SECTION 3. DISCUSSION AND RECOMMENDATIONS

In order to develop the required bearing and lateral load resistances for the new CCTV, VMS, and speed reader structures, we recommend supporting the CCTV, VMS, and speed reader structures on drilled shaft foundations. The CCTV, VMS, and speed reader structures should be supported on 36 or 48-inch diameter drilled shaft foundations. Based on the anticipated structural loads and the subsoil conditions encountered at each site, the length of the 36-inch diameter drilled shafts supporting the CCTV and speed reader structures would range from about 12 to 15 feet. The length of the 48-inch diameter drilled shafts supporting the VMS structures would range from about 20 to 30 feet.

The drilled shaft subcontractor will need to have the appropriate equipment and tools to drill through the cobbles, boulders, and basalt rock where encountered. Basalt rock was encountered at the Kualakai VMS, Kunia West CCTV, and H-2 CCTV sites. Residual and saprolitic soils were encountered at the Kualakai CCTV, H-2 VMS, and Waipio CCTV sites. It should be noted that there is a high potential for encountering basalt rock in the form of unweathered boulders and cobbles in the residual and saprolitic soils.

The performance of the drilled shafts depends significantly upon the contractor's method of construction, construction procedures, and workmanship. Therefore, the contractor should follow 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

In order to develop the required bearing and lateral load resistances, the proposed new CCTV camera, VMS, and speed reader 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 site (CCTV, VMS, and speed reader) are presented in the following tables.

CCTV DRILLED SHAFT FOUNDATION				
Site	**Unfactored Compressive Load Shaft Capacity** (kips)	**Compressive Load Service Limit State** (kips)	**Shaft Diameter** (inches)	**Shaft Length** (feet)
Palailai CCTV	60	20	36	15
Kualakai CCTV	60	20	36	15
Waipio CCTV	60	20	36	15
H-2 CCTV	60	20	36	15
Kunia West CCTV	60	20	36	12

VMS DRILLED SHAFT FOUNDATION				
Site	**Unfactored Compressive Load Shaft Capacity** (kips)	**Compressive Load Service Limit State** (kips)	**Shaft Diameter** (inches)	**Shaft Length** (feet)
Farrington VMS	120	40	48	20
H-2 VMS	120	40	48	30
Kualakai VMS	120	40	48	20

SPEED READER DRILLED SHAFT FOUNDATION				
Site	**Unfactored Compressive Load Shaft Capacity** (kips)	**Compressive Load Service Limit State** (kips)	**Shaft Diameter** (inches)	**Shaft Length** (feet)
Palailai Speed Reader	60	20	36	15
Speed Reader 4	60	20	36	15

The drilled shaft foundation lengths provided in the above tables are measured from the design finished grades (ground level) to the tip of the drilled shaft. The cast-in-place concrete drilled shafts would derive vertical support principally from skin friction between the shafts and the surrounding soils.

3.1.1 Uplift Load Resistance

In general, uplift loads may be resisted by a combination of the dead weight of the drilled shaft and by shear along the shaft surface and the adjacent soils. Considering that the drilled shafts are designed based on adhesion between the shaft and the surrounding soils, we recommend using the following uplift load capacities for the extreme event and strength limit states. For the strength limit state, a resistance factor of 0.35 has been applied to the extreme event limit state uplift load capacities. In addition, the resistance factor was reduced by 20 percent for the single non-redundant drilled shaft. The project structural engineer should check the structural capacity of the shaft member in tension.

