

Locating Gardiners Clay near the Brookhaven (Long Island, NY) Landfill

Omkar Aphale and David J. Tonjes

Department of Technology and Society, Stony Brook University

1. Abstract

The presence of Gardiners Clay could prevent leachate leaking from the landfill in the Town of Brookhaven (Suffolk County, NY) from reaching the Magothy aquifer. We reviewed available hydrogeologic literature to infer the extent and characteristics of this clay unit. Our depiction of a continuous clay layer near the landfill conforms with published regional stratigraphic reports, although local details are somewhat idiosyncratic. Natural variability, human interpretation of data, and differences in mathematical inferential techniques create the potential for alternative explanations of the clay layering.

2. Background

The Town of Brookhaven Waste Management Facility is located in the hamlet of Brookhaven, Suffolk County, New York (Figure 1). The landfill, constructed in 1976, was one of the first artificially lined landfills in the country. However, by 1980 it was determined that the liner system failed some time after installation causing widespread groundwater contamination (Dvirka and Bartilucci, 2010). The impact is on the Upper Glacial aquifer (the water table aquifer); the contamination extent appears to be limited to advective patterns, southeasterly from the site. Our long term project is to develop a 3-dimensional, transient-state groundwater flow and contaminant transport simulation model for the Brookhaven landfill that accurately captures the dynamics between groundwater and key area streams. Here we specify one key element of the model framework.

The stratigraphic profile of the geology of the landfill site and vicinity consists of (from bottom to top): Precambrian bedrock, Cretaceous members of the Raritan Formation and the Matawan Group-Magothy Formation, upper Pleistocene deposits such as Monmouth Greensand, Gardiners Clay, and the Upper Glacial and Holocene deposits. These units generally dip and thicken in the southeasterly direction (Figure 2).

The presence/absence of Gardiners Clay underneath the landfill site is of particular importance as this is important to determine if landfill leachate is transported from the Upper Glacial aquifer in to the Magothy aquifer. The thickness and continuity of the clay unit, if present, will determine the effectiveness of confinement by Gardiners Clay (Doriski and Wilde-Katz, 1983; deLaguna, 1963).

