APPENDIX M: GEOTECHNICAL STUDY

Georgetown University Boathouse
Environmental Assessment

April 2006

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November 14, 2002

Georgetown University
c/o Mr. Chris Jordan
New South Building, West Lobby
3700 O Street, N.W.
Washington, D.C. 20057

Subject: **Geotechnical Engineering Report, Proposed New Boathouse, K Street, N.W., Georgetown University, Washington, D.C. (Our Reference No. 02121204)**

Dear Mr. Jordan:

Schnabel Engineering Associates, Inc. is pleased to submit our report for the above referenced project. This report has been prepared in accordance with our proposal/agreement dated August 16, 2002, as authorized by you on September 24, 2002.

Scope of Services

Services performed under this agreement included the drilling of 12 soil test borings, soil laboratory testing, and preparation of a geotechnical engineering report. This geotechnical engineering report addresses the following:

1. Evaluation of estimated subsurface conditions within the proposed building site.
2. Recommended foundation requirements for support of the proposed building and floor slabs on grade.
3. Recommendations regarding handling of ground water in design.
4. Seismic site coefficients, per table 1610.3.1 of BOCA building code.

5. Recommendations for construction of loadbearing fills including an assessment of excavated on site soils for reuse as backfill.

6. Comments regarding geotechnical construction considerations for use in the design and construction plans and specifications.

Services with respect to environmental matters, paving design, slope stability analysis, erosion control, cost or quantity estimates, plans, specifications, and construction observation and testing are not included in the scope of services.

1.0 Summary of Conclusions and Recommendations

Schnabel Engineering Associates, Inc. performed a Geotechnical Subsurface Investigation for the proposed site at 3700 K Street in northwest Washington, D.C. Based on our geotechnical investigation we offer the following:

1. Soil borings performed during this study indicated generally loose fill underlain by Alluvial and residual soils. The existing fill extended to a maximum depth of about 13 below the existing ground surface. The alluvial soils extended to a maximum depth of 32 feet. Auger refusal was encountered at depths varying between 8.5 and 32 feet. Obstructions were encounters in the fill and possible boulders in the residual soils and disintegrated rock.

2. Due to the variable subsoil conditions and the presence of obstruction and boulders, we recommend that additional borings and rock coring be performed at four locations on the site.

3. Due to the presence of soft existing soils, deep foundations will be required for support of the proposed structure. We recommend using pipe piles for support of the proposed boathouse as detailed herein. Timber piles may also be feasible but they are susceptible to driving difficulties due to boulders. Preaugering will be required to penetrate through boulders and obstructions and to reduce vibration effects on the existing sewer line.

4. Earth supported slabs are not considered suitable, and framed floor slabs are recommended as detailed herein. Based on water level readings within the borings, special subdrainage will not be necessary beneath the floor slabs. The building will be flooded during high water levels of the Potomac.

This summary has been prepared for the convenience of the users of this report. This summary does not contain all the information presented in this report; therefore, the entire report should be read to assure all pertinent information is transmitted.

2.0 Description of the Site and Proposed Construction

The site of the proposed boathouse is located about 75 yards to the west of the terminus of K Street in N.W. Washington, D.C. The site is bounded on the north by a 30-foot high slope with a bike path on top, and on the south by the Potomac River. The site is mainly wooded, with a clear grassy area on the easternmost edge. Existing grades within the proposed building on the site range between El 10.5 on the north, and about El 7 on the southern edge, next to the Potomac River. There is also an 84-inch surcharge sewer pipe that passes through the site. The top of the pipe is about 2 to 3 feet below grade.

The proposed structure is a two-story wood-framed building with no levels below grade. We have considered that the lowest level will be at or about existing grades estimated at El 9±. Maximum wall loads are not expected to exceed 5 kips/linear foot, and maximum column loads are expected to be 50 to 75 kips.

The above information was obtained from our site information provided to us by your office, our field visits and structural data, and a topographic plan prepared by Ehlert Bryan Inc.

3.0 Subsurface Conditions

A total of six soil test borings were drilled by our drilling subcontractor on October 9, 2002. The results of the test boring are presented in Appendix A at the end of this report. Previous soil borings performed by us at the site were also considered in our analysis and are included in Appendix B. The approximate boring locations are shown in Figure 2.

