

**DRAFT REPORT FOR REVIEW AND COMMENT.  
PLEASE CONTACT OUR OFFICE WITH REVIEW COMMENTS.**

**DRAFT**  
**GEOTECHNICAL ENGINEERING EXPLORATION**  
**IAO VALLEY STATE MONUMENT FLOOD REPAIRS**  
**JOB NO. J45CM41A**  
**INTERIM REMEDIAL MEASURES**  
**WAILUKU, MAUI, HAWAII**

**W.O. 7417-00(A)    DECEMBER 1, 2016**

Prepared for

**WILSON OKAMOTO CORPORATION**

and

**STATE OF HAWAII**  
**DEPARTMENT OF LAND & NATURAL RESOURCES**



**GEOLABS, INC.**  
Geotechnical Engineering and Drilling Services

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THIS WORK WAS PREPARED BY  
ME OR UNDER MY SUPERVISION.

**DRAFT**

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2006 Kalihi Street • Honolulu, HI 96819

Hawaii • California



## **GEOLABS, INC.**

*Geotechnical Engineering and Drilling Services*

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December 1, 2016  
W.O. 7417-00(A)

**Mr. Brian Chang**  
**State of Hawaii**  
**Department of Land & Natural Resources**  
1151 Punchbowl Street  
Honolulu, HI 96813

Dear **Mr. Chang**:

Geolabs, Inc. is pleased to submit our draft report entitled "Geotechnical Engineering Exploration, Iao Valley State Monument Flood Repairs, Job No. J45CM41A, Interim Remedial Measures, Wailuku, Maui, Hawaii" prepared for the design of the project.

Our work was performed in general accordance with the scope of services outlined in our fee proposal dated October 24, 2016.

Please note that the soil samples and rock cores recovered during our field exploration (remaining after testing) will be stored for a period of two months from the date of this report. The samples will be discarded after that date unless arrangements are made for a longer sample storage period. Please contact our office for alternative sample storage requirements, if appropriate.

Detailed discussion and specific design recommendations are contained in the body of this report. If there is any point that is not clear, please contact our office.

Very truly yours,

**GEOLABS, INC.**

**DRAFT**

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**Gerald Y. Seki, P.E.**  
Vice President

GS:AJF:as

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**SUMMARY OF FINDINGS AND RECOMMENDATIONS**

An intense rainfall and flood event occurred on September 13, 2016 that affected numerous locations on the Island of Maui including the Iao Valley State Monument Park. Based on our September 19, 2016 site visit, an extraordinary heavy rainfall event produced extreme flood stage runoff that damaged and destroyed some existing park infrastructure. The damage included a large-scale slope failure, various streamside slope failures including destruction of pedestrian paths, bridge foundation scour, and destabilization of boulders on various slopes above the pedestrian pathways. Based on our reconnaissance, five (5) primary areas of storm damage affecting public safety were documented. The five areas of storm damage may be generalized as follows:

1.     Parking Lot Slope Failure
2.     Pedestrian Bridge Instability
3.     Short Loop Trail Failure
4.     Long Loop Trail Failure
5.     Potential Rockfall Hazards

We understand it is desired to approach the emergency repairs as a two-stage effort. Stage 1 involves a preliminary assessment of the damages and provision of recommendations and design work for emergency interim repairs including either stabilizing or closing portions of the park for possible limited re-opening of the park for public access. Stage 2 involves additional engineering assessment and design of the permanent repairs. This report covers Stage 1 for interim remedial measures for the flood damage in an effort to re-open portions of the park for public access.

Our borings at the parking lot slope failure generally encountered a pavement structure consisting of about 4 inches of asphaltic concrete and 12 inches of medium dense sandy fill material overlying about 20 to 40 feet of fill material consisting of very dense gravel, cobbles, and boulders with some silty sand and a colluvial/alluvial deposit consisting of very dense gravel, cobbles, and boulders with some clayey sand to the maximum depth explored of about 81.5 feet below the existing ground surface. We encountered groundwater in the borings drilled at the time of our field exploration at depths varying from approximately 51 to 62 feet below the existing ground surface. Considering the project is located adjacent to the Wailuku Stream, the groundwater levels may vary in response to the water level in the stream. In addition, it should be noted that the groundwater

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**SUMMARY OF FINDINGS AND RECOMMENDATIONS**

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levels are subject to change due to rainfall, seasonal precipitation, surface water runoff, and other factors.

Our borings at the pedestrian bridge generally encountered a relatively thin pavement structure overlying colluvial/alluvial deposits consisting of dense to very dense gravel, cobbles, and boulders and medium dense to very dense silty sand to the maximum depth explored of about 28 feet below the existing ground surface. We did not encounter groundwater in the borings at the pedestrian bridge at the time of our field exploration.

For temporary support of the slope face materials at the parking lot slope failure during the interim remedial repair, we recommend placing a minimum of 1-inch thick of shotcrete with fiber flash coating on the slope face. Prior to placing the shotcrete, the existing fill materials encountered on the slope face should be cut-back to a slope inclination of 0.5H:1V or flatter and scaling of the slope face should be performed to remove existing loose and unstable surface rocks. In addition, geocomposite drains should be placed on the face of the slope between the shotcrete to reduce the potential for the build-up of hydrostatic pressures. To reduce the potential for additional erosion at the slope toe from future flood events, we recommend installing a slope toe protection system consisting of a 19-foot wide by 10-foot high buttress fill covered with grouted rubble paving (GRP).

The existing concrete footing supporting the intermediate pier on the eastern side of the pedestrian bridge appears to have been exposed and undermined by heavy stream flow scour. We understand it is desired to construct an additional pier support adjacent to the existing intermediate pier foundation. Based on the subsurface conditions anticipated at the location of the new pier foundation, we recommend utilizing a shallow spread and/or strip footings for foundation support of the new pier planned at the pedestrian bridge. Due to the apparent undermining of the existing intermediate pier footing, we recommend embedding the new footing to a depth equal to the depth of the existing intermediate pier footing, which we have estimated to be approximately 9.5 feet below the existing ground surface.

In general, the on-site granular soils may be re-used as a source of general fill material, provided they are free of vegetation, deleterious materials, and rock fragments greater than 6 inches in maximum dimension. In addition, general fill materials should contain less than 15 percent particles passing the No. 200 sieve.

The text of this report should be referred to for detailed discussions and specific geotechnical recommendations.

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END OF SUMMARY OF FINDINGS AND RECOMMENDATIONS

## SECTION 1. GENERAL

This report presents the results of our geotechnical engineering exploration performed for the *Iao Valley State Monument Flood Repairs* project located in the Wailuku area on the Island of Maui, Hawaii. The project location and general vicinity are shown on the Project Location Map, Plate 1.

This report summarizes the findings and geotechnical recommendations resulting from our field exploration, laboratory testing, and engineering analyses for the project. These findings and geotechnical recommendations are intended for the design of interim remedial measures for the project including site grading, temporary slope protection, bridge foundations, trail path restoration, and potential rockfall hazards. The findings and recommendations presented herein are subject to the limitations noted at the end of this report.

### 1.1 Project Considerations

The project site is at the Iao Valley State Park visitor center in the Wailuku area on the Island of Maui, Hawaii. The Iao State Park encompasses a portion of the valley floor and lower elevation talus slopes in Iao Valley. The park consists of an existing parking lot and a system of paved foot paths, which traverse some generally lower height but steepened colluvial slopes.

An intense rainfall and flood event occurred on September 13, 2016 that affected numerous locations on the Island of Maui including the Iao Valley State Monument Park. As a result, on September 16, 2016 the Governor signed a 60-day emergency proclamation for flood damage to assist State and County agencies with storm damage rehabilitation.

A site visit to observe the storm damage was conducted on September 19, 2016. Based on our on-site meeting with representatives of the State Department of Land & Natural Resources (DLNR), we understand it is desired to approach the emergency repairs as a two-stage effort. Stage 1 involves a preliminary assessment of the damages and provision of recommendations and design work for emergency interim repairs including either stabilizing or closing portions of the park for possible limited re-opening



SECTION 1. GENERAL

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of the park for public access. Stage 2 involves additional engineering assessment and design of the permanent repairs. This report covers Stage 1 for interim remedial measures for the flood damage in an effort to re-open portions of the park for public access. A separate geotechnical engineering report will be prepared for the Stage 2 work efforts.

Based on our September 19, 2016 site visit, extraordinary heavy rainfall event produced extreme flood stage runoff that damaged and destroyed some existing park infrastructure. The damage included a large-scale slope failure, various streamside slope failures including destruction of pedestrian paths, bridge foundation scour, and destabilization of boulders on various slopes above the pedestrian pathways. Based on our reconnaissance, five (5) primary areas of storm damage affecting public safety were documented. The five areas of storm damage may be generalized as follows:

1. Parking Lot Slope Failure
2. Pedestrian Bridge Instability
3. Short Loop Trail Failure
4. Long Loop Trail Failure
5. Potential Rockfall Hazards

The parking lot slope failure consists of a length of steep streamside slope composed of fill and colluvial/alluvial boulder and soil deposits bordering Wailuku Stream (formerly Iao Stream) which was undermined by flooding and subsequently collapsed into the stream. The affected slope is adjacent to the main parking lot and access driveway. Under normal operation, the driveway experiences heavy vehicle traffic including buses and other large maintenance vehicles. The slope undermining by heavy stream flow at the toe of the slope caused a large-scale top-to-bottom failure of the slope face.

A concrete and steel pedestrian bridge crossing at Iao Stream provides public access to a scenic overlook and various pathways on the opposite stream bank. The existing concrete bridge pier footing on the eastern side of the pedestrian bridge appears to have been exposed and undermined by heavy stream flow scour. The eastern bridge pier footing was constructed in the stream channel near the eastern stream bank.

The Short Loop Trail failure consists of an approximate 40-foot length of streamside pathway composed of asphaltic concrete and steel railings that fully collapsed

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**SECTION 1. GENERAL**

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and were lost as a result of stream bank erosion by heavy stream flow. The failure occurred along a localized section of pedestrian pathway that parallels the stream in the lower rock garden adjacent to the parking lot. The path fell about 15 feet into the channel below leaving a near vertical and irregular eroded scarp face composed of boulders and cobbles bordering the stream.

The Long Loop Trail failure consists of approximately 300 linear feet of concrete pathway and steel railings which was destroyed by flood water at the southwestern corner of the park where a streamside loop trail was established. The pedestrian pathway extends across a low-relief topographic plain adjacent to the main stream channel. It appears that heavy stream discharge overwhelmed the main channel and spread laterally across the low-lying terrain adjacent to the stream channel.

Based on our observations, some slope areas at the western portion of the park adjacent to existing pedestrian pathways show signs of accelerated slope erosion from heavy storm runoff. Scour on the slopes have created exposure of potential falling rock hazards.

A layout of the project site is shown on the Site Plan, Plate 2. Photographs of the observed flood damage are presented on Plates 3.1 through 3.8.

## **1.2 Purpose and Scope**

The purpose of our exploration was to obtain an overview of the surface and subsurface conditions to develop an idealized soil/rock data set to formulate geotechnical engineering recommendations for the design of interim remedial measures for the project. The work was performed in general accordance with our fee proposal dated October 24, 2016. The scope of work for this exploration included the following tasks and work efforts:

1. Performance of field reconnaissance at the project site to observe the damaged areas by our project geologist and project manager.
2. Research and review of the available plans and in-house soil and geologic information related to the project area.

SECTION 1. GENERAL

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3. Coordinate staking of borehole locations and verify presence and locations of utilities.
4. Mobilization and demobilization of a truck-mounted drill rig currently on Maui and two operators from Oahu to the project site and back.
5. Mobilization and demobilization of a portable drill rig and two operators from Oahu to the project site and back.
6. Drilling and sampling of three borings extending to depths ranging from about 19 to 28 feet below the existing ground surface at the bridge location and three borings to depths ranging from 80.2 to 81.5 feet at the parking lot location.
7. Coordination of the field exploration and logging of the borings by our geologist.
8. Laboratory testing of selected soil samples obtained during the field exploration as an aid in classifying the materials and evaluating their engineering properties.
9. Analyses of the field and laboratory data to formulate geotechnical recommendations for the interim remediation repair for the project.
10. Preparation of this report summarizing our work and presenting our findings and geotechnical recommendations.
11. Coordination of our overall work on the project by our project engineer.
12. Quality assurance of our work and client/design team consultation by our principal engineer.
13. Miscellaneous work efforts such as drafting, word processing, and clerical support.
14. Preparation of Geotechnical drawings for the interim remediation repair construction documents.
15. Preparation of Technical Specifications for the interim remediation repair construction documents.

Detailed descriptions of our field exploration methodology and the Logs of Borings are presented in Appendix A. Results of the laboratory tests performed on selected soil samples are presented in Appendix B. Photographs of the rock cores are presented in Appendix C.

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END OF GENERAL

## SECTION 2. SITE CHARACTERIZATION

### 2.1 Regional Geology

Maui is the second largest island of the Hawaiian Archipelago. It was formed by the activity of two volcanoes, East Maui or Haleakala, and West Maui. The broad, gently sloping plain connecting the two volcanoes, known as the Maui Isthmus, was formed when lavas of the Haleakala Volcano banked against the already existing West Maui Volcano.

The East Maui Volcano, better known as the Haleakala Mountain, makes up the eastern portion of the Island of Maui. Haleakala Mountain is considered to be dormant with the last eruption taking place on the southerly side of the mountain around 1790. Haleakala Mountain consists largely of the Honomanu Volcanic Series that built the mountain from three rift zones, probably during the Pliocene and early Pleistocene Epochs.

The volcanic rocks of the West Maui Volcano have been divided into three volcanic series. The oldest, Wailuku Volcanic Series, is comprised of basaltic lava flows and associated pyroclastic and intrusive rocks, which built the major shield volcano. The Wailuku Volcanic Series was covered by a thin, discontinuous “frosting” of andesitic and trachytic flows, domes, and pyroclastic deposits known as the Honolua Volcanic Series. After a long period of inactivity, where erosion incised deep valleys into the volcanic flows, volcanic activity returned with eruptions that produced the flows and cones of the Lahaina Volcanic Series.

In the mountainous regions of Hawaii, erosion processes are dominated by the detachment of soil and rock materials from steep valley walls. The detached materials fall or are otherwise transported down slope toward the valley axis, primarily by gravity as colluvium. Once these materials reach the stream in the valley, stream flow processes become dominant, and the materials are further transported and may be deposited as alluvium.