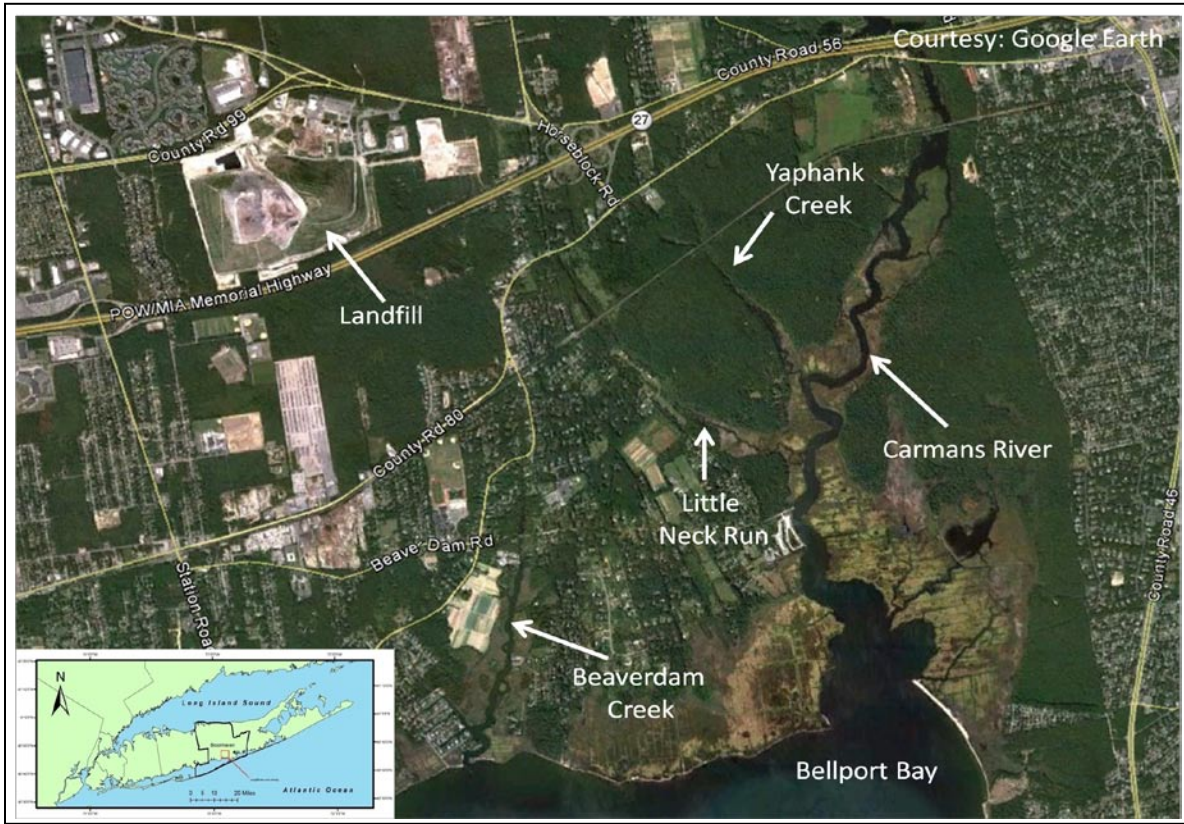


Figure 1: Aerial view of the Brookhaven landfill site and its vicinity

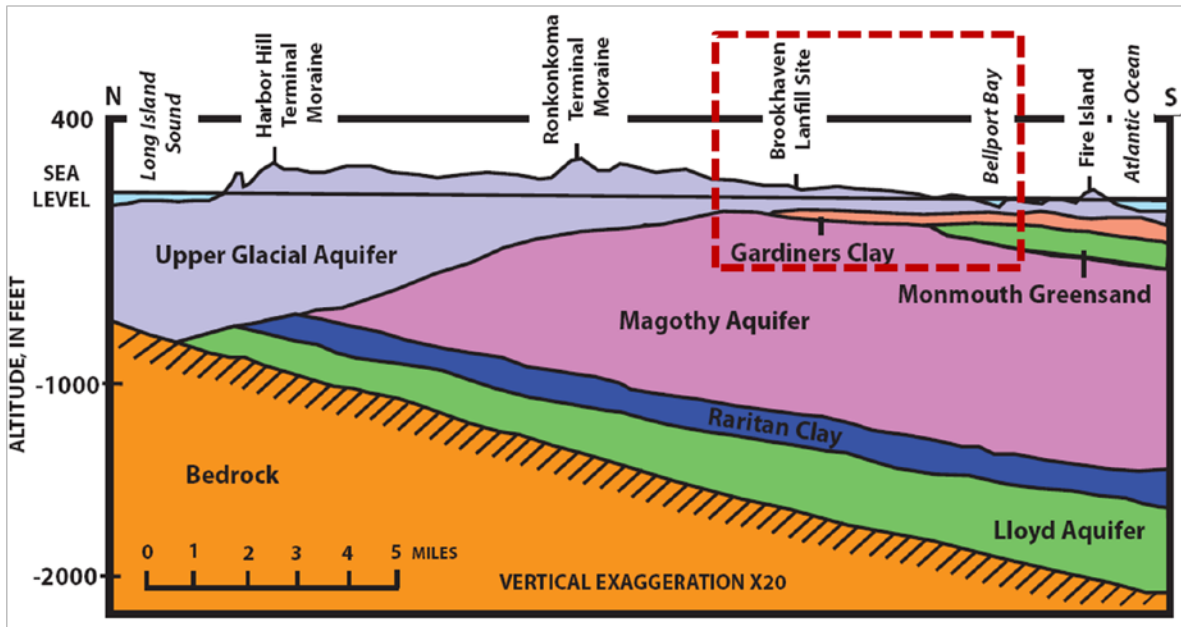


Figure 2: Generalized cross section of Long Island geology near the study area (shown with dashed box) (modified from McClymonds and Franke, 1972)

3. Methodology

The presence and extent of the Gardiners Clay were screened by reviewing available geologic information. Reviewed material included past regional or site-specific studies conducted by a number of researchers and organizations, such as the USGS or the consultants for the Town of Brookhaven, Dvirka and Bartilucci (D&B). In addition, geological drilling logs were obtained from the New York State Department of Environmental Conservation (NYSDEC) and from D&B. This boring information was arrayed in transects to generate two dimensional profiles reflecting the pattern of sediment deposition underneath the study area. Finally, a three dimensional layer showing the extent of Gardiners Clay was generated using Visual MODFLOW v. 4.2 (Waterloo Hydrogeologic Inc., Ontario, Canada).