UPLIFT LOAD CAPACITIES FOR CCTV DRILLED SHAFT FOUNDATION			
		Uplift Load Capacity (kips)	
Site	**Shaft Diameter** (feet)	**Extreme Event Limit State**	**Strength Limit State**
Palailai CCTV	36	15	4
Kualakai CCTV	36	15	4
Waipio CCTV	36	15	4
H-2 CCTV	36	15	4
Kunia West CCTV	36	15	4

UPLIFT LOAD CAPACITIES FOR VMS DRILLED SHAFT FOUNDATION			
		Uplift Load Capacity (kips)	
Site	**Shaft Diameter** (feet)	**Extreme Event Limit State**	**Strength Limit State**
Farrington VMS	48	270	75
H-2 VMS	48	215	60
Kualakai VMS	48	270	75

UPLIFT LOAD CAPACITIES FOR SPEED READER DRILLED SHAFT FOUNDATION			
		Uplift Load Capacity (kips)	
Site	**Shaft Diameter** (feet)	**Extreme Event Limit State**	**Strength Limit State**
Palailai Speed Reader	36	11	3
Speed Reader 4	36	11	3

3.1.2 Lateral Load Resistance

The lateral load resistance of drilled shafts 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. Based on the loading conditions and the subsurface soil conditions, the results of our analyses are summarized in the following tables.

FOUNDATION ANALYSES RESULTS FOR CCTV 36-INCH DIAMETER DRILLED SHAFTS					
Site	**Loading Condition**	**Maximum Horizontal Deflection** (inch)	**Maximum Induced Shear** (kips)	**Maximum Induced Moment** (kip-feet)	**Depth to Maximum Moment** (feet)
Palailai CCTV	Service	0.1	27	161	1.7
	Extreme Event	0.1	21	119	1.5
Kualakai CCTV	Service	0.1	24	168	3
	Extreme Event	0.1	18	125	3
Waipio CCTV	Service	0.1	22	160	1.2
	Extreme Event	0.1	18	118	1.1
H-2 CCTV	Service	0.1	21	161	1.7
	Extreme Event	0.1	16	119	1.7
Kunia West CCTV	Service	0.1	24	159	1
	Extreme Event	0.1	19	118	0.8

FOUNDATION ANALYSES RESULTS FOR VMS 48-INCH DIAMETER DRILLED SHAFTS					
Site	**Loading Condition**	**Maximum Horizontal Deflection** (inch)	**Maximum Induced Shear** (kips)	**Maximum Induced Moment** (kip-feet)	**Depth to Maximum Moment** (feet)
Farrington VMS	Service	0.2	76	729	2.8
	Extreme Event 1	0.4	101	931	3.4
H-2 VMS	Service	0.3	100	1011	4.5
	Extreme Event	2.4	257	3236	6.9
Kualakai VMS	Service	0.1	81	714	1.6
	Extreme Event 1	0.2	97	909	2.2

FOUNDATION ANALYSES RESULTS FOR VMS 48-INCH DIAMETER DRILLED SHAFTS					
Site	**Loading Condition**	**Maximum Horizontal Deflection** (inch)	**Maximum Induced Shear** (kips)	**Maximum Induced Moment** (kip-feet)	**Depth to Maximum Moment** (feet)
Palailai Speed Reader	Service	0.1	6.2	33	0.8
	Extreme Event	0.1	7.2	39	1.0
Speed Reader 4	Service	0.1	6.5	36	2.7
	Extreme Event	0.1	7.7	44	3.0

3.1.3 Torsional Resistance

In general, the CCTV and VMS 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. We wish to emphasize that the sides of the drilled holes should be relatively free of loose materials and that the concrete for the drilled shaft should have close contact with the in-situ soils after the drilled shaft has been constructed to provide the torsional resistance required.

3.1.4 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.

3.1.5 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 was encountered at the Kualakai VMS, Kunia West CCTV, and H-2 CCTV sites. In addition, residual and saprolitic soils were encountered at the Kualakai CCTV, H-2 VMS, and Waipio CCTV sites. There is a high potential for encountering basalt rock in the form of unweathered boulders and cobbles in the residual and saprolitic soils. The drilled shaft subcontractor will need to have the appropriate equipment and tools to drill through the basalt rock, boulders, and cobbles, where encountered.

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 placement of concrete. Therefore, Geolabs observation of the drilled shaft installation operations is necessary to confirm the assumed subsurface conditions and should be designated as 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 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 a review of the drilled shaft construction submittals and 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