In general, stream flows in Hawaii are intermittent and flashy (i.e., the streams transmit large volumes of water for very short durations). Because of this, the transport of

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**SECTION 2. SITE CHARACTERIZATION**

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sediment is intermittent, and the bulk of the stream's hydraulic load consists of a poorly sorted mixture of boulders, cobbles, gravel, sands, and fine soil. When the erosion base level changes with the passage of time, the stream sediment loads are left as deposits.

When alluvial and colluvial deposits are buried in-place for long periods of time, chemical processes begin to alter the materials, simultaneously causing a breakdown and weathering of the materials. Chemical processes may also cause induration, or cementation, of the sedimentary products into poorly to moderately consolidated sedimentary rock termed conglomerate. Simultaneously, ground erosion processes continue in the higher terrain above the valley floors. This continued upland erosion generates new unconsolidated alluvial and colluvial earth materials, which are then transported down slope and cover the older indurated deposits. Depending on the local erosion base level and rate of transport, these newer sediments may be generally transient in terms of geologic time. In addition, their consistency and density are generally less than those of the older, partially consolidated deposits.

The project site setting is within the low hills at the central valley floor within Iao Valley. The project site is adjacent to the confluence of three branching tributary streams feeding Iao Stream. The project site resides within the ancient collapsed caldera of the West Maui Volcano that has since been partially filled with colluvial talus rock and alluvial soils derived from the high-energy mass wasting (landslide) of the bordering valley walls. As a result, the site is underlain by an appreciable thickness of broken talus rock (colluvium) including poorly-sorted granular materials ranging from cobbles and gravel to extremely large boulders in excess of 15 feet in dimension. These materials were deposited in place for a very long time and have since undergone some chemical weathering which supports consolidation of the mixed alluvial and colluvial materials into a sedimentary rock material conglomerate. Continued stream incision has exposed these deposits at the ground surface today.

## **2.2 Existing Site Conditions**

The project site is at the Iao Valley State Park visitor center at the end of Iao Valley Road in the Wailuku area on the Island of Maui, Hawaii. The Iao Valley State Park encompasses a portion of the valley floor and lower elevation talus slopes in Iao Valley.

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**SECTION 2. SITE CHARACTERIZATION**

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The park consists of an existing parking lot and a system of paved foot paths which traverse some generally lower height but steepened colluvial slopes.

As previously mentioned, five primary areas of storm damage affecting public safety were documented during our site reconnaissance. The following sections describe the general existing site conditions for the five areas of storm damage. In addition, Photographs of the observed storm damage are presented on Plates 3.1 through 3.8.

### 2.2.1 Parking Lot Slope Failure

The parking lot slope failure site generally consists of a length of steep streamside slope adjacent to the main parking lot and access driveway composed of fill and colluvial/alluvial boulder and soil deposits bordering Wailuku Stream. The slope undermining by heavy stream flow at the toe of the slope that caused a large-scale top-to-bottom failure of the slope face.

The affected slope is approximately 180 feet in length and stands approximately 50 to 60 feet above Wailuku Stream, which is at the base of the slope. It appears an approximate 6 to 10-foot wide wedge of slope face material was lost during the full height slope failure. The failed slope now has an average inclination of about one-fourth horizontal to one vertical (0.25H:1V) from top to bottom with some sub-vertical slope segments. An undulating top of cliff has formed within about 7 to 12 feet of the existing driveway guardrail and pavement.

Based on the topographic plan provided, existing ground surface elevations at the parking lot slope failure range from about +913 feet Mean Sea Level (MSL) at the base of the failed slope to about +964 feet MSL at the top of the slope near the existing parking lot.

### 2.2.2 Pedestrian Bridge

The pedestrian bridge is a steel and concrete bridge crossing at Iao Stream that provides public access to a scenic overlook and various pathways on the western side of the project site. The existing pedestrian bridge has a span of about 67 feet and is supported by concrete/CMU abutments at each end of the bridge and an intermediate pier near the eastern side the stream bank. The existing concrete

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**SECTION 2. SITE CHARACTERIZATION**

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footing supporting the intermediate pier on the eastern side of the pedestrian bridge appears to have been exposed and undermined by heavy stream flow scour.

Based on the topographic plan provided, existing ground surface elevations at the pedestrian bridge range from about +958 feet MSL at the base of the intermediate bridge footing to about +984 feet MSL at the western bridge abutment.

### 2.2.3 Short Loop Trail Failure

The Short Loop Trail failure is an approximate 40-foot length of streamside pathway composed of asphaltic concrete and steel railings that fully collapsed and were lost as a result of stream bank erosion by heavy stream flow. The failure occurred along a localized section of pedestrian pathway that parallels the stream in the lower rock garden adjacent to the parking lot. The path fell about 15 feet into the channel below leaving a near-vertical and irregular eroded scarp face composed of boulders and cobbles bordering the stream.

Based on the topographic plan provided, existing ground surface elevations at the Short Loop Trail failure range from about +926 feet MSL at the base of the failed slope to about +948 feet MSL at the top of the slope on the western side of the trail loop.

### 2.2.4 Long Loop Trail Failure

The Long Loop Trail failure is approximately 300 linear feet of concrete pathway and steel railings that were destroyed by flood water at the southwestern corner of the park where a streamside loop trail was established. The pedestrian pathway extends across a low-relief topographic plain adjacent to the main stream channel. It appears that heavy stream discharge overwhelmed the main channel and spread laterally across the low-lying terrain adjacent to the stream channel. Based on our observations, the concrete pathway was undermined adjacent to the main channel and broken into pieces by heavy flood runoff carrying debris such as boulders and vegetation.

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**SECTION 2. SITE CHARACTERIZATION**

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Based on the topographic plan provided, existing ground surface elevations at the Long Loop Trail failure range from about +929 feet MSL at the base of the failed slope area to about +956 feet MSL at the top of the slope on the eastern side of the trail loop.

#### 2.2.5 Potential Rockfall Hazards

Based on our site observations, some slope areas at the western portion of the park adjacent to existing pedestrian pathways show signs of accelerated slope erosion from heavy storm runoff and scour on the slopes have created exposure of potential falling rock hazards.

The height of the slope in this area above the path ranges from about 20 to 55 feet with a slope inclination ranging from about 0.5H:1V to 1H:1V. The slope was vegetated with various vine/fern ground cover and scattered Christmas Berry trees and shrubbery with appreciable open ground exposure. Many loose and unsupported surface cobbles and boulders, in addition to semi-embedded rocks, were present on the slope face during our site reconnaissance.

We observed scattered boulders ranging up to about 3 feet in dimension on the slope surface. A large mass of intact rock (possible a single massive boulder or outcropping composed of consolidated colluviums) was observed at about mid-slope just above the bridge intersection with the pedestrian path. The mass appeared relatively stable with few visible rock fractures or separation discontinuities.

In addition, a large boulder of approximately 10 feet in diameter was observed to be perched precariously above a portion of the lower loop trail. Based on our observations, signs of runoff scour and removal of supporting material was observed at the base of the boulder.

Based on the topographic plan provided, existing ground surface elevations at the potential rockfall hazard sites range from about +984 feet MSL at the base of the slope to about +1,043 feet MSL at the top of the slope on the western side of the park.



## SECTION 2. SITE CHARACTERIZATION

**2.3 Subsurface Conditions**

We explored the subsurface conditions at the project site by drilling and sampling six borings, designated as Boring Nos. 1 through 6, extending to depths ranging from about 19 to 81.5 feet below the existing ground surface. The approximate boring locations are shown on the Site Plan, Plate 2.

The following subsections provide a brief description of the subsurface materials encountered in the borings drilled at the parking lot slope failure and the pedestrian bridge. The distribution of the drilled borings is described in the following table. Detailed descriptions of the materials encountered from our field exploration are presented on the Logs of Borings, Plates A-1 through A-6, in Appendix A. Results of the laboratory tests performed on selected samples obtained from our field exploration are presented in Appendix B. Photographs of the rock cores are presented in Appendix C.

LOCATION	APPLICABLE BORINGS
Pedestrian Bridge	Boring Nos. 1 through 3
Parking Lot Slope Failure	Boring Nos. 4 through 6

**2.3.1 Pedestrian Bridge**

Our borings at the two bridge abutments (Boring Nos. 1 and 3) generally encountered a pavement structure consisting of about 1 to 2 inches of asphaltic concrete overlying 4 to 11 inches of fill material consisting of medium dense to dense silty sand and gravel. The pavement structure was underlain by a colluvial/alluvial deposit consisting of dense to very dense gravel, cobbles, and boulders and medium dense to very dense silty sand to the maximum depth explored of about 21 feet below the existing ground surface.

Our boring near the intermediate pier (Boring No. 2) was drilled on the pedestrian bridge deck and generally encountered about 4 inches of concrete deck and about 7.5 feet of open space under the deck until the existing ground surface under the bridge deck was encountered. Similar to Boring Nos. 1 and 3, a colluvial/alluvial deposit consisting of loose to medium dense silty sand and dense to very dense

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**SECTION 2. SITE CHARACTERIZATION**

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gravel, cobbles, and boulders was encountered to the maximum depth explored of about 28 feet below the existing ground surface.

We did not encounter groundwater in the borings at the pedestrian bridge at the time of our field exploration. Considering the pedestrian bridge crosses Iao Stream, groundwater levels likely will vary in response to the water level in the stream. In addition, it should be noted that groundwater levels are subject to change due to rainfall, time of year, seasonal precipitation, surface water runoff, and other factors.

### **2.3.2 Parking Lot Slope Failure**

Our borings at the parking lot slope failure (Boring Nos. 4 through 6) generally encountered a pavement structure consisting of about 4 inches of asphaltic concrete overlying 12 inches of fill material consisting of medium dense silty sand and gravel. The pavement structure was underlain by about 20 to 40 feet of fill material consisting of very dense gravel, cobbles, and boulders with some silty sand and a colluvial/alluvial deposit consisting of very dense gravel, cobbles, and boulders with some clayey sand to the maximum depth explored of about 81.5 feet below the existing ground surface.

We encountered groundwater in the borings drilled at the time of our field exploration at depths varying from approximately 51 to 62 feet below the existing ground surface. The groundwater levels encountered generally correspond to about Elevations +898.5 to +903.5 feet MSL. Considering the project is located adjacent to Wailuku Stream, the groundwater levels may vary in response to the water level in the stream. In addition, it should be noted that the groundwater levels are subject to change due to rainfall, seasonal precipitation, surface water runoff, and other factors.

## **2.4 Seismic Design Considerations**

Based on the International Building Code (2006 Edition), the project site may be subject to seismic activity, and seismic design considerations will need to be addressed. The following sections provide discussions on the seismicity, soil profile type for seismic design, and the potential for liquefaction at the project site.

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**SECTION 2. SITE CHARACTERIZATION**

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**2.4.1 Earthquakes and Seismicity**

In general, earthquakes that occur throughout the world are caused by shifts in the tectonic plates. In contrast, earthquake activity in Hawaii is linked primarily to volcanic activity. Therefore, earthquake activity in Hawaii generally occurs before or during volcanic eruptions. In addition, earthquakes may result from the underground movement of magma that comes close to the surface but does not erupt. The Island of Hawaii experiences thousands of earthquakes each year, but most are so small that they can only be detected by sensitive instruments. However, some of the earthquakes are strong enough to be felt, and a few cause minor to moderate damage.

In general, earthquakes associated with volcanic activity are most common on the Island of Hawaii. Earthquakes that are directly associated with the movement of magma are concentrated beneath the active Kilauea and Mauna Loa Volcanoes on the Island of Hawaii. Because the majority of earthquakes in Hawaii (over 90 percent) are related to volcanic activity, the risk of seismic activity and degree of ground shaking diminishes with increased distance from the Island of Hawaii. The Island of Hawaii has experienced numerous earthquakes greater than Magnitude 5 (M5+); however, earthquakes are not confined only to the Island of Hawaii. To a lesser degree, the Island of Maui has experienced several earthquakes greater than Magnitude 5. Therefore, moderate to strong earthquakes have occurred in the County of Maui.

**2.4.2 Soil Profile Type for Seismic Design**

Based on the subsurface materials anticipated at the project site and the geologic setting of the area, we anticipate the project site may be classified from a seismic analysis standpoint as being a “Very Dense Soil and Soft Rock” site corresponding to a Site Class C soil profile type based on the 2006 International Building Code (Table No. 1613.5.2). Based on Site Class C, the following seismic design parameters were estimated and may be used for seismic analysis of the project.

## SECTION 2. SITE CHARACTERIZATION

<b>SEISMIC DESIGN PARAMETERS</b>	
<b>Parameter</b>	<b>Value</b>
Mapped MCE Spectral Response Acceleration, $S_S =$	0.957g
Mapped MCE Spectral Response Acceleration, $S_1 =$	0.244g
Site Class =	"C"
Site Coefficient, $F_a =$	1.017
Site Coefficient, $F_v =$	1.556
Adjusted MCE Spectral Response Acceleration, $S_{MS} =$	0.973g
Adjusted MCE Spectral Response Acceleration, $S_{M1} =$	0.380g
Design Spectral Response Acceleration, $S_{DS} =$	0.649g
Design Spectral Response Acceleration, $S_{D1} =$	0.253g
Peak Bedrock Acceleration, PBA (Site Class B) =	0.357g
Peak Ground Acceleration, PGA (Site Class C) =	0.248g

#### 2.4.1 Liquefaction Potential

Based on the International Building Code, 2006 Edition, the project site may be subjected to seismic activity, and the potential for soil liquefaction at the project site will need to be evaluated.

Soil liquefaction is a condition where saturated cohesionless soils located near the ground surface undergo a substantial loss of strength due to the build-up of excess pore water pressures resulting from cyclic stress applications induced by earthquakes. In this process, when the loose saturated sand deposit is subjected to vibration (such as during an earthquake), the soil tends to densify and decrease in volume causing an increase in pore water pressure. If drainage is unable to occur rapidly enough to dissipate the build-up of pore water pressure, the effective stress (internal strength) of the soil is reduced. Under sustained vibrations, the pore water pressure build-up could equal the overburden pressure, essentially reducing the soil shear strength to zero and causing it to behave as a viscous fluid. During liquefaction, the soil acquires a mobility sufficient to permit both horizontal and vertical movements, and if not confined, will result in significant deformations.

## SECTION 2. SITE CHARACTERIZATION

Soils most susceptible to liquefaction are loose, uniformly graded, fine-grained sands and loose silts with little cohesion. The major factors affecting the liquefaction characteristics of a soil deposit are as follows.