4. Results

The technical literature differs widely regarding the depth and thickness of the Gardiners Clay underneath the landfill site and its vicinity. Gerathy and Miller (1985) suggested absence of the Gardiners Clay across Horseblock Road, slightly north of the landfill. On the other hand, Voorhis (1986) reported presence of (i) discontinuous thin bands of brown clay with sandy facies at Patchogue-Yaphank Road, north of the landfill at an elevation of -137 ft msl; (ii) a 15 foot layer of sandy clay at an elevation of -89 ft msl on Bellport Station Road, west of the landfill; and (iii) a 28 ft thick layer of the Gardiners Clay on the Head of the Neck Road well site south of the landfill at an elevation of -118 ft msl. Buxton and Modica (1992) suggested that Gardiners Clay is not present underneath the landfill. On the contrary, Dvirka and Bartilucci (1994a) suggest that the Gardiners Clay extends north of the Long Island Expressway, north of the landfill site. In other instances, deLaguna (1963) and Weiss (1954) suggested presence of Gardiners Clay at the northern boundary of the Brookhaven National Laboratory (BNL). Conversely, Smolensky et al. (1989) restricted the extent of the Gardiners Clay slightly north of Sunrise Highway, about three miles due south of the BNL site.

In order to resolve these differences, we created regional and local transects based on field data logging. The regional transects, based on data archived by NYSDEC, tended to show clay presence north of the landfill site, both east and west of the site. The clay lens tended to thicken to the south, and a transect along Fire Island showed hundreds of feet of relatively low-conductivity material (Gardiners Clay plus Monmouth Greensand). On-site well logs also found a consistent pattern of some clay, at -100 ft msl or deeper. The top and bottom facies of the clay were not found at consistent depths, although they all tended to be within a range -50 ft to -150 ft msl. This suggests the clay lies on an eroded Magothy surface, and in its own turn was eroded: a slightly different picture than the even layering usually drawn in regional mappings.

Thus, our interpretation is that there is a continuous clay lens from north of the Brookhaven landfill that thickens appreciably to the south and extends into the Atlantic Ocean (Figure 3 a-d). The surface of the clay is not even but rather has local erosional features, and its interface with the Magothy is similarly corrugated.

