SECTION 3. DISCUSSION AND RECOMMENDATIONS

In order to develop the required bearing and lateral load resistances for the new sign structures, we recommend supporting the sign structures on drilled shaft foundations. The sign structures should be supported on drilled shafts having a minimum diameter of 60 or 72 inches. Based on the anticipated structural loads and the subsoil conditions encountered at each site, the recommended shaft lengths for the 60-inch and 72-inch diameter drilled shafts supporting the sign structures range between 14 and 30 feet.

The drilled shaft subcontractor should have the appropriate equipment and tools to drill through the basalt rock, volcanic tuff, boulders, and cobbles encountered at the sign structure sites. The performance of the drilled shafts depends significantly upon the contractor's method of construction, construction procedures, and workmanship. Therefore, the contractor should review the recommendations and general guidelines presented in the "Drilled Shaft Construction Considerations" subsection of this report. Detailed discussion of these items and our geotechnical engineering design recommendations are presented in the following sections.

3.1 Drilled Shaft Foundations

Based on the structural loading information provided, the sign structure foundations will be subjected to relatively high ground line moments. In order to develop the required bearing and lateral load resistances, the proposed new sign structures may be supported by a foundation system consisting of cast-in-place concrete drilled shafts. Our recommendations for the drilled shaft foundations at each sign site are presented in the following table.

DRILLED SHAFT FOUNDATION DESIGNS			
Destination Sign I.D.	**Number of Post Supports**	**Minimum Shaft Diameter** (inches)	**Minimum Shaft Embedment Length** (feet)
H1EBR-253	2	60	14
H1WB-421	1	72	16
H1EB-305	1	60	30
78WB-853	2	60	28
H1NBR-722	2	60	28
H1EB-104	1	72	18

The cast-in-place concrete drilled shafts would derive vertical support principally from skin friction between the shafts and the surrounding soils. The end bearing component of the drilled shafts has been discounted in our analysis.

3.1.1 Lateral Load Resistance

The lateral load resistance of each drilled shaft is a function of the stiffness of the surrounding soil, the stiffness of the drilled shaft, allowable deflection at the top of the drilled shaft, and the induced moment in the drilled shaft. The lateral load analyses were performed using the program LPILE for Windows, which is a microcomputer adaptation of a finite difference, laterally loaded deep foundation program originally developed at the University of Texas at Austin. The program solves for deflection and bending moment along a deep foundation under lateral loads as a function of depth. The analysis was carried out with the use of non-linear "p-y" curves to represent soil moduli. The lateral deflection was then computed using the appropriate soil moduli at various depths.

Based on the provided structural loads and the subsurface soil conditions at each destination sign location, the results of our analyses are summarized in the following table. The project structural engineer should verify the drilled shaft structural capacity for the calculated induced stresses.

LATERAL DEFLECTION AND MAXIMUM INDUCED MOMENT & SHEAR IN THE DRILLED SHAFTS					
Destination Sign I.D.	**Limit State**	**Lateral Head Deflection** (inches)	**Maximum Induced Shear** (kips)	**Maximum Induced Moment** (kip-feet)	**Depth to Maximum Moment** (feet)
H1EBR-253	Extreme Event I	0.2	299.7	1,717	5.0
H1WB-421	Extreme Event I	0.4	780.0	2,308	5.5
H1EB-305	Extreme Event I	0.7	94.8	1,358	7.0
78WB-853	Extreme Event I	0.7	156.4	1,758	7.5
H1NBR-722	Extreme Event I	0.9	119.3	1,325	8.0
H1EB-104	Extreme Event I	0.4	499.5	2,000	7.0

For the analysis of the drilled shaft foundations, we have assumed that a minimum concrete compressive strength of 4,500 pounds per square inch (psi) will be specified and a nominal longitudinal reinforcing steel of about 1 percent of the cross-sectional area of the drilled shaft will be used.

In general, drilled shaft foundations are constructed by drilling a hole down into the bearing strata, placing reinforcing steel, and then pumping high slump concrete to fill up the hole. The result is a cast-in-place concrete drilled shaft for foundation support. Based on the subsurface conditions encountered at each project site, we envision the drilled shaft foundations would derive vertical support primarily from skin friction between the drilled shaft and the surrounding materials. The end bearing component of the drilled shafts has been discounted in our analysis since the relatively small vertical loading will be resisted mainly by skin friction before reaching the shaft tip.

3.1.2 Torsional Resistance

In general, the sign structures may be subjected to torsional moments resulting in torsion on the drilled shaft foundations. Torsion may be resisted by the side shear along the drilled shaft surface and adjacent soils. Based on our analyses, we believe that the recommended diameter of drilled shafts extending to the depths recommended should be capable of resisting the torsional moment without significant movement of the foundations. It is our understanding that frequency analyses for modeling the foundation along with the structure for the two large cantilever signs structures under high torsional loads will be performed for Signs H1WB-421 and H1EB104. For the required analyses, “p-y” curves for the pile cap and the drilled shaft were estimated using the LPILE program for a composite pile with an upper pile section consisting of 7.5 feet by 7.5 feet by 5 feet thick with the top of the pile at 6 inches above the finish ground surface. The second pile section from the 5 feet below the top of the pile to the design bottom consists of a 72-inch diameter drilled shaft. Results of the generated non-linear “p-y” curves are summarized and present on Plates 3.1 through 4.2.