FACTORS	LIQUEFACTION SUSCEPTIBILITY
Grain Size Distribution	Fine and uniform sands and silts are more susceptible to liquefaction than coarse or well-graded sands.
Initial Relative Density	Loose sands and silts are most susceptible to liquefaction. Liquefaction potential is inversely proportional to relative density.
Magnitude and Duration of Vibration	Liquefaction potential is directly proportional to the magnitude and duration of the earthquake.

Based on the subsurface conditions encountered, the phenomenon of soil liquefaction is not a design consideration for this project site. The risk for potential liquefaction is non-existent based on the subsurface conditions encountered.

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END OF SITE CHARACTERIZATION

### SECTION 3. DISCUSSION AND RECOMMENDATIONS

Based on our September 19, 2016 site visit, an extraordinary heavy rainfall event produced extreme flood stage runoff that damaged and destroyed some existing park infrastructure. The damage included a large-scale slope failure adjacent to the main parking lot and access driveway, various streamside slope failures including destruction of pedestrian paths, bridge foundation scour, and destabilization of boulders on various slopes above the pedestrian pathways.

In general, we believe that the primary geotechnical considerations for the design of interim remedial measures for the project include the following:

- Temporary slope protection at parking lot slope failure
- Adequate foundation support for the new pier at the pedestrian bridge
- Scaling of existing loose and unstable surface rocks on slopes
- Site preparation and grading

For temporary support of the slope face materials at the parking lot slope failure, we recommend placing a minimum of 1-inch thick of shotcrete with fiber flash coating on the slope face. Prior to placing the shotcrete, the existing fill materials encountered on the slope face should be cut-back to a slope inclination of 0.5H:1V or flatter and scaling of the slope face should be performed to remove existing loose and unstable surface rocks. In addition, geocomposite drains should be placed on the face of the slope between the shotcrete to reduce the potential for the build-up of hydrostatic pressures.

To reduce the potential for additional erosion at the slope toe from future flood events, we recommend installing a slope toe protection system consisting of a 19-foot wide by 10-foot high buttress fill covered with grouted rubble paving (GRP), as shown on Plate 4. In addition, pedestrians and vehicles should be placed behind a 30-foot setback from top of slope for safety considerations.

Based on the subsurface conditions anticipated at the location of the new pier foundation, we recommend utilizing a shallow spread and/or strip footings for foundation support of the new pier planned for the interim repair measure at the pedestrian bridge. Due to the apparent undermining of the existing intermediate pier footing, we recommend

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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embedding the new footing to a depth equal to the depth of the existing intermediate pier footing, which we have estimated to be approximately 9.5 feet below the existing ground surface.

In general, the on-site granular soils may be re-used as a source of general fill material, provided they are free of vegetation, deleterious materials, and rock fragments greater than 6 inches in maximum dimension. In addition, general fill materials should contain less than 15 percent particles passing the No. 200 sieve.

### **3.1 Temporary Slope Protection at Parking Lot Slope Failure**

Based on our site reconnaissance, the affected slope adjacent to the main parking lot and access driveway is approximately 180 feet in length and stands approximately 50 to 60 feet above Wailuku Stream, which is at the base of the slope. It appears an approximate 6 to 10-foot wide wedge of slope face material was lost during the full height slope failure. The failed slope now averages about a 0.25H:1V inclination from top to bottom with some sub-vertical slope segments. An undulating top of cliff has formed within about 7 to 12 feet of the existing driveway guardrail and pavement.

As previously mentioned, our borings at the parking lot slope failure generally encountered a pavement structure overlying about 20 to 40 feet of fill material consisting of very dense gravel, cobbles, and boulders with some silty sand and a colluvial/alluvial deposit consisting of very dense gravel, cobbles, and boulders with some clayey sand to the maximum depth explored of about 81.5 feet below the existing ground surface.

Items pertaining to the temporary slope protection at the parking lot slope failure are addressed in the subsequent subsections and include the following:

1. Temporary Traffic Barrier
2. Site Preparation
3. Slope Cut-Back
4. Slope Scaling
5. Shotcrete Facing
6. Drainage
7. Slope Toe Protection

Ideally, remedial measures for the slope protection would consist of the installation of soil nails and a thick shotcrete layer on the slope face. Due to cost and time constraints,

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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we understand that a temporary interim repair is desired. Therefore, the placement of an initial shotcrete layer will be performed for the temporary repair. We assume that the permanent repair will be performed shortly thereafter. Should the permanent repair be delayed for an extended amount of time, repair of the thin initial shotcrete layer may be required.

A Geolabs representative should monitor the temporary slope protection operations to observe whether undesirable materials are encountered during the excavation process, and to confirm whether the exposed soil conditions are similar to those assumed herein.

### 3.1.1 Temporary Traffic Barrier

We understand park usage/traffic by the public is generally high with a steady stream of arriving and departing sightseers on a daily basis. Considering the top of the failed slope area is about 7 to 12 feet away from the existing driveway guardrail and pavement, we recommend installing temporary traffic barriers at least 30 feet away from the top of failed slope as a safety precaution. The traffic barriers should be placed along the entire length of the parking lot and should remain in-place until a long-term repair such as soil nails and additional shotcrete are installed.

### 3.1.2 Site Preparation

At the on-set of earthwork, the area within the contract grading limits at the parking lot slope failure should be cleared and grubbed thoroughly. Vegetation, debris, deleterious materials, and other unsuitable materials should be removed and disposed of properly off-site or in a designated area to reduce the potential for contamination of the excavated materials.

Soft and yielding areas encountered during clearing and grubbing below areas designated to receive fill, such as the slope toe protection, should be over-excavated to expose firm material, and the resulting excavation should be backfilled with 6-inch minus general fill material wrapped in a woven geotextile fabric, such as Mirafi FW700 or equivalent. The excavated soft soils should not be



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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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re-used as fill materials and should be properly disposed of off-site or in landscaped areas, if appropriate.

### 3.1.3 Slope Cut-Back

After clearing and grubbing, the existing fill materials encountered on the slope face should be cut-back to a slope inclination of 0.5H:1V or flatter. Our borings performed in this area generally encountered fill materials about 20 to 40 feet thick consisting of medium dense gravel, cobbles, and boulders with some silty sand. Therefore, we recommend cutting back at least the top 30 feet of the failed slope area to a slope inclination of 0.5H:1V or flatter.

### 3.1.4 Slope Scaling

Slope scaling is the careful, systematic removal of loose rock and debris from a slope face using manual labor methods such as hand and prybar removal. Slope scaling is typically performed by an experienced scaling crew(s) working methodically with hand tools from top down and across the slope face. Care is taken to avoid over-steepening of the slope resulting in new rock slope instability.

After cutting back the fill materials encountered on the slope face, we recommend scaling the slope to remove loose materials prior to placement of the geocomposite drains and shotcrete.

### 3.1.5 Shotcrete Facing

For temporary support of the slope face materials, we recommend placing a minimum of 1-inch thick of shotcrete with fiber flash coating. Shotcrete should have a minimum compressive strength at 28 days of 4,000 pounds per square inch (psi) and have a maximum 0.45 water to cement ratio. A shrinkage reducing admixture, such as Eclipse or Master Life AS20 or equivalent, should be added at a dosage of 128 ounces per cubic yard as recommended by the manufacturer. In addition, shotcrete should contain 7.5 pounds of Strux 90/40 synthetic structural fiber, or equivalent.

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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Shotcrete placement should be performed by an experienced nozzleman. Prior to production shotcreting, it is recommended that test panels of shotcrete be constructed for inspection.

### 3.1.6 Drainage

The shotcrete slope face should be well drained to reduce the potential for build-up of hydrostatic pressures. A typical drainage system for the shotcrete slope would consist of 2 to 3-foot wide strips of a prefabricated drainage composite product (geocomposite drains) placed on the face of the slope between the shotcrete with a center-to-center spacing of about 8 feet. The cut face of the slope should be relatively flat for the placement of the prefabricated drainage product. The prefabricated drainage composite product should extend from the top to the base of the slope and should be hydraulically connected to a weep hole at the planned toe protection at the base of the slope, as shown on Plate 4.

### 3.1.7 Slope Toe Protection

To reduce the potential for additional erosion at the slope toe from future flood events, we recommend installing a slope toe protection system consisting of a 19-foot wide by 10-foot high buttress fill covered with grouted rubble paving (GRP), as shown on Plate 4. The fill material behind the GRP should consist of 6-inch minus general fill material wrapped in a woven geotextile fabric, such as Mirafi FW700 or equivalent.

On-site granular material can be used for the 6-inch minus general fill material, provided the material meet the requirements specified in the “Fills and Backfills” section presented herein. The 6-inch minus fill materials should be placed in level lifts of about 2 feet thick or less, with each lift wrapped in the woven geotextile fabric.

The GRP covering should consist of 2-ton boulders, 2 to 3-foot in nominal diameter with voids in-filled with concrete placed at a slope inclination of 1.5H:1V or flatter. A toe stone key should be provided at the base of the toe protection system extending below the planned scour depth. It should be noted that estimated scour

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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depth at the failed parking lot slope area have not been provided at the time this report was prepared. The toe stone should consist of 3 to 5-ton boulders with a nominal diameter of about 4 to 5 feet. To reduce the potential for hydrostatic pressures to build-up behind the toe protection system, weep holes consisting of 6-inch diameter PVC pipes should be provided with a center-to-center spacing of about 8 feet or less, as shown on Plate 4.

### **3.2 Pedestrian Bridge Foundations**

The existing concrete footing supporting the intermediate pier on the eastern side of the pedestrian bridge appears to have been exposed and undermined by heavy stream flow scour. We understand it is desired to construct an additional pier support adjacent to the existing intermediate pier foundation for the temporary interim repair.

Based on the subsurface conditions anticipated at the location of the new pier foundation, we recommend utilizing a shallow spread and/or strip footings for foundation support of the new pier planned at the pedestrian bridge. An allowable bearing pressure of up to 4,000 pounds per square foot (psf) may be utilized for the design of bridge foundations bearing on the underlying dense gravelly cobbles and boulders. This bearing value is for supporting dead-plus-live loads and may be increased by one-third ( $1/3$ ) for transient loads, such as those caused by wind or seismic forces.

To provide uniform bearing support of the foundations, we recommend placing a minimum 6-inch thick layer of mud slab consisting of lean concrete or mortar below the footings to serve as a leveling course. We do not recommend the use of soil type backfills below and along the stream side of the bridge footing because the footings are located adjacent to an active waterway.

Due to the apparent undermining of the existing intermediate pier footing, we recommend embedding the new footing to a depth greater than or equal to the depth of the existing intermediate pier footing, which we have estimated to be approximately 9.5 feet below the existing ground surface. Soft and/or loose materials encountered at the bottom of the footing excavations should be over-excavated to expose the underlying dense gravelly cobbles and boulders. The over-excavation should be backfilled with lean

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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concrete, or the bottom of footing may be extended deeper to bear on the more competent subgrade materials.

If foundations are designed and constructed in strict accordance with the recommendations presented herein, we estimate total settlements of the foundations to be less than 1 inch. Differential settlements between adjacent footings supported on similar materials may be on the order of about 0.5 inch or less.

Lateral loads acting on the structures may be resisted by friction between the base of the foundation and the bearing materials and by passive earth pressure developed against the near-vertical faces of the embedded portion of foundations. A coefficient of friction of 0.6 may be used for footings bearing directly on the dense gravely cobbles and boulders. Resistance due to passive earth pressure should be neglected.

### **3.3 Short and Long Loop Trail Restoration**

Based on our observations, existing concrete walkways and staircases along portions of both the Short and Long Loop Trails were significantly damaged and/or destroyed by flood waters and stream bank erosion. We understand it is desired restore at least portions of the trails with concrete walkways as part of the interim remedial measures for the project.

Based on the subsurface conditions anticipated along the trail paths, we recommend supporting the concrete walkways on at least 6 inches of non-expansive, select granular fill material to provide a uniform bearing surface and level working platform. A geotextile fabric, such as Mirafi 180N or equivalent, should be provided below and along the sides of the non-expansive, select granular fill layer to reduce the potential for migration of the granular fill material into the underlying cobbles and boulders. The select granular fill material should be moisture-conditioned to above the optimum moisture content and compacted to a minimum of 90 percent relative compaction. Prior to placing the geotextile fabric and select granular fill material, the walkway subgrade should be compacted to a firm and unyielding surface.

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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We recommend concrete walkways be at least 4 inches thick. In addition, control joints should be provided at intervals equal to the width of the walkways with expansion joints at right-angle intersections.

### **3.4 Rockfall Hazard Mitigation**

Rockfall is a type of natural mass wasting process that is in-part responsible for the evolution of mountain slopes. Rockfall is a common natural hazard due to the steep volcanic terrain comprising the mountains and valleys of the Islands of Hawaii. Rockfall activity involves the detachment of a rock mass from the slope face and the fall of rock materials under the force of gravity. Rockfall may involve a single unstable block of rock outcrop or it may involve a rockslide which encompasses multiple rock components.

Falling rock behavior can be complicated by the varying character of the ground surface and topography encountered along the rock fall line. Rocks may either roll, bounce, or have combined movement vectors. Falling rock may also hang up temporarily or permanently on the slope without reaching the bottom under the effects of terrain roughness, topography, vegetation, and the presence of natural features such as berms and terraces formed by other rock outcroppings.

Under the current state of engineering practice combined with the use of proven rockfall control methods, it is still impractical to mitigate 100 percent of all potential rockfall activity at a site. However, with careful engineering and quality construction during the installation of appropriate rockfall mitigation controls, the risk for rockfall activity can be substantially reduced.

For this project, the identified potential rockfall hazards represent weakly to moderately consolidated colluvial and alluvial cobbles and boulders with soil matrix. Due to the type of rock deposit material composing the slopes, including a general wide range in rock shapes and degrees of inter-grain cementation, traditional geologic mapping of slope face rock fractures and discontinuities is not applicable. Thus, the focus of our evaluation is based on capturing the anticipated potential rockfall adjacent to the trail pathways or providing appropriate setbacks for debris catchment or hazard avoidance.

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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**3.4.1 Rock Slope Scaling**

Rock slope scaling is the careful, systematic removal of loose rock and debris from a slope face using manual labor methods such as hand and prybar removal. Mechanized rock slope scaling is undesirable at this project site due to the potential for inadvertent overly-intensive rock removal causing rock slope instability. Rock slope scaling is typically performed by an experienced scaling crew(s) working methodically with hand tools from top down and across the slope face. Care is taken to avoid over-steepening of the slope resulting in new rock slope instability. Occasionally, extra slope scaling effort is needed to stabilize local rock outcroppings or interconnected masses of fractured rock material in order to develop a stabilized slope face.