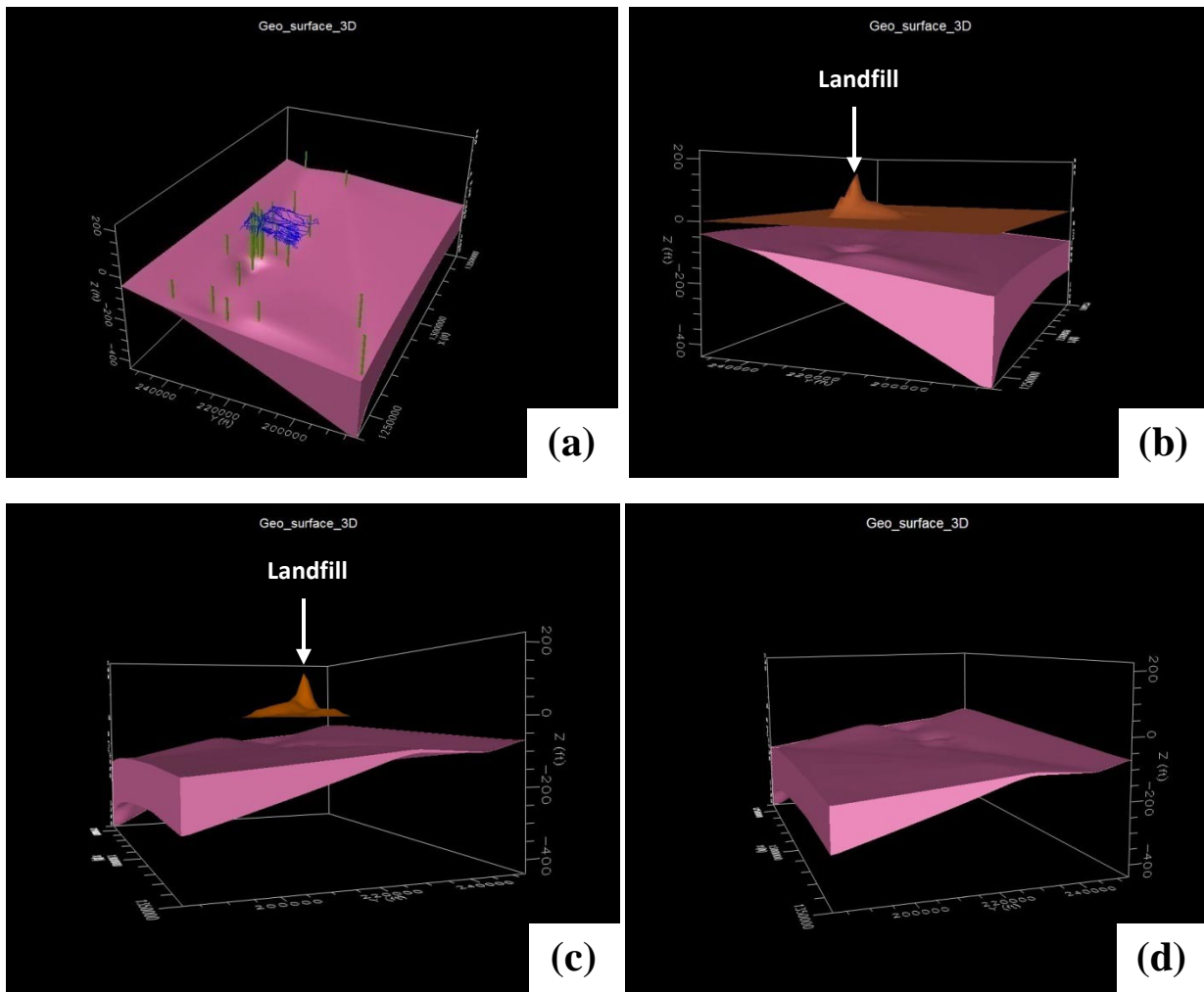


Figure 3: The 3-D layer of the Gardiners Clay (in pink) around the study area generated using Visual MODFLOW as viewed from (a) and (b) southwest, and from (c) and (d) southeast.

5. Discussion

A reasonably accurate interpretation of the geology is needed to create a conceptually sound model domain (Anderson and Woessner, 1992; Buxton and Reilly, 1985). Review of available geologic data helps to define the geologic framework for such models (Buxton and Smolensky, 1999). However, the utility of the available geologic literature is limited due to:

- a. Variation in the physical phenomena
- b. Subjectivity of human interpretation
- c. Differences in mathematical inferential techniques

5.1. Natural variability

Gardiners clay is typically represented as a wedge that occurs near the south shoreline of Long Island and thickens to the south (Buxton and Modica, 1992). But sediments on Long Island were subjected to repeated periods of glacial deposition and intra or inter-glacial restructuring (Sirkin, 1982). This restructuring may have been spatially uneven resulting into localized variations in stratigraphy of particular geologic units. For example, Figure 4 shows the variation in the physical extent of Gardiners Clay ascribed by Smolensky et al. (1989) suggesting that the clay unit is not found in the Forge River basin.

Nonetheless, using widely spaced information points, we usually construct linear interpolations that are extremely unlikely to be accurate. To be sure, there is no reason to support other interpretations, but there is great likelihood that the geologic framework does not evenly vary between the wells. The “linearity assumption” is only used because alterations are even less attractive.