3.1.3 Foundation Settlement

Settlement of the drilled shaft foundation will result from elastic compression of the shaft and subgrade response of the foundation embedded in the soils encountered at the site. We anticipate that the total settlements of the drilled shafts are estimated to be less than 0.5 inches. We believe that a significant portion of the settlement will be elastic and should occur as the loads are applied.

3.1.4 Drilled Shaft Construction Considerations

In general, the performance of drilled shafts depends significantly upon the contractor's method of installation and construction procedures. The following conditions would have a significant effect on the effectiveness and cost of the drilled shaft foundations.

The load-bearing capacities of drilled shafts depend, to a significant extent, on the friction between the shaft and the surrounding soils. Therefore, proper construction techniques, especially during the drilling operations, are important. The contractor should exercise care in drilling the shaft holes and in placing concrete into the drilled holes.

Basalt rock and volcanic tuff formations were encountered at the Signs H1EBR-253, 78WB-853, H1WB-421 and H1EB-104 sites. In addition, cobbles and boulders were encountered at the Sign H2NBR-722 site. The drilled shaft subcontractor will need to have the appropriate equipment and tools to drill through the basalt rock, volcanic tuff, boulders, and cobbles, where encountered.

Based on our field exploration, alluvial deposits consisting of loose to medium dense silty gravel and silty sand were encountered at the Signs H1EB-305 and H2NBR-722 sites. These loose soils may likely cave-in and/or slough off during the drilling operations. To reduce the potential for caving-in of the drilled holes, the temporary casing may be required during the drilled shaft installation and/or the use of drilling fluids (polymer slurry) may be necessary to maintain the integrity of the drilled hole during drilled shaft installation. Drilling by methods utilizing drilling fluids may have a significant effect on the supporting capacity of the drilled shaft; therefore, use of drilling fluids would require prior evaluation and acceptance by Geolabs.

Care should be exercised during the removal of the temporary casing to reduce the potential for "necking" of the drilled shaft. Therefore, a minimum 5-foot head of concrete above the bottom of the casing or adequate concrete head to counter the hydrostatic pressures due to the groundwater conditions, where encountered, should be maintained during the removal of the casing.

The groundwater conditions may pose construction difficulties because proper observation of the sides and bottoms of the drilled shaft may not be possible. Groundwater conditions are anticipated within the depths of the drilled shaft excavations at Signs H1EBR-253, H1EB-305, H1WB-421 and H2NBR-722 sites. Concrete placement by tremie methods will be required during drilled shaft construction where groundwater is encountered in the drilled holes. The concrete should be placed in a suitable manner by displacing the water in an upward fashion from the bottom of the drilled hole. A low-shrink concrete mix with high slump (7 to 9-inch slump range) should be used to provide close contact between the drilled shafts and the surrounding soils. The concrete should be placed in a suitable manner to reduce the potential for segregation of the aggregates from the concrete mix. In addition, the concrete should be placed promptly after drilling (within 24 hours after drilling of the holes) to reduce the potential for softening of the sides of the drilled holes.

A Geolabs representative should be present to observe the drilling and installation of drilled shafts during construction. Although the drilled shafts are designed based primarily on skin friction, the bottom of the drilled hole should be relatively free of loose materials prior to the placement of concrete. Therefore, Geolabs' observation of the drilled shaft installation operations is necessary to confirm the assumed subsurface conditions and should be designated a “Special Inspection” item.

3.2 Design Review

Drawings and specifications for the proposed construction should be forwarded to Geolabs for review and written comments prior to bid advertisement. This review is necessary to evaluate the conformance of the plans and specifications with the intent of the foundation and earthwork recommendations provided herein. If this review is not made, Geolabs cannot assume responsibility for misinterpretation of the recommendations presented.

3.3 Construction Observation

Geolabs should be retained to provide geotechnical engineering services during construction of the proposed project. The critical item of construction monitoring that requires "Special Inspection" includes observation of the drilled shaft construction.

A Geolabs representative should monitor other aspects of earthwork construction to observe compliance with the intent of the design concepts, specifications, or recommendations and to expedite suggestions for design changes that may be required in the event that subsurface conditions differ from those anticipated at the time this report was prepared. The recommendations provided herein are contingent upon such observations. If the actual exposed subsurface conditions encountered during construction are different from those assumed or considered in this report, then appropriate modifications to the design should be made.

END OF DISCUSSION AND RECOMMENDATIONS