Slope scaling is recommended as part of the interim remedial repairs to reduce the volume of potential rockfall involving the existing loose and unstable surface rocks on the slope. Slope scaling would need to be repeated at intervals without a protective fence structure along the slope toe to maintain some level of limited hazard reduction for pedestrians. Slope scaling as a stand-alone improvement is considered an interim mitigation measure that must be repeated to maintain the hazard reduction.

If rockfall mitigation effort is not performed, uncontrolled and potentially dangerous rockfall impact at the pathway is likely and should be expected to occur at some time due to the presence of appreciable source rock materials on the slope.

**3.4.2 Single Boulder Removal**

Based on our site observations, a large boulder of approximately 10 feet in diameter was observed to be perched precariously above a portion of the lower loop trail, as shown on the Site Plan, Plate 2, and Photograph No. 16 on Plate 3.8. This boulder was originally documented in our preliminary rockfall hazard assessment of the existing slope conditions at the park in January 2016. At the time of our January 2016 assessment, we observed the boulder to be set on sloping ground with several small boulders lodged underneath. We determined the lodged boulders provided some basal support and marginal stability against

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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sliding/rolling, but recommended boulder stabilization due to the marginally stable condition and the potential for serious injury if the rock was to fall.

Based on our observation of the single boulder condition following the flood of September 13, 2016, we observed a portion of the existing embankment which supports the boulder had eroded and collapsed by the storm water wash-out.

The embankment supporting the boulder is composed of loose/medium dense, highly weathered rock and soil (older colluvium). The partial collapse of the embankment material occurred at the front, downslope side of the boulder. We also observed some loss of pre-existing granular supporting material from the base of the boulder where it contacts the slope surface. The loss of basal support material appears to have left the boulder restrained on the slope by only a few remaining key cobbles and a small boulder acting as a wedge.

Based on our observations, we believe the boulder stability is compromised by the erosion and partial collapse of the supporting embankment due to the flood runoff. Therefore, we recommend moving the boulder to an adjacent stable ground setting to reduce the potential for a dangerous rockfall event, prior to reopening of the park for public access.

### **3.5 Site Grading**

We anticipate site grading at the project site to generally consist of relatively shallow excavations for foundation and toe protection construction, and cut slope excavations to achieve the design finished grades. Items of site grading that are addressed in the subsequent subsections include the following:

1. Site Preparation
2. Fills and Backfills
3. Fill Placement and Compaction Requirements
4. Excavations
5. Cut Slopes

A Geolabs representative should monitor site grading operations to observe whether undesirable materials are encountered during the site preparation and

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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excavation, and to confirm whether the exposed soil conditions are similar to those assumed herein.

### 3.5.1 Site Preparation

At the on-set of earthwork, the area within the contract grading limits should be cleared and grubbed thoroughly. Vegetation, debris, deleterious materials, and other unsuitable materials should be removed and disposed of properly off-site or in a designated area to reduce the potential for contamination of the excavated materials.

Soft and yielding areas encountered during clearing and grubbing below areas designated to receive fill, such as the slope toe protection and concrete walkways, should be over excavated to expose firm material, and the resulting excavation should be backfilled with 6-inch minus general fill material wrapped in a woven geotextile fabric, such as Mirafi FW700 or equivalent. The excavated soft soils should not be re-used as fill materials and should be properly disposed of off-site or in landscaped areas, if appropriate. After clearing and grubbing, areas to receive fills should be compacted to a firm and unyielding surface.

Saturation and subsequent yielding of the exposed subgrade due to inclement weather and poor drainage may require over-excavating the soft areas and replacing these areas with engineered fill. A Geolabs representative in the field should evaluate the need for over-excavation due to soft subgrade soil conditions.

### 3.5.2 Fills and Backfills

In general, the on-site granular soils may be re-used as a source of general fill material, provided they are free of vegetation, deleterious materials, and rock fragments greater than 6 inches in maximum dimension. In addition, general fill materials should contain no more than 15 percent particles passing the No. 200 sieve.

We do not anticipate the need for imported general fill materials for the project. However, if imported general fill materials are needed, Geolabs should be consulted to provide supplemental recommendations for imported fill materials needed for the project.



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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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Imported fill materials should consist of crushed basalt or coral. The select granular fill should be well graded from coarse to fine with particles no larger than 3 inches in largest dimension and should contain between 10 and 30 percent particles passing the No. 200 sieve. The material should have a laboratory CBR value of 20 or more and should have a maximum swell of less than 1 percent when tested in accordance with ASTM D1883. Geolabs should test imported fill materials a minimum of 7 days prior to being transported to the project site for the intended use.

### 3.5.3 Fill Placement and Compaction Requirements

General fill materials should be placed in level lifts not exceeding 2 feet in loose thickness, moisture-conditioned to above the optimum moisture content, and compacted to at least 90 percent relative compaction. The non-expansive select granular fill materials should be placed in level lifts of about 8 inches in loose thickness, moisture-conditioned to above the optimum moisture, and compacted to at least 90 percent relative compaction.

Relative compaction refers to the in place dry density of soil expressed as a percentage of the maximum dry density of the same soil established in accordance with ASTM D1557. Optimum moisture is the water content (percentage by weight) corresponding to the maximum dry density.

Compaction should be accomplished by sheepsfoot rollers, vibratory rollers, or other types of acceptable compaction equipment. Water tamping, jetting, or ponding should not be allowed to compact the fills.

### 3.5.4 Excavations

Based on the anticipated grading and our field exploration, excavation for this project will generally consist of shallow excavations for foundation and toe protection construction and cut slope excavations to achieve the design finished grades. The planned excavations will likely encounter cobbles and boulders with some soil. It is anticipated that most of the material may be excavated with normal heavy excavation equipment. However, deep excavations and boulder excavations may require the

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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use of hoerams. Special care should be taken to avoid inadvertent overly-intensive rock removal causing slope instability.

The above discussions regarding the rippability of the subsurface materials are based on field data from the borings drilled at the site. Contractors should be encouraged to examine the site conditions and the subsurface data to make their own reasonable and prudent interpretation.

### **3.5.5 Cut Slopes**

Cut slopes at the parking lot slope failure should be designed with a slope inclination of 0.5 horizontal to one vertical (0.5H:1V) or flatter, provided shotcrete is placed along the slope face in the interim and additional shotcrete and soil nails be provided for long-term stability.

### **3.6 Design Review**

Preliminary and final drawings and specifications for the project should be forwarded to Geolabs for review and written comments prior to bid solicitation for construction. 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 be responsible for misinterpretation of our recommendations.

### **3.7 Post-Design Services/Services During Construction**

Geolabs should be retained to provide geotechnical engineering services during construction. The critical items of construction monitoring that require "Special Inspection" include the following:

- Observation of site and subgrade preparation
- Observation of cut slope excavations
- Observation of shotcrete placement
- Observation of toe protection construction
- Observation of fill and backfill placement
- Observation of the bridge foundation excavation
- Observation of slope scaling
- Observation of single boulder stabilization/relocation

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**SECTION 3. DISCUSSION AND RECOMMENDATIONS**

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A Geolabs representative also should monitor other aspects of earthwork construction to observe compliance with 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. Geolabs should be accorded the opportunity to provide geotechnical engineering services during construction to confirm our assumptions in providing the recommendations presented herein.

If the actual exposed subsurface conditions encountered during construction differ from those assumed or considered herein, Geolabs should be contacted to review and/or revise the geotechnical recommendations presented herein.

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END OF DISCUSSION AND RECOMMENDATIONS

## SECTION 4. LIMITATIONS

The analyses and recommendations submitted herein are based in part upon information obtained from the site reconnaissance and field borings. Variations of the subsurface conditions between and beyond the field borings may occur, and the nature and extent of these variations may not become evident until construction is underway. If variations then appear evident, it will be necessary to re-evaluate the recommendations presented herein.

The field boring locations indicated herein are approximate, having been estimated by taping from visible features shown on the Preliminary Topographic Survey Plan transmitted by Wilson Okamoto Corporation on November 16, 2016. Elevations of the borings were estimated from contours and spot elevations shown on the same plan. The field boring locations and elevations should be considered accurate only to the degree implied by the methods used.

The stratification breaks shown on the graphic representations of the borings depict the approximate boundaries between soil types and, as such, may denote a gradual transition. Water level data from the borings were measured at the times shown on the graphic representations and/or presented in the text of this report. These data have been reviewed and interpretations made in the formulation of this report. Considering the project site is located adjacent to Wailuku and Iao Streams, the groundwater levels may vary in response to the water level in the streams. In addition, it should be noted that the groundwater levels are subject to change due to rainfall, seasonal precipitation, surface water runoff, and other factors.

This report has been prepared for the exclusive use of Wilson Okamoto Corporation and the State of Hawaii, Department of Land and Natural Resources and their project consultants for specific application to the design of interim remedial measures for the *Iao Valley State Monument Flood Repairs* project in accordance with generally accepted geotechnical engineering principles and practices. No warranty is expressed or implied.

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**SECTION 4. LIMITATIONS**

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This report has been prepared solely for the purpose of assisting the design engineers in the design of interim remedial measures for the project. Therefore, this report may not contain sufficient data, or the proper information, to serve as a basis for detailed construction cost estimates.

The owner/client should be aware that unanticipated soil conditions are commonly encountered. Unforeseen subsurface conditions, such as perched groundwater, soft deposits, hard layers or cavities, may occur in localized areas and may require additional probing or corrections in the field (which may result in construction delays) to attain a properly constructed project. Therefore, a sufficient contingency fund is recommended to accommodate these possible extra costs.

This geotechnical engineering exploration conducted at the project site was not intended to investigate the potential presence of hazardous materials existing at the project site. It should be noted that the equipment, techniques, and personnel used to conduct a geo-environmental exploration differ substantially from those applied in geotechnical engineering.

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END OF LIMITATIONS

**CLOSURE**

The following plates and appendices are attached and complete this report:

Project Location Map..... Plate 1

Site Plan..... Plate 2

Photographs of Observed Storm Damage ..... Plates 3.1 thru 3.8

Temporary Slope Protection at Parking Lot Slope Failure..... Plate 4

Field Exploration ..... Appendix A

Laboratory Tests ..... Appendix B

Photographs of Rock Cores ..... Appendix C

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Respectfully submitted,

**GEOLABS, INC.**

**DRAFT**

By \_\_\_\_\_  
**Andrew J. Felkel, P.E.**  
Project Engineer

**DRAFT**

By \_\_\_\_\_  
**Gerald Y. Seki, P.E.**  
Vice President

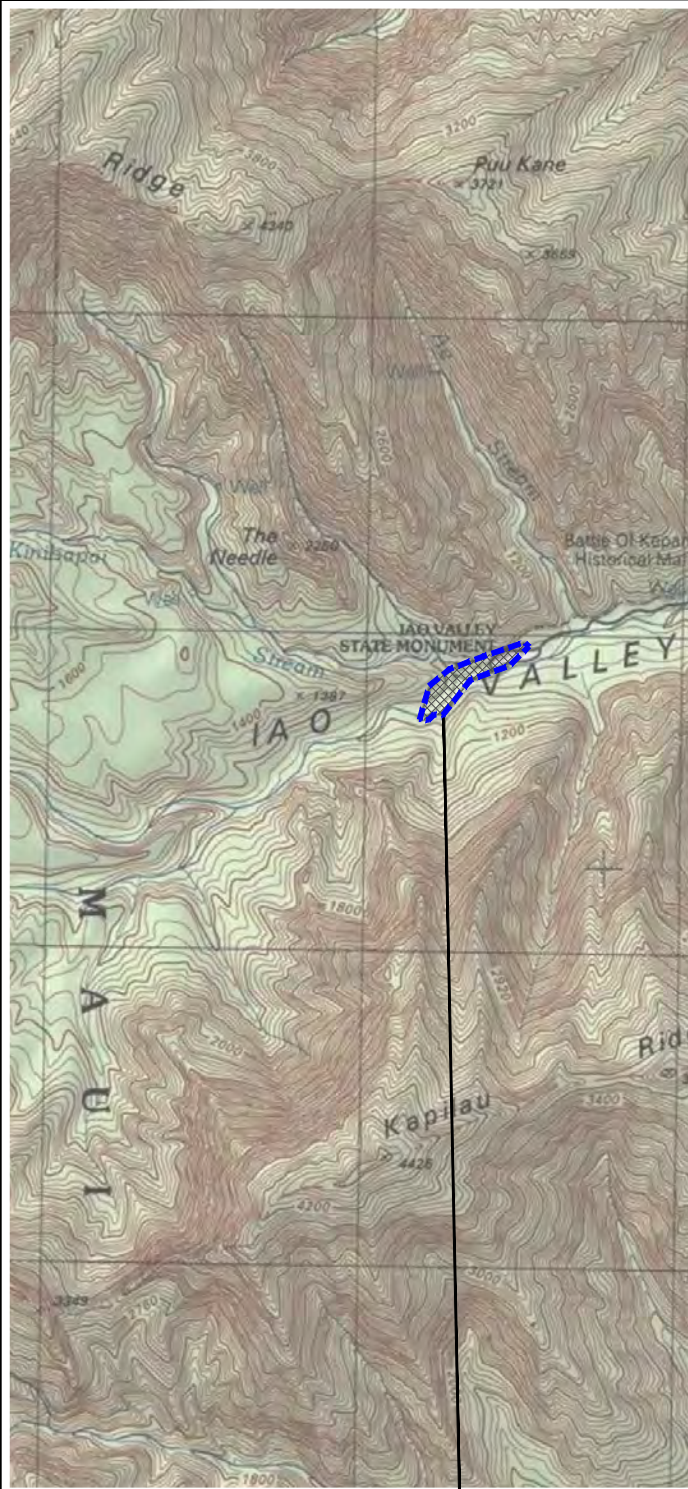
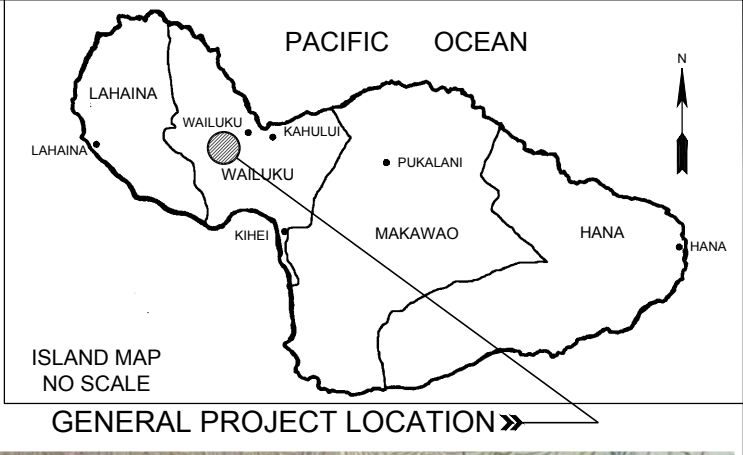
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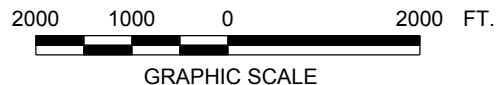
**PLATES**

