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August 27, 2015

Geotechnical Investigation: Moloka‘i Flume, Irrigation Improvements

August 27, 2015
AECOM Project No. 60429130

Mr. Aaron Kreitzer
HDR, Inc.
1132 Bishop St., Suite 1200
Honolulu, HI 96813

SUBJECT: GEOTECHNICAL INVESTIGATION:
MOLOKAʻI FLUME, IRRIGATION IMPROVEMENTS
KAUNAKAKAI, MOLOKAʻI, HAWAIʻI

Dear Mr. Kreitzer:

AECOM is pleased to provide the results of our geotechnical investigation for the proposed irrigation improvements on Molokaʻi related to the above-ground water flume above Kaunakakai, Molokaʻi, Hawaiʻi. In brief, the improvements involve an above ground flume that is in disrepair. We understand that it is proposed to install a buried pipe beneath the roadway to replace the open flume.

Our work consisted of completing a field investigation including borings and geologic reconnaissance, conducting laboratory testing, performing engineering analyses, and writing this report.

At the location of the inside edge of the roadway, the materials encountered consisted of 1 to 2.5 feet of fill, over weak basalt lava rock, over strong basalt at 6 to 8 feet. Accordingly, hard rock requiring at least a hoe ram is considered likely to get the trench excavation to design depth. There are additional recommendations in the report.

We trust this report meets the current project needs. Please call us if you require additional information or clarification.

Sincerely,

AECOM

Larry R. Rapp, PE
Principal Geotechnical Engineer

LARRY R. RAPP
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This work was prepared by me
or under my supervision

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List of Acronyms and Abbreviations

AECOM	AECOM Technical Services, Inc.
ASTM	American Society of Testing and Materials
CLSM	controlled low-strength mix
HDR	HDR, Inc.
Ma	millions of years before present
pcf	pounds per cubic foot
SPT	standard penetration test
VWD	Valley Well Drilling, LLC

1 INTRODUCTION

AECOM Technical Services, Inc., (AECOM) is pleased to provide the results of our geotechnical investigation regarding the irrigation improvements on Moloka‘i related to the above-ground water flume above Kaunakakai, Moloka‘i, Hawai‘i. The site is located on a one-lane dirt road, starting about 2.75 miles from Kaunakakai, approximately as shown on the Site Vicinity Map, Figure 1. A closer view of the subject site and the various project components is provided on the Site Index Map, Figure 2.

AECOM's work was performed in general accordance with AECOM's proposal dated February 3, 2015 and the subsequent agreement between AECOM and HDR, Inc. (HDR) dated May 27, 2015.

2 PROJECT DISCUSSION

2.1 Project Description

An irrigation tunnel was constructed in the 1960s as part of the Molokai Irrigation System. The tunnel exits about 3.1 miles *mauka*, or inland, from Kaunakakai. Water from this irrigation tunnel passes into an underground pipe and soon discharges into an existing, above-ground flume at the upstream headwall, as shown on Figure 2. The flume is about 1,600 feet long, eventually discharging the water into an underground pipe at the downstream headwall. The flume is located along the downslope edge of a single-lane dirt road that provides access to the tunnel (and beyond).

The existing flume measures about 3.5 feet high and 4.5 feet wide and is in some disrepair. Originally entirely covered with adjoining segments of concrete slabs about 3 inches thick, many (maybe half or more) of these segments have since deteriorated or disappeared. Some open sections have been replaced by hog wire attached to wood boards (2 x 4s and 2 x 6s), but other sections are uncovered.

The project involves replacing the flume with a buried, 4-foot-diameter, concrete pipe and abandoning the existing flume in-place. It is proposed to bury the new pipe such that the top would be about 2 feet deep below the surface of the roadway, indicating a minimum trench depth of at least 6 feet plus any required pipe bedding thickness. The pipe would be located within the roadway, most likely up against the up-slope side of the road.

We understand that there is no known geotechnical information available at the location (e.g., a geotechnical report on the as-built flume). The purpose of this geotechnical investigation is to identify anticipated soil conditions along the route to provide information for HDR as designer and for the utility contractor as constructor.