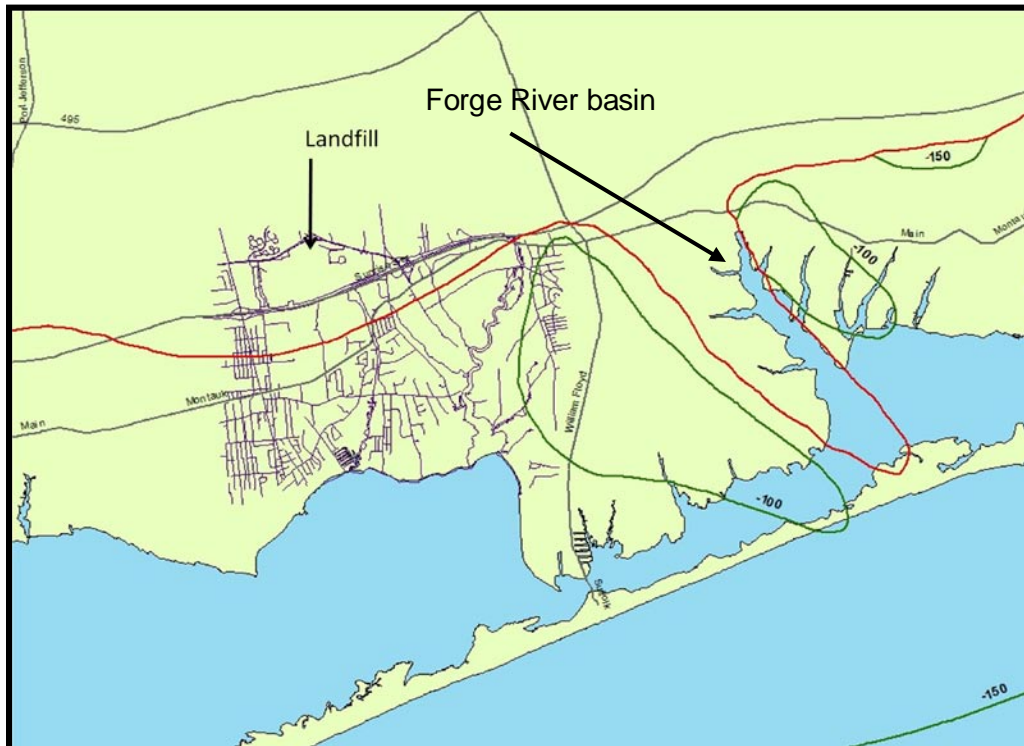


Figure 4: Elevation contours indicating the terminal extent of the Gardiners Clay (red lines). Note the absence of the Gardiners Clay from the area that approximately overlaps with the Forge River basin. (modified from Smolensky et al., 1989)

5.2. Subjectivity of human interpretation

The quality of the observational data depends on factors such as the level of sophistication of the laboratory or field procedures used for exploration, adherence to procedural standards, and expertise of the analyst(s)/observer(s). Human subjectivity affects the interpretation of collected data in the following ways:

5.2.1. Data collection methods:

Standardized observations were not made in the set of obtained drilling logs. Dvirka and Bartilucci (1994b) used a modified version of the Burmeister soil classification system to describe the samples obtained during the drilling operations. However, other boring logs such as for public supply wells (from NYSDEC) did not specify the type of methodology used for classification. In addition, even within the D&B geologists descriptions methods were not consistent.

For example, Table 1 shows the sections of the drilling logs relating to Gardiners Clay (along transect C-C', Figure 5). These, different descriptions were often interpreted as applying to same physical phenomenon, but that required interpreting the geologists' interpretations of the observed sediments. Figure 6 shows our interpreted Gardiners Clay surfaces.

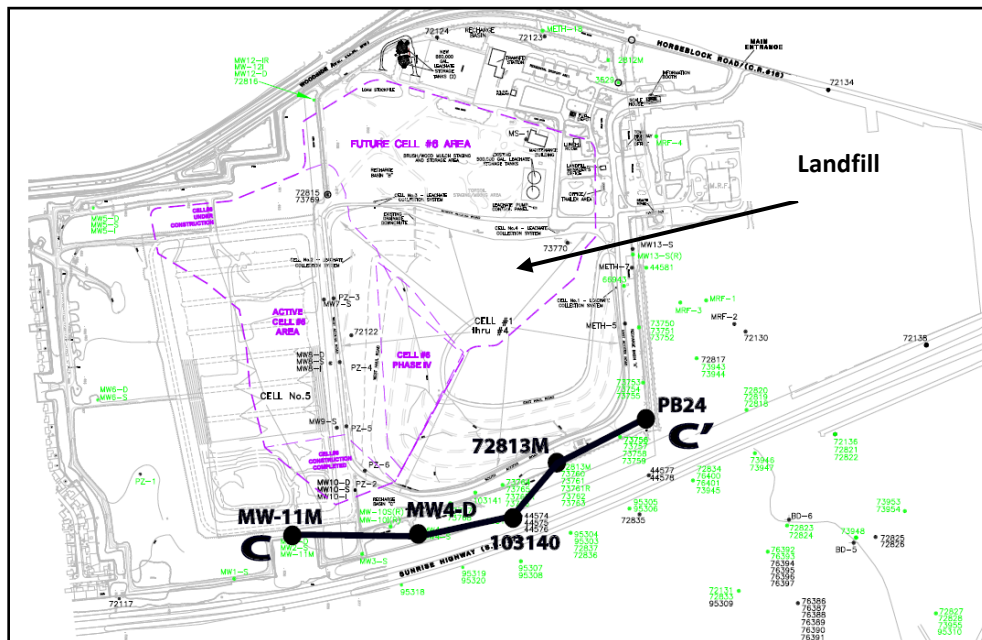


Figure 5: Location of the geologic cross sections C-C'