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PROJECT LOCATION »

**PROJECT LOCATION MAP**  
**IAO VALLEY STATE MONUMENT FLOOD REPAIRS**  
**JOB NO. J45CM41A**  
**INTERIM REMEDIAL MEASURES**  
**WAILUKU, MAUI, HAWAII**

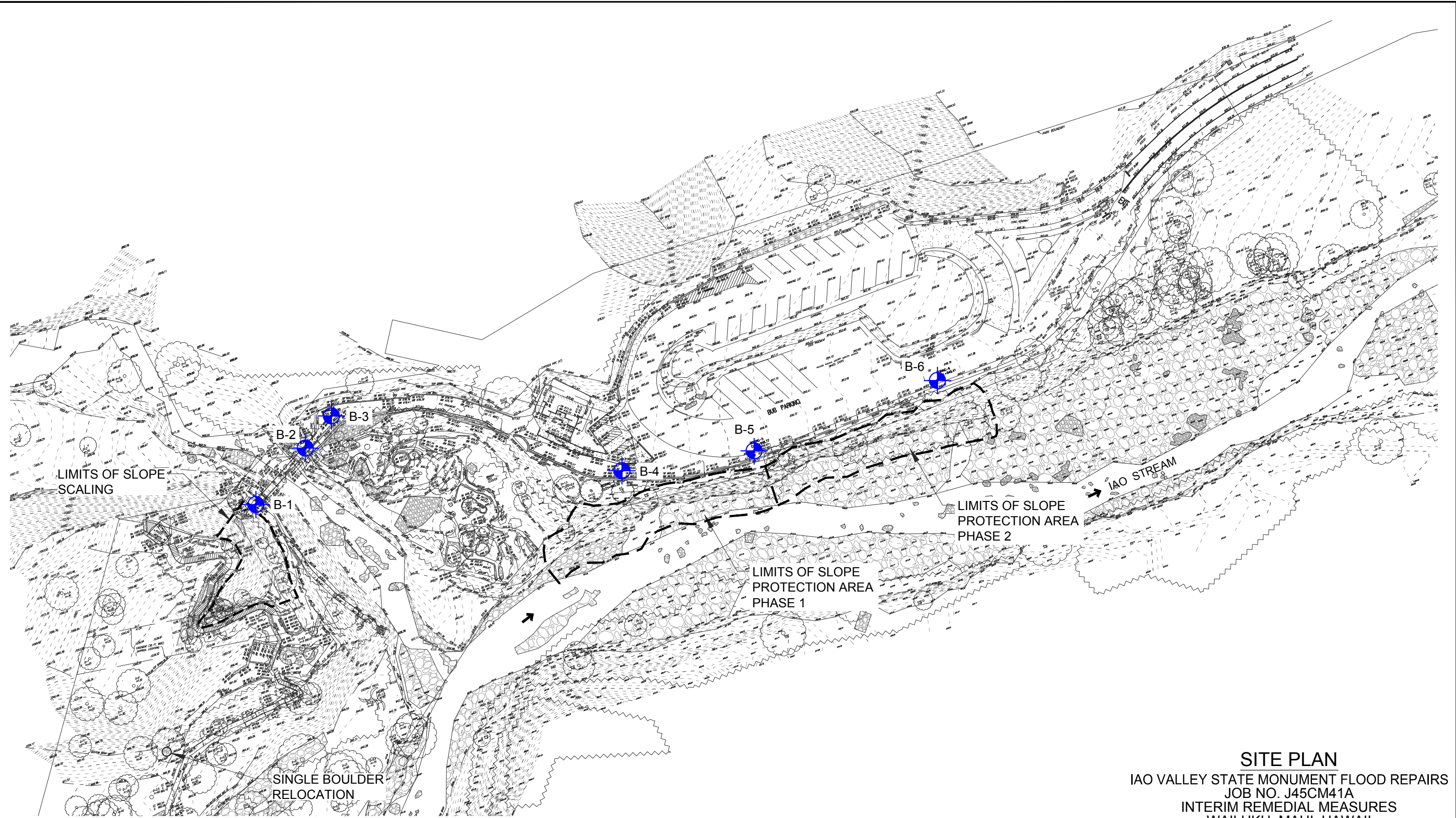


<b>GEOLABS, INC.</b>		
<i>Geotechnical Engineering</i>		
DATE	DRAWN BY	PLATE
NOVEMBER 2016	ASP	
SCALE	W.O.	1
1" = 2,000'	7417-00(A)	

REFERENCE: MAP CREATED WITH TOPO!® ©2010 NATIONAL GEOGRAPHIC; ©2007 TELE ATLAS, REL. 1/2007.

CAD User: ASPASIONJR File Last Updated: November 22, 2016 2:31:02pm Plot Date: November 22, 2016 - 3:32:46pm  
 File: T:\Drafting\Working\7417-00(A)IaoValleyStateMonument\FloodRepairs\7417-00PLM.dwg\PLM  
 Plotter: DWG To PDF.pc3 Plotstyle: GEO-No-Dithering.ctb





CAD User: ASPASIONJR File Last Updated: November 23, 2016 4:27:17pm Plot Date: December 01, 2016 - 4:40:02pm  
 File: T:\Drafting\Working\7417-00(A)\IaoValley\State\Monument\FloodRepairs\7417-00SITEPLAN.dwg SitePlan  
 Plotter: DWG To PDF.pc3 Plotstyle: GEO-No Dithering-Blue-Boring.ctb

**LEGEND:**  
 APPROXIMATE BORING LOCATION



**SITE PLAN**  
 IAO VALLEY STATE MONUMENT FLOOD REPAIRS  
 JOB NO. J45CM41A  
 INTERIM REMEDIAL MEASURES  
 WAILUKU, MAUI, HAWAII

GEOLABS, INC.		
Geotechnical Engineering		
DATE	DRAWN BY	PLATE
NOVEMBER 2016	ASP	
SCALE	W.O.	
1" = 80'	7417-00(A)	2

REFERENCE: PRELIMINARY TOPOGRAPHIC SURVEY PLAN RECEIVED FROM WILSON OKAMOTO CORPORATION ON NOVEMBER 16, 2016.

Iao State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii



**Photograph No. 1:** View upstream of the parking lot slope failure site on September 13, 2016



**Photograph No. 2:** View downstream of the parking lot slope failure site.

Iao State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii



**Photograph No. 3:** Existing top of slope condition with view in the upstream direction.



**Photograph No. 4:** Existing top of slope condition with view in the downstream direction.

Iao State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii



**Photograph No. 5:** Existing condition of the parking lot slope failure site from the stream elevation. Note the semi-consolidated character of the older colluvial deposits exposed in the lower portion of the slope, in contrast to the overlying unconsolidated overcast fill materials comprising the upper portion of the slope.



**Photograph No. 6:** Closer view of the semi-consolidated older colluvial materials comprising the lower slope at the parking lot slope failure site.

Iao State Monument Flood Repairs  
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Wailuku, Maui, Hawaii



**Photograph No. 7:** Existing condition of the pedestrian bridge with view towards the north abutment.



**Photograph No. 8:** Exposure by stream scour of the existing bridge pier foundation at the north abutment of the bridge.

Iao State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii



**Photograph No. 9:** Exposure by stream scour of the existing bridge pier foundation at the northern abutment of the bridge.



**Photograph No. 10:** Bank failure and loss of pathway and railings at the short loop trail.

Iao State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii



**Photograph No. 11:** Stream bank collapse truncating the northern portion of the long loop trail.



**Photograph No. 12:** Stream bank collapse truncating the northern portion of the long loop trail.

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Wailuku, Maui, Hawaii



**Photograph No. 13:** Portion of the concrete pathway on the long loop trail destroyed by floodwater.



**Photograph No. 14:** Undermining and exposure of existing basaltic cobbles and boulders mantling the taller slopes adjacent to the pathway. Site of proposed slope scaling.



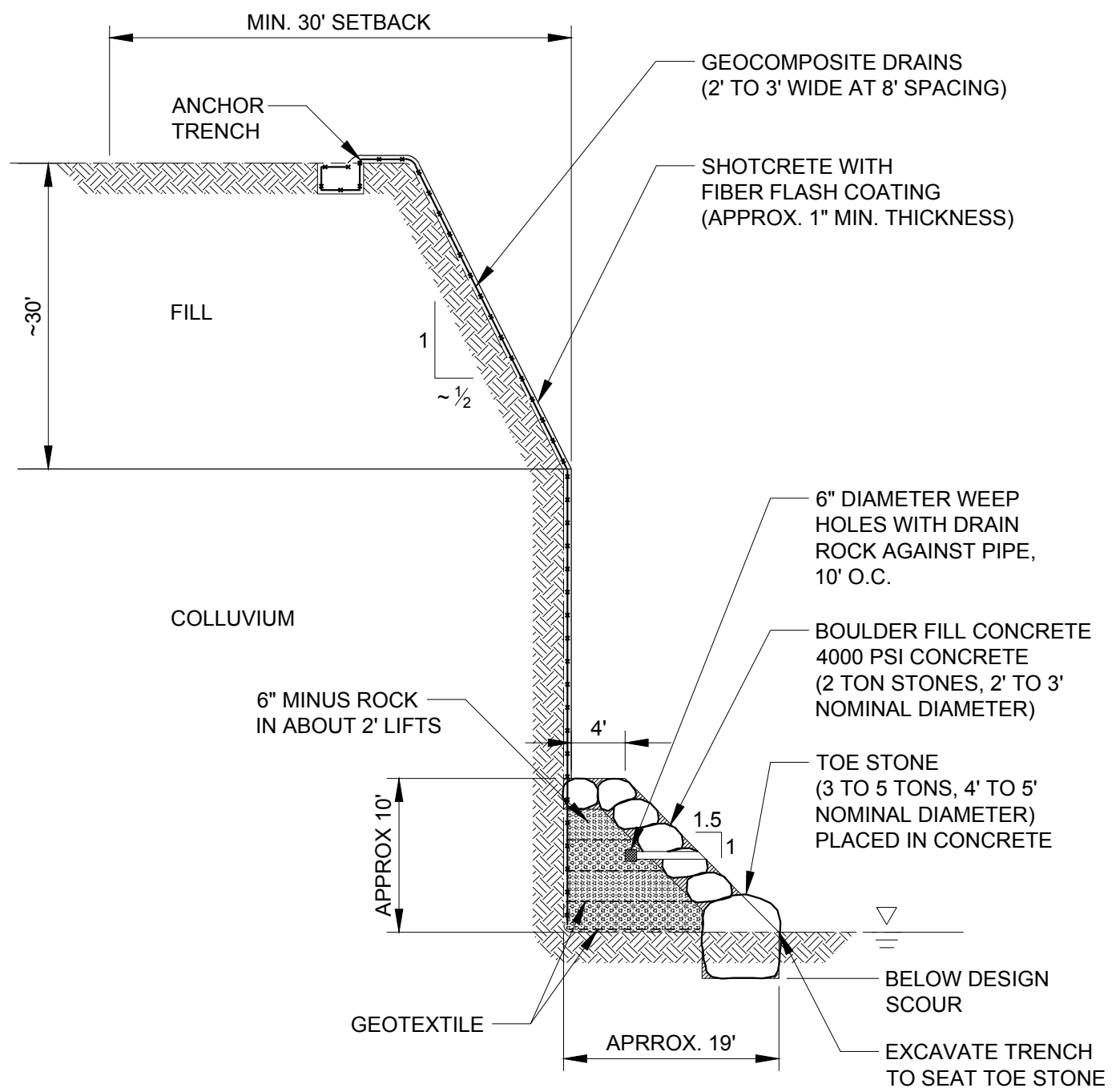
Iao State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii



**Photograph No. 15:** Undermining and exposure of existing basaltic cobbles and boulders mantling the taller slopes adjacent to the pathway. Site of proposed slope scaling.



**Photograph No. 16:** Single large boulder proposed for stabilization along a section of the remaining portion of the long loop trail.



**TEMPORARY SLOPE PROTECTION AT  
PARKING LOT SLOPE FAILURE**  
IAO VALLEY STATE MONUMENT FLOOD REPAIRS  
JOB NO. J45CM41A  
INTERIM REMEDIAL MEASURES  
WAILUKU, MAUI, HAWAII

CAD User: ASPASIONJR File Last Updated: November 23, 2016 4:27:05pm Plot Date: December 01, 2016 - 2:24:53pm  
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Plotter: DWG To PDF.pc3 Plotstyle: GEO-No-Dithering.ctb

	<b>GEOLABS, INC.</b>		PLATE  <b>4</b>
	<i>Geotechnical Engineering</i>		
	DATE SEPTEMBER 2016	DRAWN BY ASP	
SCALE NOT TO SCALE	W.O. 7417-00(A)		

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**APPENDIX A**

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## **APPENDIX A**

### Field Exploration

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We explored the subsurface conditions at the project site by drilling and sampling six borings, designated as Boring Nos. 1 through 6, extending to depths ranging from about 19 to 81.5 feet below the existing ground surface. The approximate boring locations are shown on the Site Plan, Plate 2. The borings were drilled using a truck-mounted drill rig and portable drilling equipment equipped with continuous flight augers and coring tools.

Our geologists classified the materials encountered in the borings by visual and textural examination in the field in general accordance with ASTM D2488, Standard Practice for Description and Identification of Soils, and monitored the drilling operations on a near-continuous (full-time) basis. These classifications were further reviewed visually and by testing in the laboratory. Soils were classified in general accordance with ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), as shown on the Soil Log Legend, Plate A-0.1. Deviations made to the soil classification in accordance with ASTM D2487 are described on the Soil Classification Log Key, Plate A-0.2. Graphic representations of the materials encountered are presented on the Logs of Borings, Plates A-1 through A-6.

