

# WATER TANKS

By Steven Law and John Kasprzak

## *Long-Term Settlement of a Large Water Standpipe*

The Accokeek standpipe is the southernmost water tank within Maryland's Washington Suburban Sanitary District (WSSD). The WSSD consists of Montgomery and Prince George's Counties and covers an area of more than 1,000 square miles adjacent to the nation's capital. The water and sewer services in this area are provided by the Washington Suburban Sanitary Commission (WSSC).

The standpipe is located approximately one mile north of the county line between Prince George's and Charles Counties and on a property bounded by Livingston and Bealle Hill Roads. It has a design capacity of 3.65 million gallons and is one of the largest water tanks within the WSSD. There are a total of 32 water tanks in operation within the WSSD including standpipes and elevated tanks. The oldest tank dates back to 1928. The WSSC is currently planning several new tanks.

The Accokeek standpipe design was initiated in October 1967 with a soil investigation of the proposed site. The soil investigation was performed by Mueser, Rutledge, Wentworth & Johnston (MRWJ) Consulting Engineers of New York City. The design was completed in March 1972. Construction of the standpipe was awarded to Pittsburgh-Des Moines Steel Co. (PDM). The construction began in the summer of 1972 and was completed in June 1973. Therefore, the Accokeek standpipe has a service history of more than 25 years.

### Features

The standpipe diameter is 75' with a total height of approximately 120'. It is constructed with steel plates having a thickness ranging from 0.25" to 0.96". The thickest plates are used for the lowest elevation of the standpipe and the plate thickness is reduced as the tank elevation increases.

The steel tank is based on a circular concrete mat foundation with a thickness of 3'8" and a diameter of 85'. The bottom of the concrete mat is approximately 3' below the finished grade. The thickness of the mat is increased to 5' near the edge. A 1"-thick layer of sand is used as a cushion between the top of the concrete mat and the bottom of the steel tank.

The tank is connected to the WSSC water transmission mains through a 16" ductile iron inlet-outlet pipe. Water in the tank is regulated with a check valve and an altitude valve installed on the 16" inlet-outlet pipe in a concrete vault. The vault is approximately 50 feet away from the perimeter of the tank. When the tank is filled to the overflow mark, the water is drained by a 10" cast iron overflow line. A 9' x 29' pipe vault is built near the edge of the tank and below the concrete mat foundation. The vault facilitates the connection of the 16" and 10" pipelines to the bottom of the tank and allows maintenance. In order to accommodate the anticipated settlement of the tank, flexible pipe joints were used inside the pipe vault.