Boring	Description
11M ^a	160'-182' : Black to silvery black micaceous, lignitic SILT, some clay, little to some f sand
	185'-187' : No recovery-drilling indicates clay
	190'-192': Same As Above
	195': Drilling change at approximately 195' indicating sand
4D ^a	172'-174': 0-1.2' → Br f S, a(+)§; no prt, mica, dense, wet
	1.2-2.1' → Gy br C l(+), fs, tr(-) c: ang qtz, faint br prt, damp, stiff, mica
	2.1-2.2' → Or br f(-) c S, l(-) §yc, tr (-)f(+)cg; rnd, stiff, damp
72813M ^a, it appears that the Gardiners Clay is present here (180'-183' and 185'-190') in a sandy facies with some interbedded silt and clay and possibly even some gravel
PB24 ^b	Top of semi-confining unit encountered at 140 ft below grade.....End of drilling at 150.5 ft

Table 1: Excerpts from drilling logs at the wells along the transect C-C' at the depths where presence of the Gardiners Clay was inferred (^a Dvirka and Bartilucci, 1996a; ^b Dvirka and Bartilucci 1996b)

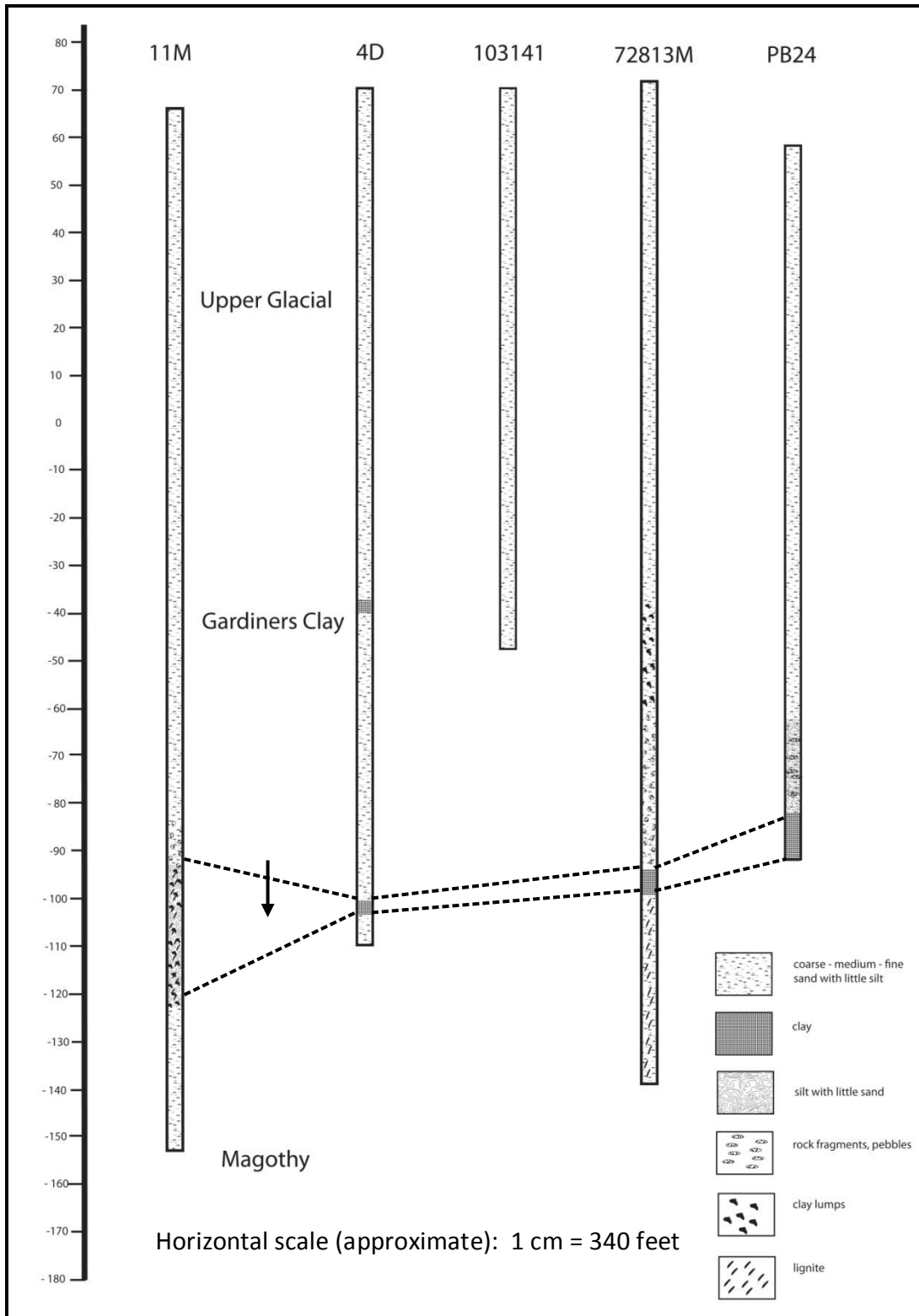


Figure 6: Geologic cross section C-C' showing approximate position and thickness of the Gardiners Clay as inferred from the boring logs (interpolated surface of the Gardiners Clay is shown with dotted line)

5.2.2. Discretization and Zoning:

Continuous phenomena, such as geologic units and their hydrogeologic properties, were simplified either by (i) segregating units with distinct properties (discretization), or by (ii) lumping hydrogeologically similar units together (zoning). Both processes have physical basis but also are a result of discrimination by observers.