Relatively “undisturbed” soil samples were obtained in general accordance with ASTM D3550-01(2007), Ring-Lined Barrel Sampling of Soils, by driving a 3-inch OD Modified California sampler with a 140-pound hammer falling 30 inches. In addition, some samples were obtained from the drilled borings in general accordance with ASTM D1586, Penetration Test and Split-Barrel Sampling of Soils, by driving a 2-inch OD standard penetration sampler using the same hammer and drop. The blow counts needed to drive the sampler the second and third 6 inches of an 18-inch drive are shown as the “Penetration Resistance” on the Logs of Borings at the appropriate sample depths. The penetration resistance shown on the logs of borings indicates the number of blows required for the specific sampler type used. The blow counts may need to be factored to obtain the Standard Penetration Test (SPT) blow counts.

Core samples of the rock materials encountered at the project site were obtained by using diamond core drilling techniques in general accordance with ASTM D2113, Diamond Core Drilling for Site Investigation. Core drilling is a rotary drilling method that uses a hollow bit to cut into the rock formation. The rock material left in the hollow core of the bit is mechanically recovered for examination and description. Rock cores were described in general accordance with the Rock Description System, as shown on the Rock Log Legend, Plate A-0.3. The Rock Description System is based on the publication “Suggested Methods for the Quantitative Description of Discontinuities in Rock Masses” by the International Society for Rock Mechanics (March 1977).

Recovery (REC) is used as a subjective guide to the interpretation of the relative quality of rock masses. Recovery is defined as the actual length of material recovered from a coring attempt versus the length of the core attempt. For example, if 3.7 feet of material is

## Appendix A

### Field Exploration

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recovered from a 5.0-foot core run, the recovery would be 74 percent and would be shown on the Logs of Borings as REC = 74%.

The Rock Quality Designation (RQD) is also a subjective guide to the relative quality of rock masses. RQD is defined as the percentage of the core run in rock that is sound material in excess of 4 inches in length without discontinuities, discounting drilling induced fractures or breaks. If 2.5 feet of sound material is recovered from a 5.0-foot core run in rock, the RQD would be 50 percent and would be shown on the Logs of Borings as RQD = 50%. Generally, the following is used to describe the relative quality of the rock, based on the "Practical Handbook of Physical Properties of Rocks and Minerals."

<b><u>Rock Quality</u></b>	<b><u>RQD</u> (%)</b>
Very Poor	0 – 25
Poor	25 – 50
Fair	50 – 75
Good	75 – 90
Excellent	90 – 100



**GEOLABS, INC.**

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# Soil Log Legend

## UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

MAJOR DIVISIONS			USCS	TYPICAL DESCRIPTIONS		
COARSE-GRAINED SOILS	GRAVELS	CLEAN GRAVELS LESS THAN 5% FINES		<b>GW</b> WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES		
		GRAVELS WITH FINES MORE THAN 12% FINES		<b>GP</b> POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES		
		SANDS	CLEAN SANDS LESS THAN 5% FINES		<b>SW</b> WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	
			SANDS WITH FINES MORE THAN 12% FINES		<b>SP</b> POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	
	SANDS	50% OR MORE OF COARSE FRACTION PASSED THROUGH NO. 4 SIEVE	SANDS WITH FINES MORE THAN 12% FINES		<b>SM</b> SILTY SANDS, SAND-SILT MIXTURES	
			CLAYEY SANDS, SAND-CLAY MIXTURES		<b>SC</b>	
		FINE-GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		<b>ML</b> INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
						<b>CL</b> INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
	<b>OL</b> ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY					
SILTS AND CLAYS	LIQUID LIMIT 50 OR MORE			<b>MH</b> INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS		
				<b>CH</b> INORGANIC CLAYS OF HIGH PLASTICITY		
				<b>OH</b> ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS		
HIGHLY ORGANIC SOILS				<b>PT</b> PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS		

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

**LEGEND**

- |  |  |      |   |
|--|--|------|---|
|  | (2-INCH) O.D. STANDARD PENETRATION TEST            | LL   | LIQUID LIMIT (NP=NON-PLASTIC)                           |
|  | (3-INCH) O.D. MODIFIED CALIFORNIA SAMPLE           | PI   | PLASTICITY INDEX (NP=NON-PLASTIC)                       |
|  | SHELBY TUBE SAMPLE                                 | TV   | TORVANE SHEAR (tsf)                                     |
|  | GRAB SAMPLE  | UC   | UNCONFINED COMPRESSION OR UNIAXIAL COMPRESSIVE STRENGTH |
|  | CORE SAMPLE  | TXUU | UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION (ksf)     |
|  | WATER LEVEL OBSERVED IN BORING AT TIME OF DRILLING |      |   |
|  | WATER LEVEL OBSERVED IN BORING AFTER DRILLING      |      |   |
|  | WATER LEVEL OBSERVED IN BORING OVERNIGHT           |      |   |

Plate

A-0.1



**GEOLABS, INC.**

Geotechnical Engineering

**Soil Classification Log Key**

(with deviations from ASTM D2488)

**GEOLABS, INC. CLASSIFICATION\***

**GRANULAR SOIL (- #200 <50%)**

- **PRIMARY** constituents are composed of the largest percent of the soil mass. Primary constituents are capitalized and bold (i.e., **GRAVEL, SAND**)
- **SECONDARY** constituents are composed of a percentage less than the primary constituent. If the soil mass consists of 12 percent or more fines content, a cohesive constituent is used (**SILTY** or **CLAYEY**); otherwise, a granular constituent is used (**GRAVELLY** or **SANDY**) provided that the secondary constituent consists of 20 percent or more of the soil mass. Secondary constituents are capitalized and bold (i.e., **SANDY GRAVEL, CLAYEY SAND**) and precede the primary constituent.
- **accessory descriptions** compose of the following:  
 with some: >12%  
 with a little: 5 - 12%  
 with traces of: <5%  
 accessory descriptions are lower cased and follow the Primary and Secondary Constituents (i.e., **SILTY GRAVEL with a little sand**)

**COHESIVE SOIL (- #200 ≥ 50%)**

- **PRIMARY** constituents are based on plasticity. Primary constituents are capitalized and bold (i.e., **CLAY, SILT**)
- **SECONDARY** constituents are composed of a percentage less than the primary constituent, but more than 20 percent of the soil mass. Secondary constituents are capitalized and bold (i.e., **SANDY CLAY, SILTY CLAY, CLAYEY SILT**) and precede the primary constituent.
- **accessory descriptions** compose of the following:  
 with some: >12%  
 with a little: 5 - 12%  
 with traces of: <5%  
 accessory descriptions are lower cased and follow the Primary and Secondary Constituents (i.e., **SILTY CLAY with some sand**)

**EXAMPLE:** Soil Containing 60% Gravel, 25% Sand, 15% Fines. Described as: **SILTY GRAVEL** with some sand

**RELATIVE DENSITY / CONSISTENCY**

Granular Soils			Cohesive Soils			
N-Value (Blows/Foot)		Relative Density	N-Value (Blows/Foot)		PP Readings (tsf)	Consistency
SPT	MCS		SPT	MCS		
0 - 4	0 - 7	Very Loose	0 - 2	0 - 4		Very Soft
4 - 10	7 - 18	Loose	2 - 4	4 - 7	< 0.5	Soft
10 - 30	18 - 55	Medium Dense	4 - 8	7 - 15	0.5 - 1.0	Medium Stiff
30 - 50	55 - 91	Dense	8 - 15	15 - 27	1.0 - 2.0	Stiff
> 50	> 91	Very Dense	15 - 30	27 - 55	2.0 - 4.0	Very Stiff
			> 30	> 55	> 4.0	Hard

**MOISTURE CONTENT DEFINITIONS**

- Dry: Absence of moisture, dry to the touch
- Moist: Damp but no visible water
- Wet: Visible free water, usually soil is below water table

**ABBREVIATIONS**

- WOH: Weight of Hammer
- WOR: Weight of Drill Rods
- SPT: Standard Penetration Test Split-Spoon Sampler
- MCS: Modified California Sampler
- PP: Pocket Penetrometer

**GRAIN SIZE DEFINITION**

Description	Sieve Number and / or Size
Boulders	> 12 inches (305-mm)
Cobbles	3 to 12 inches (75-mm to 305-mm)
Gravel	3-inch to #4 (75-mm to 4.75-mm)
Coarse Gravel	3-inch to 3/4-inch (75-mm to 19-mm)
Fine Gravel	3/4-inch to #4 (19-mm to 4.75-mm)
Sand	#4 to #200 (4.75-mm to 0.075-mm)
Coarse Sand	#4 to #10 (4.75-mm to 2-mm)
Medium Sand	#10 to #40 (2-mm to 0.425-mm)
Fine Sand	#40 to #200 (0.425-mm to 0.075-mm)

Plate

**A-0.2**

\*Soil descriptions are based on ASTM D2488-09a, Visual-Manual Procedure, with the above modifications by Geolabs, Inc. to the Unified Soil Classification System (USCS).



**GEOLABS, INC.**

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**Rock Log Legend**

**ROCK DESCRIPTIONS**

	<b>BASALT</b>		<b>FINGER CORAL</b>
	<b>BOULDERS</b>		<b>LIMESTONE</b>
	<b>BRECCIA</b>		<b>SANDSTONE</b>
	<b>CLINKER</b>		<b>SILTSTONE</b>
	<b>COBBLES</b>		<b>TUFF</b>
	<b>CORAL</b>		<b>VOID/CAVITY</b>

**ROCK DESCRIPTION SYSTEM**

**ROCK FRACTURE CHARACTERISTICS**

*The following terms describe general fracture spacing of a rock:*

- Massive:** Greater than 24 inches apart
- Slightly Fractured:** 12 to 24 inches apart
- Moderately Fractured:** 6 to 12 inches apart
- Closely Fractured:** 3 to 6 inches apart
- Severely Fractured:** Less than 3 inches apart

**DEGREE OF WEATHERING**

*The following terms describe the chemical weathering of a rock:*

- Unweathered:** Rock shows no sign of discoloration or loss of strength.
- Slightly Weathered:** Slight discoloration inwards from open fractures.
- Moderately Weathered:** Discoloration throughout and noticeably weakened though not able to break by hand.
- Highly Weathered:** Most minerals decomposed with some corestones present in residual soil mass. Can be broken by hand.
- Extremely Weathered:** Saprolite. Mineral residue completely decomposed to soil but fabric and structure preserved.


**HARDNESS**

*The following terms describe the resistance of a rock to indentation or scratching:*

- Very Hard:** Specimen breaks with difficulty after several "pinging" hammer blows.  
Example: Dense, fine grain volcanic rock
- Hard:** Specimen breaks with some difficulty after several hammer blows.  
Example: Vesicular, vugular, coarse-grained rock
- Medium Hard:** Specimen can be broked by one hammer blow. Cannot be scraped by knife. SPT may penetrate by ~25 blows per inch with bounce.  
Example: Porous rock such as clinker, cinder, and coral reef
- Soft:** Can be indented by one hammer blow. Can be scraped or peeled by knife. SPT can penetrate by ~100 blows per foot.  
Example: Weathered rock, chalk-like coral reef
- Very Soft:** Crumbles under hammer blow. Can be peeled and carved by knife. Can be indented by finger pressure.  
Example: Saprolite






	<b>GEOLABS, INC.</b> Geotechnical Engineering	IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII	Log of Boring  <span style="font-size: 2em; color: blue;">2</span>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Approximate Ground Surface Elevation (feet) : 976.2 *
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					Description
							5				4-inch <b>CONCRETE (BRIDGE DECK)</b> <b>SPACE BENEATH BRIDGE DECK</b>
Sieve - #200 = 18.4%	14				5		10		SM		Brown <b>SILTY SAND (BASALTIC)</b> with some gravel, loose to medium dense, moist (colluvium)
	8		100 63		20/0" Ref.		15				Brownish gray to gray <b>GRAVELLY COBBLES (BASALTIC)</b> with some sand, dense to very dense, moist (older colluvium)
	3		75		50/2" Ref.		20				grades with boulders (basaltic)
			70				25				grades more gravelly
			42				30				Boring terminated at 28 feet
							35				

Date Started: November 17, 2016	Water Level: $\nabla$ Not Encountered	Plate  <span style="font-size: 1.5em;">A - 2</span>
Date Completed: November 18, 2016		
Logged By: S. Latronic	Drill Rig: Big Beaver	
Total Depth: 28 feet	Drilling Method: 4" Solid Stem Auger & NQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	


BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>3</b></p>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
			90		41						Approximate Ground Surface Elevation (feet): 983.5 *
	11										2-inch <b>ASPHALTIC CONCRETE</b>
	5										Grayish brown <b>SANDY GRAVEL (BASALTIC)</b> with a little silt, dense, moist (fill)
			100								Brownish gray <b>GRAVELLY COBBLES (BASALTIC)</b> with some silty sand, subrounded, dense, moist (older colluvium)
			100		50/1" Ref.		5				grades more sandy locally
			71								
			33								
Sieve - #200 = 18.5%	17				21					SM	Gray <b>SILTY SAND (BASALTIC)</b> with a little gravel and traces of clay, medium dense, moist (older colluvium)
			67								Gray <b>GRAVELLY COBBLES (BASALTIC)</b> with some sand, subrounded, dense, moist (older colluvium)
			50				15				grades more sand and gravel locally
			75								grades with boulders (basaltic)
							20				Boring terminated at 19 feet
							25				
							30				
							35				

Date Started: November 15, 2016	Water Level:  Not Encountered	Plate <b>A - 3</b>
Date Completed: November 16, 2016		
Logged By: S. Latronic	Drill Rig: Big Beaver	
Total Depth: 19 feet	Drilling Method: 4" Solid Stem Auger & NQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	


BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>4</b></p>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
											Approximate Ground Surface Elevation (feet): 965.5 *
	20	100			9/6" +50/5"						4-inches <b>ASPHALTIC CONCRETE</b>
	13		77		15/0"						Brown <b>SILTY SAND</b> with some gravel, medium dense, moist (fill)
	3				7		5				Brownish gray angular <b>COBBLY BOULDERS (BASALTIC)</b> with some angular to subangular gravel and silty sand, very dense, moist (overcast fill)
			83								
			72		20/0" Ref.		10				
	6	118			22/6" +30/5"		15				
			33								
	4				25		20				
			64								
			32		10/0" Ref.		25				
	7				25/1"		30				
			47								
							35				

Date Started: November 7, 2016	Water Level: ▼ 62.0 ft. 11/09/2016 1139 HRS	Plate <b>A - 4.1</b>
Date Completed: November 9, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 (Energy Transfer Ratio = 80.3%)	
Total Depth: 80.17 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	


BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>4</b></p>
--	--	---	-----------------------------------

Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
					51						(Continued from previous plate)
	10		71								Brownish gray subangular <b>COBBLY BOULDERS (BASALTIC)</b> with some clayey sand and subrounded gravel, very dense, wet (older colluvium)
	8		25		45/6" +10/0" Ref.						
	8		71		37						
	8		50		15/0" Ref.						
	17		60		23						
			74		40/6" +35/2"						Gray subrounded <b>COBBLY BOULDERS (BASALTIC)</b> with some clayey sand and subrounded gravel, very dense (older colluvium)
			48		15/0" Ref.						