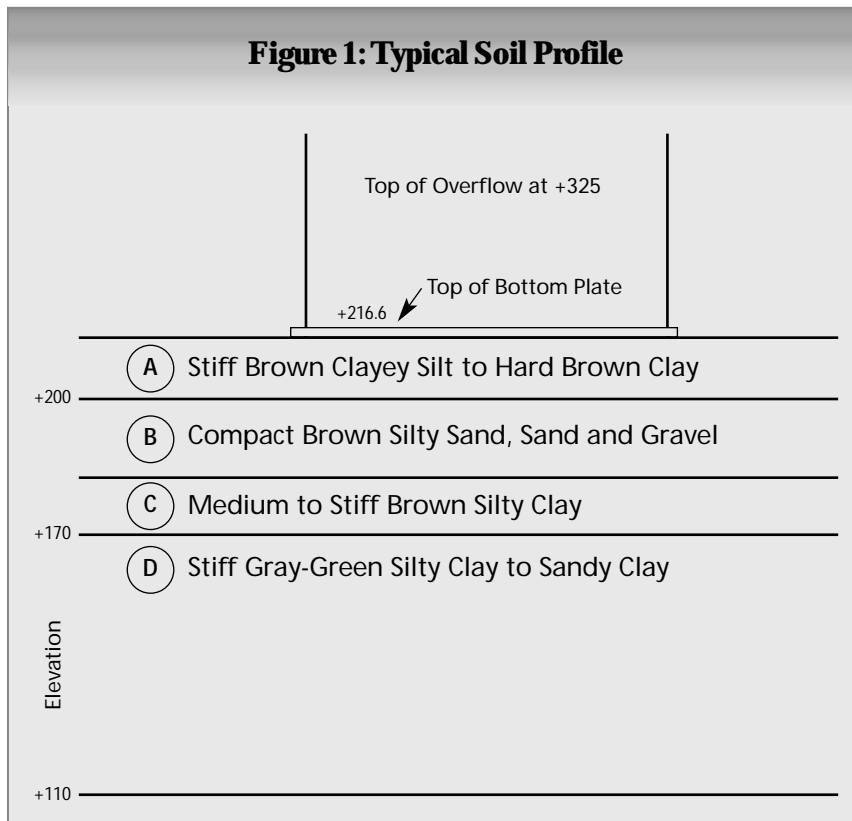
### Subsurface Site Conditions

The standpipe site is located within the coastal plain province of the east coast of the United States. Subsoils within this area were formed by the deposition of materials during periods of higher ocean levels. The site is underlain by considerable depths of moderately compact tertiary sands and clays of varying compressibility.



◀ The Accokeek standpipe is based on a circular concrete mat foundation with a thickness of 3'8" and a diameter of 85'.

**Figure 1: Typical Soil Profile**



A total of five soil borings was drilled within the footprint of the standpipe. Four were around the perimeter and one at the center. The deepest boring (Boring No.1) was extended to a depth of 112' at the north edge of the tank. The depths of the other borings varied from 50' to 70'.

The subsoil conditions at the site (as indicated by the soil boring logs) consist of four generalized soil strata. A typical

soil profile is shown in Figure 1. Stratum A is a stiff brown clayey silt to hard brown clay. Stratum B is a compact brown silty sand, sand and gravel. Stratum C is a medium to stiff brown silty clay. Stratum D is a stiff gray-green silty clay to sandy clay.

Stratum A is approximately 12' thick with a relatively uniform thickness throughout the site. The blow counts (N

values) obtained from the Standard Penetration Tests (SPT) range from 26 to 77 blows per foot except for surface samples where lower values were observed. Natural water contents confirm the compactness of this formation with values varying between 9 and 22 percent.

Stratum B has a thickness of approximately 18'. The blow counts obtained from the SPTs in this stratum generally exceed 30 blows per foot except where silty zones exist.

Stratum C is nearly 13' thick between average elevations 172 and 185. The N values obtained in this layer vary from less than 2 blows per foot to 8 blows per foot. Natural water contents of the soil samples vary from 37 to 55 percent. From the properties of the soil samples, it can be noted that this stratum is relatively more compressible and is the critical layer for the tank foundation design.

Stratum D is stiffer than the overlying stratum. Penetration resistance varies from a low of 3 blows per foot near the surface of the stratum to as high as 34 blows per foot at considerable depth. The natural water content ranges between 28 and 92 percent reflecting the variation in plasticity occurring within this formation.

Groundwater levels were observed in each boring during drilling. These levels range from elevation 190.5 to 188. All water levels are near the base of stratum B.

