Hares Corner area.

In the southwest part of the map the trend of a Potomac paleochannel can be delineated by geophysical log shapes and by the high percentage of net sand in the upper zone (up to 100%). The trend may not necessarily coincide with the greatest thickness (isopach) of the upper zone.

Slight changes in configuration of geologic boundaries or structure noted between this map and previous maps are due to inclusion of new data or reinterpretation of older data. The map can be used to determine drilling depths to the upper sandy zone, predict well performance, and indicate where the upper zone is most susceptible to pollution.



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ELEVATION OF TOP AND ISOPACH MAP OF UPPER SANDY ZONE, POTOMAC FORMATION

by
Kenneth D. Woodruff

1985

Base map—USGS Wilmington South Quadrangle

MN GN 9° 160 MILS 0°22′ 6 MILS

UTM GRID AND 1967 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

TOPOGRAPHIC CONTOUR INTERVAL 10 FEET

DEL.

QUADRANGLE LOCATION