Date Started: November 7, 2016	Water Level: ▼ 62.0 ft. 11/09/2016 1139 HRS	Plate <b>A - 4.2</b>
Date Completed: November 9, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 (Energy Transfer Ratio = 80.3%)	
Total Depth: 80.17 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	


BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>4</b></p>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
	10		69		61						(Continued from previous plate)
			42		15/0" Ref.		75				
					35/2"		80				Boring terminated at 80.17 feet
							85				
							90				
							95				
							100				
							105				

Date Started: November 7, 2016	Water Level: ▼ 62.0 ft. 11/09/2016 1139 HRS	Plate  <b>A - 4.3</b>
Date Completed: November 9, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 (Energy Transfer Ratio = 80.3%)	
Total Depth: 80.17 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	


BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>5</b></p>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
	18	97			26						Approximate Ground Surface Elevation (feet ): 958.8 *
					32						3-inches <b>ASPHALTIC CONCRETE</b>
	9	108			83						Brown <b>SILTY SAND</b> with some gravel, medium dense, moist (fill)
			33				5				Brownish gray angular <b>COBBLY BOULDERS (BASALTIC)</b> with some angular to subangular gravel and silty sand, very dense, moist (overcast fill)
			67		15/0" Ref.		10				
	14	101	37		15/0" Ref.		15				
	10		40		14/6" +15/0" Ref.		20				
			45		11/6" +40/3"		25				
	11		36		75		30				
							35				

Date Started: November 9, 2016	Water Level: ▼ 54.8 ft. 11/11/2016 1236 HRS	Plate <b>A - 5.1</b>
Date Completed: November 11, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 (Energy Transfer Ratio = 80.3%)	
Total Depth: 81.5 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	

BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16


	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>5</b></p>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
	9	121	62		37/6" +25/3"						(Continued from previous plate)
	4		70		30/5"		40				Brown and gray subangular <b>COBBLY BOULDERS (BASALTIC)</b> with some silty sand and subangular to subrounded gravel, very dense, wet (older colluvium)
			27		10/0" Ref.		45				
	18		86		40		50				
	18		42		15/0" Ref.		55				
			72		15/0" Ref.		60				
			67		15/0" Ref.		65				
							70				

Date Started: November 9, 2016	Water Level: ▼ 54.8 ft. 11/11/2016 1236 HRS	Plate <b>A - 5.2</b>
Date Completed: November 11, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 (Energy Transfer Ratio = 80.3%)	
Total Depth: 81.5 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	

BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16




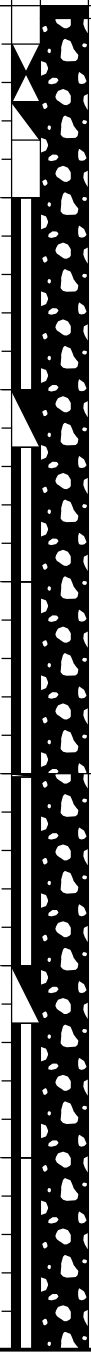
	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>5</b></p>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
			60		10/0" Ref.						(Continued from previous plate)
			70		10/0" Ref.		75				Brown and gray subrounded <b>COBBLY BOULDERS (BASALTIC)</b> with some clayey sand and subrounded to rounded gravel, very dense (older colluvium)
					43		80				
											Boring terminated at 81.5 feet
							85				
							90				
							95				
							100				
							105				

Date Started: November 9, 2016	Water Level: ▼ 54.8 ft. 11/11/2016 1236 HRS	Plate <b>A - 5.3</b>
Date Completed: November 11, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 (Energy Transfer Ratio = 80.3%)	
Total Depth: 81.5 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	


BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

	<b>GEOLABS, INC.</b> Geotechnical Engineering	IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII	Log of Boring  <span style="font-size: 2em; color: blue;">6</span>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Approximate Ground Surface Elevation (feet): 949.5 *
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					Description
	13	113			107		5			4-inches <b>ASPHALTIC CONCRETE</b>	
	100		82		16/6" + 15/0" Ref.		10		Brownish gray angular <b>COBBLY BOULDERS (BASALTIC)</b> with some angular to subangular gravel and silty sand, very dense, moist (overcast fill)		
	12		52		29		15				
			63		15/0" Ref.		20				
	10		51		20/1"		25		Brown and gray subangular <b>COBBLY BOULDERS (BASALTIC)</b> with some silty sand and subangular to subrounded gravel, very dense, wet (older colluvium)		
	3		69		16		30				
			70		15/0" Ref.		35				

BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

Date Started: November 14, 2016	Water Level: <span style="color: blue;">▼</span> 51.0 ft. 11/17/2016 1542 HRS	Plate  <span style="font-size: 1.5em;">A - 6.1</span>
Date Completed: November 15, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 <small>(Energy Transfer Ratio = 80.3%)</small>	
Total Depth: 80.5 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	


	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>6</b></p>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
	8		49		30/5"						(Continued from previous plate)
	7		81		49		40				
	27		17		30		45				
	16	114	45		26		50				
			33		15/0" Ref.		55				
			28		15/0" Ref.		60				
	31	83	43		50		65				
							70				

Brown and gray subrounded **COBBLY BOULDERS (BASALTIC)** with some clayey sand and subrounded to rounded gravel, very dense (older colluvium)

BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

Date Started: November 14, 2016	Water Level: ▼ 51.0 ft. 11/17/2016 1542 HRS	Plate  <b>A - 6.2</b>
Date Completed: November 15, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 (Energy Transfer Ratio = 80.3%)	
Total Depth: 80.5 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	

	<p><b>GEOLABS, INC.</b> Geotechnical Engineering</p>	<p>IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII</p>	<p>Log of Boring <b>6</b></p>
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Laboratory			Field				Depth (feet)	Sample	Graphic	USCS	Description
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)					
			77		15/0" Ref.					(Continued from previous plate)	
	14		60		30/3"		75				
	38				20/0" Ref.		80			Boring terminated at 80.5 feet	
							85				
							90				
							95				
							100				
							105				

Date Started: November 14, 2016	Water Level: ▼ 51.0 ft. 11/17/2016 1542 HRS	Plate <b>A - 6.3</b>
Date Completed: November 15, 2016		
Logged By: B. Aiu	Drill Rig: CME-75DG1 (Energy Transfer Ratio = 80.3%)	
Total Depth: 80.5 feet	Drilling Method: 4" Solid Stem Auger & PQ Coring	
Work Order: 7417-00(A)	Driving Energy: 140 lb. wt., 30 in. drop	

BORING LOG 7417-00(A).GPJ GEOLABS.GDT 12/1/16

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**APPENDIX B**

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## **APPENDIX B**

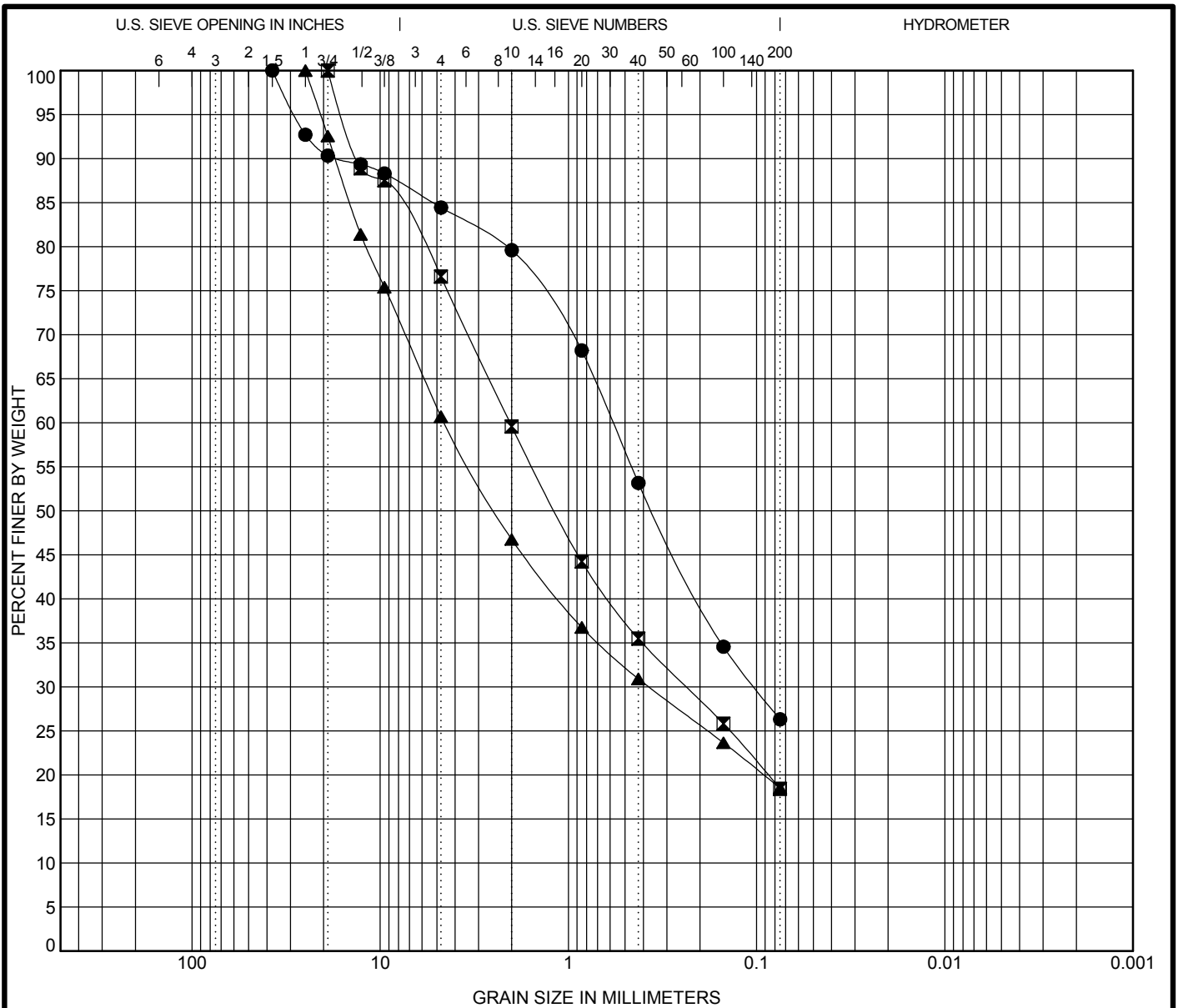
### Laboratory Tests

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Laboratory tests were not completed at the time this draft report was prepared. Laboratory test results will be included in the final report for the project.

Moisture Content (ASTM D2216) and Unit Weight (ASTM D2937) determinations were performed on selected samples as an aid in the classification and evaluation of soil properties. The test results are presented on the Logs of Borings at the appropriate sample depths.

Three Sieve Analysis tests (ASTM C117 & C136) including four hydrometer tests [ASTM D422-63(2007)e2] were performed on selected soil samples to evaluate the gradation characteristics of the soils and to aid in soil classification. Graphic presentation of the grain size distributions is provided on Plate B-1.




COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Sample	Depth (ft)	Description	LL	PL	PI	Cc	Cu
● B-1	1.5-2.5	Brown silty sand (SM) with some gravel					
☒ B-2	8.5-10.5	Brown silty sand (SM) with some gravel					
▲ B-3	10.0-11.5	Gray silty sand (SM) with some gravel					

Sample	Depth (ft)	D100 (mm)	D60 (mm)	D30 (mm)	D10 (mm)	%Gravel	%Sand	%Fine
● B-1	1.5-2.5	37.5	0.583	0.102		15.6	58.1	26.3
☒ B-2	8.5-10.5	19	2.045	0.236		23.4	58.2	18.4
▲ B-3	10.0-11.5	25	4.551	0.373		39.3	42.2	18.5

G: GRAIN SIZE 7417-00(A).GPJ GEOLABS.GDT 12/1/16

	<b>GEOLABS, INC.</b> GEOTECHNICAL ENGINEERING	<b>GRAIN SIZE DISTRIBUTION - ASTM C117 &amp; C136</b>	
	W.O. 7417-00(A)	IAO VALLEY STATE MONUMENT FLOOD REPAIRS JOB NO. J45CM41A INTERIM REMEDIAL MEASURES WAILUKU, MAUI, HAWAII	Plate <b>B - 1</b>

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**APPENDIX C**

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Iao Valley State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii

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B-1 5.75' TO 21.0'



Iao Valley State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii

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B-2 11.0' TO 28.0'