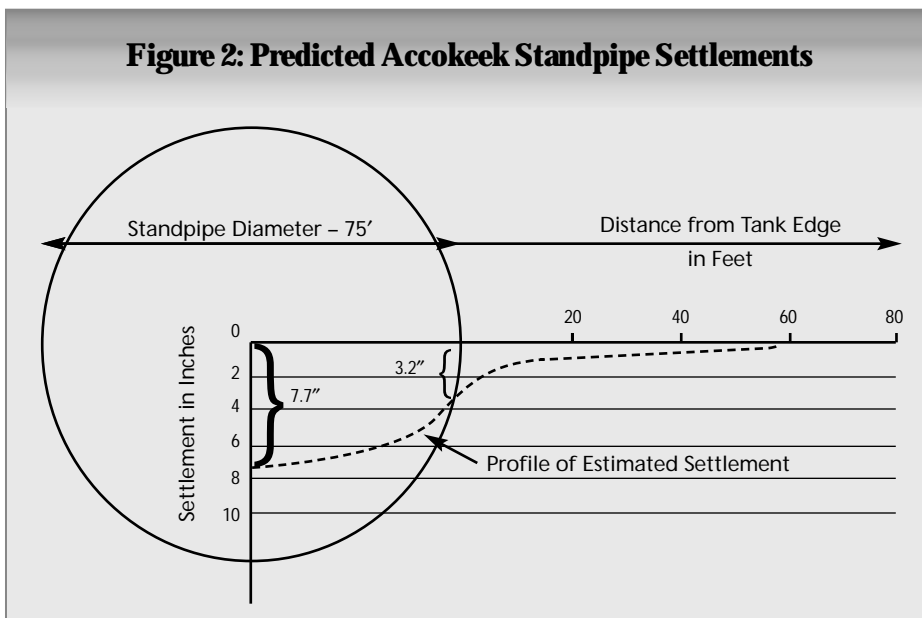
**Foundation Analyses**

MRWJ obtained 3" undisturbed clay samples during the soil investigation for laboratory testing to determine the strength and deformation characteristic of the subsoils. Unconsolidated and consolidated undrained triaxial tests were performed to determine the bearing capacity while consolidation tests were done to estimate settlements.

As a result of subsurface investigation of the site and foundation analyses, the recommended allowable soil bearing capacity for the standpipe was 7.0 ksf. For the size of the tank, it was estimated that the ultimate settlements at the center and the edge of the standpipe would be 8" and 3", respectively, as shown in Figure 2.

In order to monitor the settlements and to verify the foundation design, eight bronze bolts were provided near the edge

**Figure 2: Predicted Accokeek Standpipe Settlements**



and around the top of the foundation. Settlement at the center of the tank was not monitored due to its inaccessible location. Two permanent benchmarks were used as the references for elevation survey. Settlement readings were taken for four stages of initial filling and at least one year after the tank was put in service. Additional readings were taken after 24 years of service.

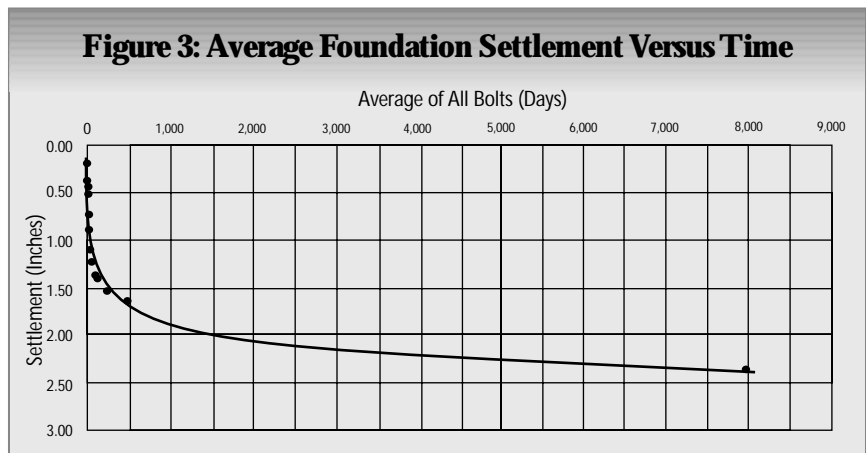
## Foundation Settlement Measurements

Measured settlements around the edge of the foundation are relatively uniform. The average total settlement around the edge of the standpipe is 2.36". The maximum and the minimum settlement are 2.56" and 2.16". Differential settlement is only a small fraction (15 percent) of the total settlement.

A chart of the average settlement versus time is presented in Figure 3. Due to the foundation soil consisting of clay strata, foundation settlement occurred over an extended period of time. It can be noted that nearly 60 percent of the total settlement occurred in the first year of operation. The total settlements compare favorably with the original design estimates.

## Conclusions

The tank has performed well structurally throughout the years. Part of the



success can be contributed to the thorough soil investigation and appropriate foundation analyses during design. Even with high predicted settlements, the tank and the piping can be properly designed.

Some of the important design features that may be derived from this case history include the following.

- Providing expansion/ball joint connections for all piping to a standpipe is always a good design practice especially where significant settlement is anticipated.
- Monitoring the actual performance of a foundation is a good practice to confirm the design of a heavy structure. A settlement monitoring program is simple and economical. The collected data provides a valuable reference for future designs of structures on similar ground conditions.

## Acknowledgements

*This article is in memory of the late Francis Nunn for his excellent record keeping of the settlement data for the initial years of the standpipe. Thanks are due to Marcia Tucker and Steve Kanošky for their support of the work and Dave Burke for editing the manuscript. Assistance from the WSSC Survey and Water Systems Control groups during data gathering also is appreciated.*

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