2.2 Project Background

The following plans for the flume were provided to us by HDR:

- Sheet 3, Tunnel Access Road Plan and Profile, dated Dec 1956
- Sheet 4 of 15, Plan and Profile of Road and Details of Intercepting Ditch at Portal
- Sheet 11 of 16, Untitled (Plan and Profile)
- Sheet 12 of 16, As-built Construction Details
- Sheet 13 of 16, As-built Construction Details

3 FIELD INVESTIGATION

The field investigation consisted of performing a geologic field reconnaissance and a drilling program. AECOM performed the field investigation on June 1 and 2, 2015.

The field reconnaissance consisted of a site walk by an AECOM geologist to evaluate the geologic conditions along the alignment of the new pipe construction.

The drilling program consisted of advancing 3 borings, designated B-1 through B-3, as indicated on Figure 3. Borings B-1 and B-2 were approximately located where originally anticipated; for logistical reasons Boring B-3 was located somewhat further to the west along the road from the original planned location.

A fourth boring, B-4 was originally considered to be drilled at the very west end of the existing flume. For safety reasons, due to the apparent instability of the adjacent, tall rock face immediately upslope of the location, and for logistical reasons, due to deeper road ruts rendering rig access problematic for the drillers at that particular location, the fourth boring was eliminated. Given the overall consistency observed in borings B-1 through B-3, we do not believe the absence of the fourth boring is deleterious to site understanding.

A Safe Work Plan was developed for this project to address the known hazards of drilling, of working in remote areas, and of other potential safety concerns. Based on as-built maps, communication with HDR, and the State's recollection, no utilities (other than the flume) were present along that section of roadway. Still, Hawaii One Call Center was notified prior to drilling; no utility company acknowledged any utilities in the area. No utilities were struck or damaged during the field investigation.

The borings were advanced by Valley Well Drilling, LLC (VWD) using a Diedrick D-25 drill rig equipped with 6-inch diameter hollow stem augers. The borings were advanced to depths of 6.5 to 8 feet below existing grade, whereupon auger refusal was encountered in the strong basalt.

Driven samples were obtained at intervals of about 2 feet using a standard penetration test (SPT) sampler or a California sampler. These samples were sealed to preserve their natural moisture content and returned to our laboratory for further review and assignment of laboratory testing. Bulk samples were also obtained from each boring location.

Preliminary boring logs were initiated in the field by an AECOM geologist. These logs were subsequently revised, as needed, based on closer observations in our laboratory and the results of laboratory testing. The results of the field investigation, along with additional details of the field work and boring logs, are presented in Appendix A. After completion, the boreholes were backfilled with cuttings and made flush with the ground surface.

4 LABORATORY TESTING

Laboratory testing was performed on selected samples obtained from the field investigation. The purpose of the laboratory testing was to help evaluate the engineering properties of the subsurface materials and to confirm visual classification of the soil. The type and number of tests was largely dictated by the type and the intactness of samples that were recovered. The geotechnical laboratory tests were performed in general accordance with the procedures of the American Society for Testing and Materials (ASTM) wherever applicable, and included the following:

- Moisture content
- Dry density
- Plasticity indices
- Sieve analyses
- Wash analyses
- Double hydrometer tests
- Chemical suite (sulfate attack and corrosion potential)
- Compaction (moisture-density relations)

The results of the laboratory tests and additional details of the laboratory testing program are provided in Appendix B. For ease of reference, a summary of some of the laboratory results are also provided on the boring logs in Appendix A.

5 SITE CONDITIONS

5.1 Local Geology

Molokaʻi is built by lava flows originating from two major volcanoes, East Molokaʻi and West Molokaʻi. The Site is located on the East Molokaʻi volcano, which covers two-thirds of the island and is thus the larger of the two volcanoes (Sherrod et al., 2007). The north half of the volcano is missing, but its remainder suggests that the volcano likely had an east–west elongation (Sherrod et al., 2007).

The geologic material originating from the East MolokaʻI volcano is termed the East Molokaʻi Volcanics. It was divided into lower and upper members by Stearns and Macdonald (1947). The lower member represents the shield stage of volcanism and is composed of typical tholeiitic basalt and formed about 1.8-1.5 millions of years before present (Ma). The upper member forms the bulk of East Molokaʻi Volcano and represents the postshield stage of volcanism. It is composed of alkalic (i.e., more silica-rich) basalt and formed about 1.5-1.3 Ma.