For example, the Upper Glacial aquifer was discretized into three aquifer layers – top, middle, and bottom. Evidence suggest that there is an downward fining of the sediments constituting the Upper Glacial aquifer - from coarse sand and gravel to medium to fine sand (with silt and clay) to fine sand. Also, the horizontal hydraulic conductivity values decrease progressively from top to bottom (Table 2). The gradation of sediment size and hydraulic conductivity is more probably continuous to some degree or another; however, the aquifer unit was divided into three discrete layers. Each layer is thus defined as having hydrologic properties and sediment type different from the others, although the distribution of grain size and conductivity is generally considered homogenous within the aquifer, and often well logs reported variations on the same lithology for the entire aquifer.

Hydrologic unit	Average Kh (ft/d)	Maximum Kh (ft/d)	Minimum Kh (ft/d)	Average groundwater velocity (ft/d)	Anisotropy ratio
Shallow UGA (0 to 70 ft below grade)	260 ^a	677 ^a	30 ^a	1-1.8 ^a	2:1– 10:1– 24:1 ^b
Intermediate UGA (70 to 100 ft below grade)	130 ^a	208 ^a	58 ^a	1-1.4 ^a	
Deep UGA (100 ft below grade to confining layer)	70 ^a	363 ^a	17 ^a	0.3-1 ^a	
Gardiners Clay	6.5 ^a	--	--	--	5:1– 24:1 ^c
Magothy aquifer	50 ^d	268 ^e	1 ^a	0.0043 ^a	30:1 – 100:1 ^b