Iao Valley State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii

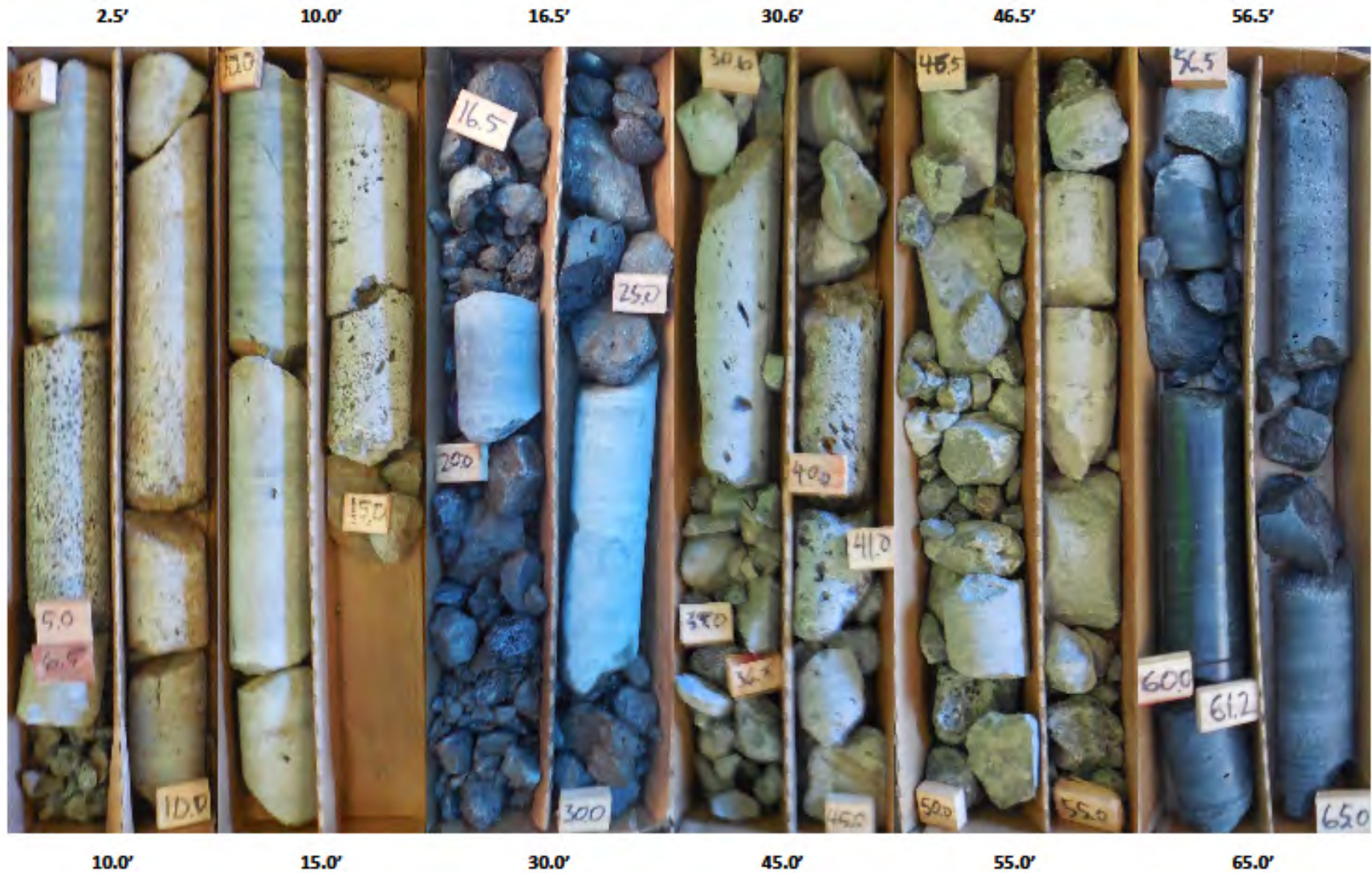
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B-3 0.8' TO 19.0'



Iao Valley State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii

B-4 2.5' TO 65.0'



Iao Valley State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii

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B-4 65.0' TO 80.0'

65.0'

75.0'

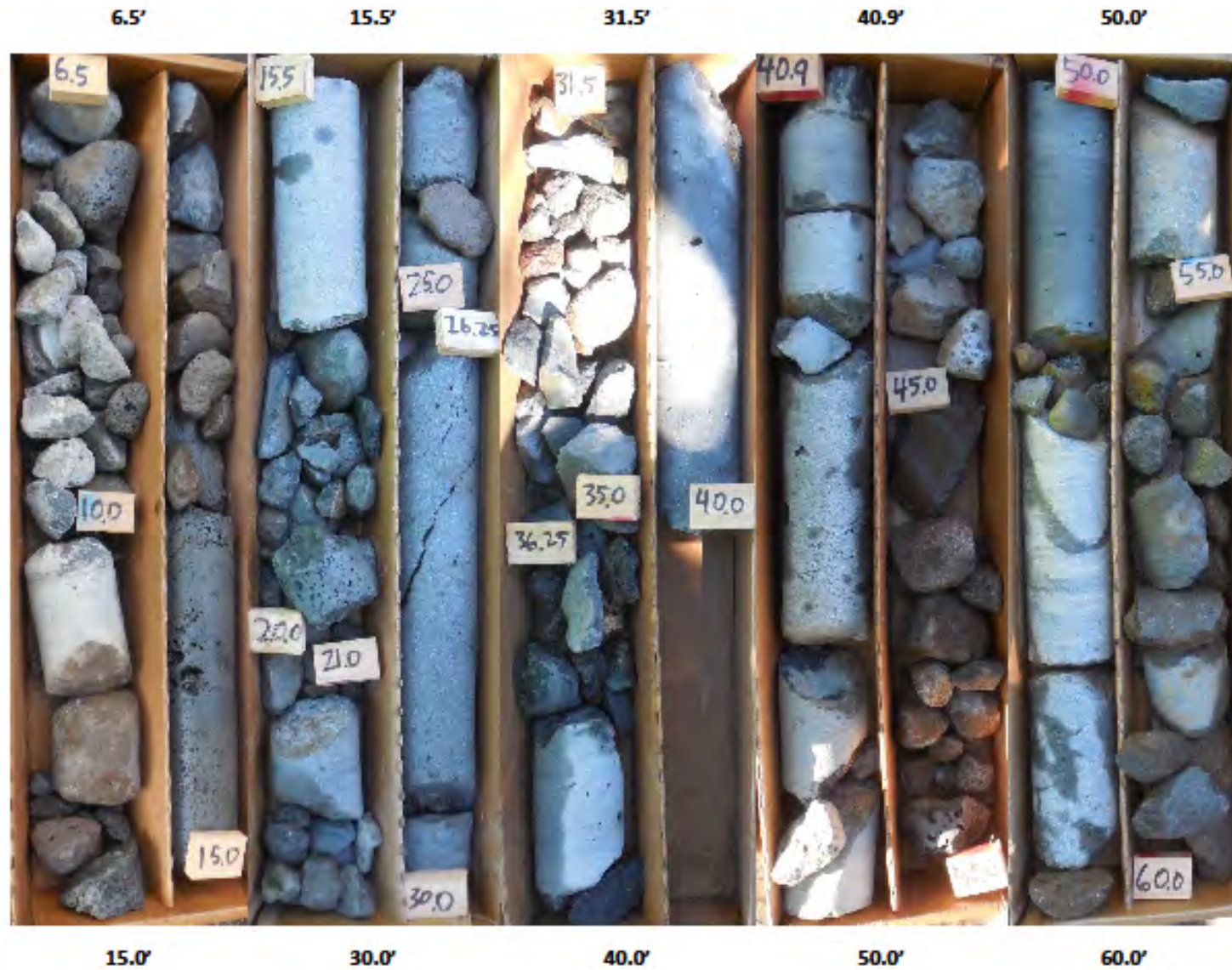


75.0'

80.0'

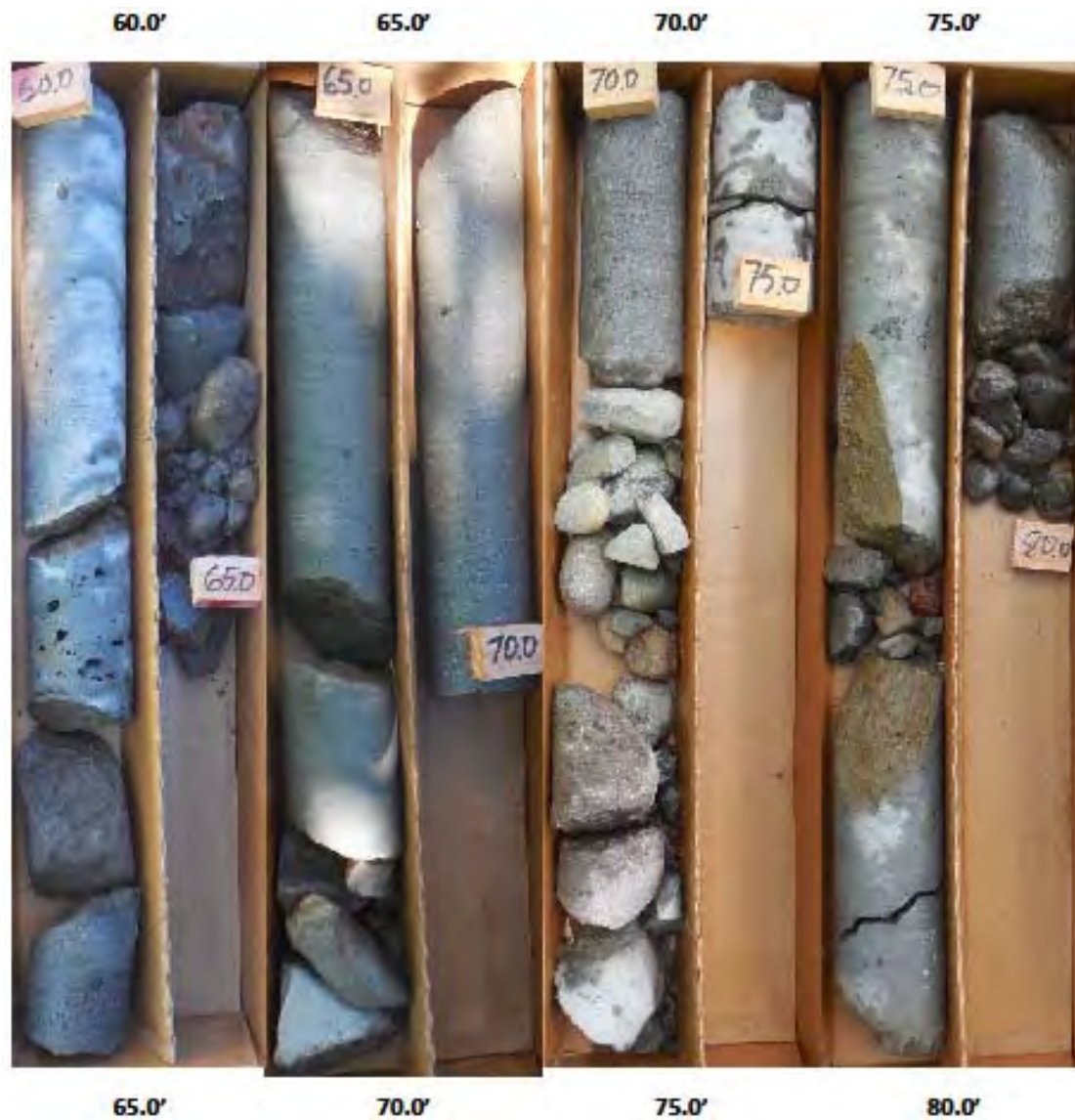
Iao Valley State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii

B-5 6.5' TO 60.0'



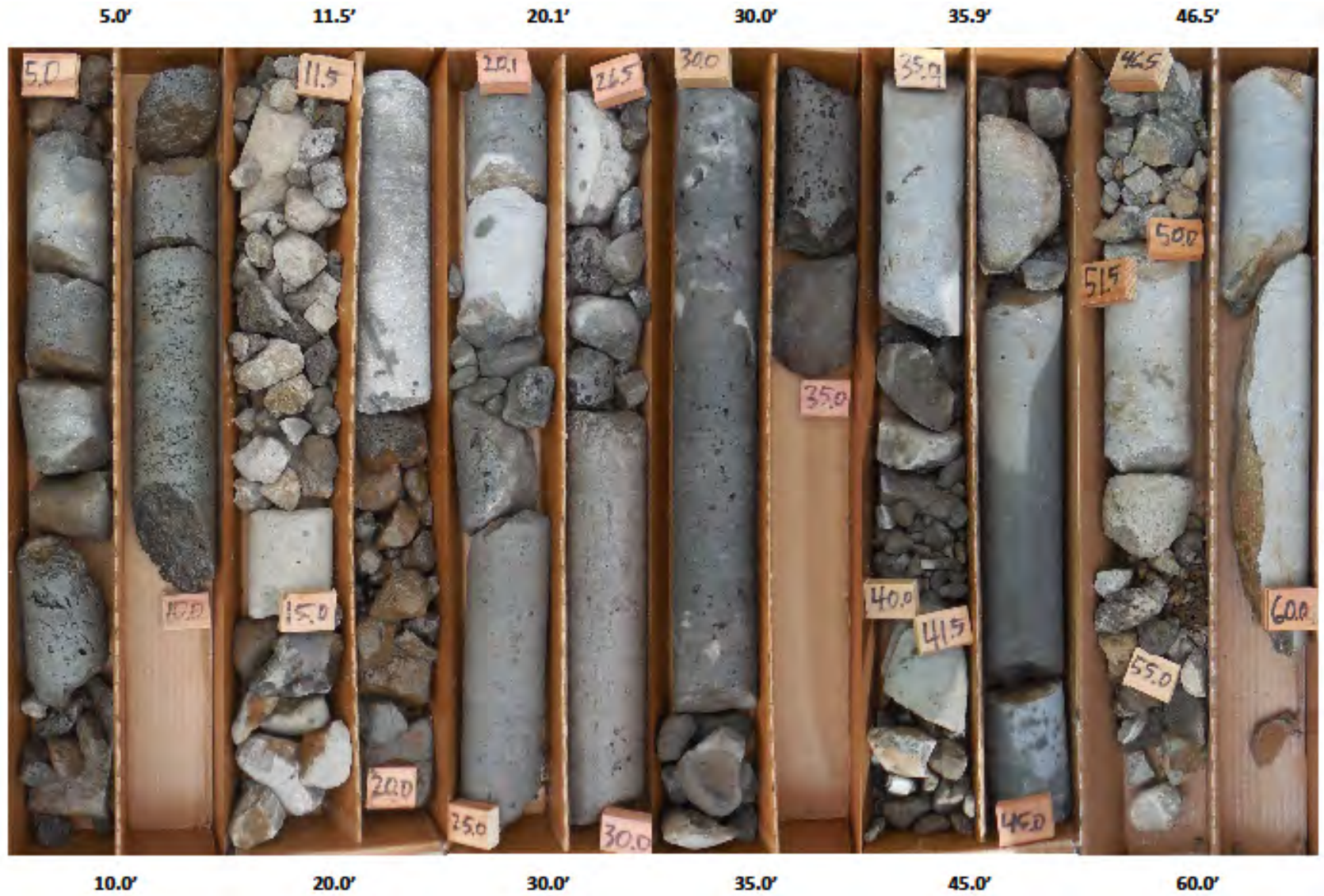
Iao Valley State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii

B-5 60.0' TO 80.0'



Iao Valley State Monument Flood Repairs  
 Job No. J45CM41A, Interim Remedial Measures  
 Wailuku, Maui, Hawaii

B-6 5.0' TO 60.0'





Iao Valley State Monument Flood Repairs  
Job No. J45CM41A, Interim Remedial Measures  
Wailuku, Maui, Hawaii

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B-6 70.0' TO 80.0'