The lower member is composed of thin-bedded, moderately to highly vesicular pahoehoe and aʻa. The beds range from a few feet to 75 feet in thickness. The basalts weather to a dark-gray, red, red-violet, or brown color and stand in sharp contrast to the upper member described below, which typically weathers to light-gray and white (Stearns and Macdonald, 1947). The basalts of the lower member are highly permeable and contain the principal aquifer of Molokaʻi.

The upper member comprises postshield strata that are preserved on the summit and flanks of the East Molokaʻi volcano. These strata form a relatively thin veneer, about 50 to 500 feet thick, over the lower member (Stearns and Macdonald, 1947). All lava flows are of the aʻa type and were erupted from bulky cinder and spatter cones and thick bulbous domes (Sherrod et. al., 2007); these vent features are numerous and exist predominantly along the western and southern flanks of the East Molokaʻi volcano (Oki and Bauer, 2001). Individual flows range from 20 to 100 feet thick and many carry heavy clinker beds. The lava flows are generally non-porphyritic but a few carry feldspar phenocrysts (larger crystals) (Stearns and Macdonald, 1947). Feldspar phenocrysts were observed in flows exposed at the site and encountered in Borings B-2 and B-3.

Based on geologic mapping, rock exposures of the eastern section of the site consist of the lower member lava flows, while the mid and western sections consist of upper member lava flows and vent deposits. The vent deposits, composed of cinder and spatter that forms bulky cones, were the eruptive sites for the lava flows of the upper member. Puu

Kakalahale (Figure 1) is a cinder cone mapped as vent deposits located immediately to the northwest of the site and intersects rock outcrops above the road at the western section of the site.

Numerous vent features, including cinder and spatter cones, exist along the western and southern flanks of the East Molokaʻi Volcano. Many of the vents, including the cinder cone Puu Luahine,

5.2 Surface Conditions

A cross section through the site would show a slope of varying steepness and height extending down to a one-lane dirt road. This dirt road would span between the toe of the slope and one side of the subject concrete flume. On the downslope side of the flume would be another slope of varying height and steepness extending down to a major drainage ravine (north fork of Kaunakakai Gulch).

The elevation of the roadway within the subject site, and therefore the existing elevation of the base of the flume, goes from about elevation 956 feet on the west end up to about elevation 961 eet on the east end of the flume, near the existing tunnel entrance.

The roadway within the subject site can be traversed by a two-wheel drive vehicle. However, we note that the driller opined that a larger drill rig might not have been able to make it up the steeper portions of the 2.75 mile road to access the site. Wheel ruts in some parts of the roadway along the flume were up to 2 feet deep. Continued degradation of the roadway surface may require that some regrading occur in the future to maintain the road's drivability.

The surface of the dirt roadway consists primarily of loose to compacted fill, present mostly due to the passing of time, the passage of vehicles, and we imagine occasional regrading when the ruts get too deep to allow passage of maintenance vehicles. A cut/fill line typical of these roads was not identified during our field investigation, and based on our site review, the road itself may indeed be essentially cut out of the existing basalt from one side to the other.

There are a number of drainage inlets along the flume, ostensibly to allow water collecting in the roadway to drain beneath the flume and outlet above the downslope ravine. Many of the drainage portals along the subject portion of the road are blocked with soil, likely as a consequence of the necessary periodic maintenance to regrade the road when the ruts become too deep.

In general, the road cut upslope of the road appear to be in adequate shape. However, the westernmost 80 longitudinal feet of slope contains large, open vertical cracks, about where shown on Figure 3, for much of the slope height. These cracks are present in a discontinuous manner from roadway grade to top of cut slope, which is about 50 feet higher in elevation.

On the downslope side of the roadway, just west of the west end of the flume, significant erosion appears to be ongoing. The erosion is occurring in light gray basalt debris, indicating the material was derived from the upper member of the East Moloka‘I Volcanics. This material is therefore interpreted to be fill and not a natural deposit.