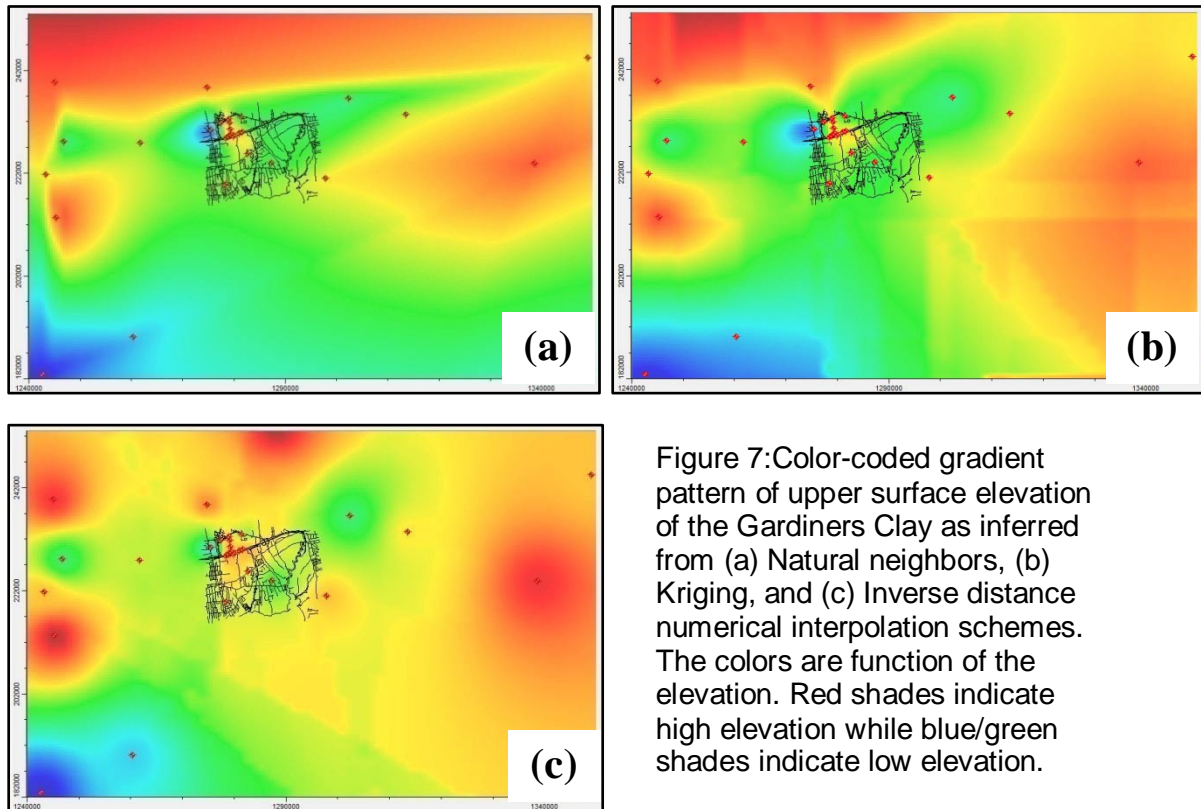
Table 2: Hydrologic characteristics of the hydrologic units at the study area (^a Dvirka and Bartilucci, 1994a; ^b Lindner and Reilly, 1983; ^c Eckhardt and Wexler, 1986; ^d Franke and Cohen, 1972; ^e Isbister, 1962; UGA = Upper Glacial aquifer)

Alternatively, two homogenous units were merged into a single zone. Gardiners Clay and Monmouth Greensand were combined to represent single aquitard because both units have similar hydrologic properties (both have much lower permeability than either the Upper Glacial aquifer above or the Magothy aquifer below) and they are physically connected, appearing to be a single unit. It was sometimes difficult to discriminate between well log descriptions of the two fine-grained members.

5.3. Differences in mathematical inferential techniques

Figure 7a-c show the color-coded gradient in the upper surface elevation of the Gardiners Clay layer as interpolated by “natural neighbors”, “kriging”, and the “inverse distance” interpolation schemes. Notice the patterns of color-coded gradients; each interpolation scheme generates a unique gradient pattern. The interpolation of natural neighbor interpolation scheme was most consistent with general pattern of the physical extent of the Gardiners Clay described in the literature (a gradual dip of the surface in southeasterly direction), and so we adopted this version.

Use of mathematical algorithms to generate inferences based on observational data is supposed to minimize the effect of human judgment. However, variation within these mathematical tools was found to influence the interpretation of geology.



6. Conclusion

In this study we used extant hydrogeologic information to depict the extent and characteristics of the Gardiners Clay underneath the Brookhaven landfill and its surroundings. We infer that this layer dips and thickens in southeasterly fashion and generates semi-confining conditions under the landfill.

Our depiction is qualified. We found that lack of geologic evidence may force an observer to overlook potential natural variations in the geology of the study area. Different reviews of the same data could conceptualize the stratigraphy differently. Although computers facilitate swift calculations and can generate seemingly attractive graphics, they do not minimize the need for human judgment.

This one example illustrates the difficulties associated with creating an accurate framework on which to base a modern, sophisticated groundwater model. Although it is a worn truism that “models simplify domain and process”, expectations with modern, multiple-thousand node models are that we will be able to populate them with good information, and so we also expect these models will easily replicate natural conditions. Alas, it is not so!

Still, available data and the tools that represent them have great utility. Not only do they help to bracket the range of potential representations but they also help to develop better understanding of the system under consideration. These data may not eliminate uncertainty from the models, but help to create a more generally agreeable model design. This step is therefore critical to portray a “reasonable” abstraction of the system, leading to a useable groundwater flow and contaminant transport simulation model.

Acknowledgments

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