3.1 Stratification

The soil test borings drilled at the site indicate the following generalized soil strata underlie the site to the depths investigated:

Stratum A: (Fill)	Below the topsoil to depths of up to about 13 feet.	Brown silty sand and clayey sand FILL with organic matter, gravel brick, obstructions and asphalt fragments; variable density (N = 3 to 100)
Stratum B: (Alluvial)	Below the topsoil and Stratum A to depths of about 13.5 to 31 feet.	Brown and gray silty SAND (SM), SILT (ML) with sand and LEAN CLAY (CL) with organic matter, obstructions, generally soft (N = WOH* to 28)
Stratum C: (Residual)	Below Stratum B to depths of about 23.5 to 38 feet, the maximum depths investigated by the borings.	Brown and gray silty SAND (SM) trace mica with boulders; generally firm (N = 34)
Stratum D: (Residual)	Below Stratum B to a depth of 40 feet in Boring No. B-4.	Brown DISINTEGRATED ROCK, with boulders, very compact (N = 100/0")

*WOH = Weight of Hammer

Up to about 1.0 foot of topsoil was encountered below the existing ground surface at the locations of the borings. These depths may vary at other locations and should not be considered as a stripping depth.

Numbers after description of the soil strata indicate the minimum and maximum penetration resistances, or N values, recorded in each stratum. N values indicated the penetration resistance in blows per foot of a standard 2 inch O.D., 1-3/8 inch I.D. sampling spoon driven with a 140-pound hammer falling 30 inches per ASTM D-1586. Where possible, the sampler is driven 18 inches, with the number of blows required for penetration recorded for each 6-inch interval. After the initial 6 inches of penetration, which is usually considered a seating interval, the number of blows required to drive the sampler the final 12 inches is generally taken as the N value.

Disintegrated rock is defined as residual earth material with a penetration resistance between 60 blows per foot and refusal. Refusal is defined as a penetration resistance of 100 blows for 2 inches penetration or less.

The group symbols indicated on the boring logs and in the soil stratification represent Unified Soil Classification symbols based on visual observation of the samples recovered, per ASTM D-2488. Criteria for visual classification of soil samples are given in Appendix A.

3.2 Geology

The existing fill of Stratum A is believed to be associated with the construction of the existing Washington Canoe Club and the installation of the existing 84-inch sewer pipe that runs through the middle of the site. Stratum B soils are believed to be recent alluvial deposits of the Potomac River. Strata C and D are natural residual soils derived from the in-place weathering of the parent bedrock. The density of these residual soils generally increases with depth. The bedrock on the site is believed to be gneiss rock.

It should be known that boulders may be located within Strata C and D and could drastically vary in size.

3.3 Ground Water

Water level readings which were obtained in the recent borings during and after completion of drilling are noted on the boring logs. The borings indicated ground water between 1 and 7 feet below grade or between about El 0 and El 7. Previous borings indicated similar ground water levels. High water of the Potomac is at about El 17 in this area.

Water level readings, which were obtained in the borings during and after completion, are noted on the boring logs. The estimated ground water levels indicated on the boring logs show our estimate of the approximate location of the hydrostatic water table at the time the borings were performed. Fluctuations in the location of the hydrostatic water table should be anticipated, depending upon environmental conditions, surface drainage, nearby Potomac River, weather and time of year, evaporation and others factors not evident at the time measurements were taken and reported herein.

3.4 Soil Laboratory Testing

Soil laboratory testing is being performed and will be submitted under separate cover when it is completed.

4.0 Foundation Engineering Analysis

The foundation engineering analysis was based on the subsurface investigation data, the structural loads and the site information furnished to us.

The soil test borings indicated up to about 13 feet of existing fill of Stratum A in the northern portion of the site and up to about 7.5 feet on the southern portion. Below the fill loose alluvial soils were encountered to depth of up to about 39 feet below grade. Spread footings and a mat were considered for support of the building; however, these are not expected to be suitable due to the potential for excessive settlements. Removing and replacing the fill is not expected to be possible due to the proximity to the Potomac River. We, therefore, have considered framed floors and deep foundations for support of the building.

We have evaluated the use of various deep foundation systems for support of the proposed building. However, the presence of boulders as well as high ground water will make installation of deep foundation systems difficult. Caissons were not considered practical due to the presence of boulders and cobbles and light loads.

Driven precast concrete piles were also evaluated but are not considered suitable due to hard drilling through the boulders and possible breakage and eccentricity problems.

Auger cast piles are considered less desirable than other deep foundation systems due to likely refusal problems and boulders as well as possible squeezing and necking due to the presence of soft alluvial soils. Therefore, we considered closed end pipe piles and timber piles the most feasible foundation systems as installation difficulties are anticipated to be fewer.

4.1 Foundation

The piles will be installed through the fill and soft and loose soils of Stratum B into the hard disintegrated and bedrock below Stratum C.

We have considered 12-inch diameter pipe piles of 25-ton capacity and 8-inch tip diameter treated timber piles of 20-ton capacity. The piling should be driven to the hard disintegrated rock and bedrock. Preaugering due to obstructions in the fill and the presence of boulders will be required in some areas to advance the piles. Some of the borings indicated refusal at relatively shallow depths and coring will be required to evaluate if refusal encountered is a result of boulders. This should be performed prior to construction. Estimated tip elevation at the boring locations and recommended capacities are as follows:

[redacted]			
B-1	-1	-1	Possible boulder coring of rock required
B-2	-6	-6	Possible boulder coring of rock required
B-3	+1	+1	Possible boulder coring of rock required
B-4	-38	-38	-
B-5	-25	-25	-
B-6	-4	-4	Obstruction in the fill, coring of rock required
B-6A	-10	-10	
SB-1	-31	-31	Possible boulder
SB-2	-14.5	-14.5	-
SB-3	-23	-23	-

Tip grades at intermediate locations may be estimated by linear interpolation. The elevations given above are for design purposes only. Actual tip elevations will need to be determined during construction and should be based on driving criteria as established during driving of control piles as discussed in Section 6.1. Total settlements of piles are not expected to exceed ½ inch and differential settlements between piles are not expected to exceed half this amount. Some hard driving should be expected due to the presence of boulders. Also, obstructions will likely be encountered within the existing fill of Stratum A. Therefore, predrilling through the upper fill and boulders and cobbles may be necessary. Also, it is suggested that point protection be included on the ends of the timber piles to reduce pile damage during driving. Pile eccentricity and pile driving problems are expected to be greater than normal and a budget should be established to account for these extra costs. Details regarding load tests are included in Section 6.1 of this report.

For the pile foundation alternatives recommended herein, it is expected that 12-inch pipe piles to be more feasible than timber piles, since steel pipe pile are estimated to have somewhat less waste from variable pile lengths, as these piles can be welded in sections. For timber piles, additional piles are needed due to lower capacity and possible damage.

The installation of piles for this project should be restricted to contractors with demonstrated ability and experience. We recommend that contractors with at least 5 years experience in the installation of any pile type selected be allowed to install these piles.

Driven piles may generate normal vibrations. Predrilling may be necessary in the upper fill soil if obstructions are encountered. A survey of nearby houses may be necessary before and after pile installation to monitor their condition during foundation construction.

In order to minimize damage to pile while driving, we recommend that hammer energy not exceed 15,000 ft.-lb.

4.2 Installation of Piles Around the Sewer Pipe

We understand that concern have risen regarding vibration damage to the sewer pipe during installation of piles. To reduce the possibility of damage, preaugering of piles will be required. We suggest that piles be preaugered to at least 10 feet below grade to minimize vibration damage. Monitoring of the pipe should be performed during pile driving.

4.3 Site Seismic Coefficient

Based on the site geology, the results of our geotechnical analysis, and that shallow foundations are anticipated for supporting the proposed buildings, the site classifies as a "Site Class C" according to the IBC 2000 code.

4.4 Floor Slabs

Earth supported floor slabs are not considered feasible due to the potential for excessive settlement. Therefore, we recommend that the lowest floor be structurally supported. Considering the ground water and river levels on the site, special drainage under the floor will generally not be required.

4.5 Floating Conditions

Consideration should be given regarding flooding of the Potomac River. Hydrostatic pressure should not be allowed to build up to reduce the potential for uplift forces and water should be allowed to move freely through the building.

5.0 Earthwork

Materials used for compacted fill of should consist of soil classified as ML, SM, SP, SW, GC, GM, GP, or GW soils per ASTM D-2487. Soils excavated from Strata A or B are not expected to be suitable for reuse as compacted fill and backfill and importation of fill will be required.

Compacted fill and backfill should be placed in loose lifts not exceeding 8 inches in thickness and compacted to at least 95 percent of the maximum dry density per ASTM D-698. If lifts of fill become excessively dry or wet due to exposure to weather, they should be scarified, dried or wetted, as necessary, to permit proper compaction. All materials used for compacted fill should be approved by the geotechnical engineer prior to use. In general, fill work should be attempted between early April and late December, as weather conditions severely restrict fill placement at other times. Some of the on-site material may be wet and may require drying prior to reuse.

6.0 Construction Considerations

6.1 Driven Piles

The estimated tip elevations for the different types of piles considered are given herein and are based on static analysis using soil design parameters determined from our field and laboratory testing of the soils at this site. Piles should be driven to a dynamic resistance as determined by the ENR formula, and to within 2 feet of the tip elevations given. Intermediate locations can be interpolated. The minimum penetration is required to assure bearing in hard disintegrated rock of Stratum D and bedrock.

At least 7 control piles should be installed in the proposed area of the boring location. The control piles will provide important information as to the driving resistances that can be anticipated during production. The contractor should be prepared to provide predrilling during both control pile and production pile installation in the even that obstructions may be encountered in Stratum A or vibrations near ground surface need to be minimized. Piles for load testing are not anticipated to be required unless unusual driving conditions are observed during installation of control or production piles.

The estimated pile tip elevations were given herein. Although we do not recommend applying a dynamic formula to determine the pile capacities, we believe the pile driving records can be used for control of the installation. The following ENR formula is recommended for use in the field:

P = 2E/(S+0.1)

P = Safe pile load, lbs.

E = Energy per blow, ft.-lbs.

S = Penetration, inches per blow for last few blows for single acting hammers, E = WH

W = Weight of ram, lbs.

H = Height of fall, ft.

For differential hammers, E = .08 (Manufacturer's rated energy)

We believe specifications should require the contractor to use a hammer with rated energy not to exceed 15,000 ft-lbs., and 9,000 ft.-lb. for pipe piles and for the treated timber pile system. We recommend that a wave equation analysis be performed prior to pile driving to evaluate stresses in piles dud to driving with the contractors' hammer proposed for use. We may provide this analysis under the construction phase of this project.

Production piles should be driven with the same hammer as was used to drive the control piles, without modification of any kind. Pile shoes may be used to reduce the possibility of pile damage.

If pipe piles are selected for this project, they should be inspected just prior to concreting to ensure that they are undamaged and free of debris and water. This observation will be essential if welds are used. Piles should not be out of plumb by more than 2%.

6.2 Observations During Construction

There is a possibility that variations in the soil conditions will be encountered during construction. In order to permit correlation between the subsurface investigation data and the actual soil conditions encountered, it is recommended that we be retained as a continuation of our services to perform professional observation of footing and floor slab subgrades, and testing of compacted backfill.

7.0 General and Limitations

Recommendations contained in this report are based on data obtained from the relatively limited number of test borings and test pits performed at the locations given herein. This report does not reflect variations, which may occur between these locations or in areas not explored. The nature and extent of these variations may not become evident until the construction period. It is important for successful completion of this project that on-site observations of pile installation, fill, and floor slab subgrades and testing of compacted fill be performed during construction.

This report has been prepared to aid in the evaluation of the site and to assist your office and the design professionals in the design of this project. It is intended for use with regard to the specific project as described herein, and substantial changes in building locations or grading plans should be brought to our attention so that we may evaluate possible effects on the recommendations given herein.

An allowance should be established to account for possible additional costs that may be required for the construction and earthwork as recommended in this report. Additional costs may be incurred for various reasons including unsuitable fill material, additional piles, ground water problems, etc.

This report should be made available to bidders prior to submitting their proposals and to the successful contractor for his information and to supply them with facts relative to the subsurface investigation, laboratory tests, etc. The opinions and conclusions expressed in this report are based upon the subsurface conditions revealed by our investigation, laboratory tests and the result of analyses and studies, which we have performed for this project.

We recommend the project specifications contain the following statement:

> "A geotechnical engineering report has been prepared for this project by Schnabel Engineering Associates, Inc. This report is for informational purposes only and should not be considered part of the contract documents. The opinions expressed in this report are those of the geotechnical engineer and represent his interpretations of the subsoil conditions, tests, and the results of analyses, which he performed. Should the data contained in this report not be adequate for the contractor's purposes, the contractor may make his own investigations, tests and analyses prior to bidding. Contractors desiring to conduct additional subsurface explorations prior to bidding should contact the architect for arrangements to enter the project site."

Additional data and reports as prepared by others that could impact upon a contractor's bid should also be made available to prospective bidders for informational purposes.

We have endeavored to prepare this report for use by the design professionals for design purposes in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are made as to the professional services included in this report.

Soil samples for this study will be held until November 10, 2001, and then discarded unless other disposition is requested.

We appreciate the opportunity to be of service to you on this project. Please contact our office if you have any question concerning this report.

Very truly yours,

SCHNABEL ENGINEERING ASSOCIATES, INC.

John Odonkor, E.I.T.
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Figure 1: Vicinity Map
Figure 2: Boring Location Plan

Appendix A:
- Subsurface Investigation Report (1 Sheet)
- General Notes (1 Sheet)
- Identification of Soil (1 Sheet)
- Boring Logs (9 Sheets)

Appendix B:
- Previous Subsurface Investigation Data
- Boring Logs (3 Sheets)