5.3 Subsurface Conditions

In general, the roadway appears to have been constructed primarily by cutting into the existing native slopes. From the borings, the upper surface of the road consisted of 2 to 2.5 feet of fill. This fill consisted of silty gravel with sand (GM) in B-1 and clayey sand with gravel (SC) in B-2 and B-3. It is our opinion that the presence of fill is mostly the result of initial smoothening of the roadway, combined with many years of driving over the roadway in all types of weather conditions, and then periodically regrading and filling in ruts and drainage rills that would develop with time within the roadway. The fill had dry unit weights of 103 and 117 pounds per cubic foot (pcf) with moisture contents between 8 and 11 percent. (A lower density and higher moisture was encountered in the fill in B-2, but given the excessively high blowcounts, is not considered to be representative.)

In Boring B-1, the 2.5 feet of fill was underlain by 3.5 feet of residual soil. Residual soil is basalt that has completely weathered in place to a soil. At this location, the residual soil is a reddish brown, clayey sand with gravel (SC).

Beneath the residual soil in B-1 and beneath the fill in B-3, we encountered basaltic saprolite, a very weak, highly to slightly weathered basalt. In B-1, a piece of a‘a clinker was encountered at the bottom of the boring. In B-2 we encountered dry, gray, hard basalt beneath the fill, though interbeds of saprolite were also encountered. The basalt had noticeable feldspar phenocrysts in Borings B-2 and B-3, and some olivine was observed in B-2.

Auger refusal was encountered in all three borings at depths of 6.5 feet to 8.0 feet. It is presumed that the strong material below the depths of refusal is composed of competent massive or thick-bedded a‘a basalt.

5.4 Groundwater

Groundwater was not encountered in Borings B-1 through B-3 and is not anticipated within the depths likely to be encountered for this project.

6 DISCUSSION AND RECOMMENDATIONS

The site appears suitable for the proposed irrigation improvements, provided that the geotechnical recommendations are adhered to during construction. In addition to the utility recommendations, a brief discussion of other noted geologic considerations are provided in Section 6.7.

6.1 UTILITY CONSTRUCTION

Based on our borings, excavation of the utility trench for replacement of the flume will encounter from about 2 to 7 feet of either soil fill, residual soil, or basalt that has weathered sufficiently to break down to a soil upon reworking. These materials should be readily excavatable with standard excavation equipment.

Below these depths, harder, more competent basalt was encountered. Therefore, for trenches 7 feet deep, excavations from 0 to 5 feet into hard basalt may be required. Despite the hardness of the basalt, fractures or weathering veins may allow for easy excavation in some of the basalt. Nevertheless, due to the refusal encountered in all three borings, we anticipate that more concentrated efforts, such as the use of a hoe-ram or jackhammer, is likely to be needed to get the trench down to proper subgrade.

A smooth trench bottom is unlikely to be obtainable due to the variability in basalt lava flows. Popouts and an uneven trench bottom can be filled up to trench subgrade using either compacted fill, additional bedding material, or a sand-cement slurry (such as a controlled low-strength mix, or CLSM).

After construction, the long term settlement of a properly backfilled and compacted trench should be less than ¼ inch.

6.2 LATERAL EARTH PRESSURES AND RESISTANCE TO LATERAL LOADS

At this time, it is unknown to AECOM if manholes are currently planned. If they are, then these, or any other structures that have components constructed below grade, will be subject to lateral earth pressures from subsurface materials and/or backfill. For design purposes, lateral earth pressures should be computed for an active condition when the wall is considered free to rotate or translate, and for restrained conditions where walls are fixed against rotation or translation at the top and the bottom. For active conditions, AECOM recommends the use of an active pressure equal to that imposed by an equivalent fluid weight of 30 pcf. For restrained conditions, an equivalent fluid weight of 50 pcf may be used for design. Traffic adjacent to excavations or subterranean structures will also impose lateral loads on shoring and structures. Lateral pressure distribution due to wheel loading is shown in Figure 4.

To provide resistance to lateral loads, a passive pressure equal to that imposed by an equivalent fluid weight of 350 pcf may be used in design. An allowable coefficient of friction of 0.4 may be used in combination with the passive resistance.

In addition to these pressures, subterranean structures should be designed to resist a uniform lateral pressure distributed over the height of the structure equal to 0.5 times the surcharge loads imposed by areal loads (such as stockpiles or construction equipment) if any.

6.3 VERTICAL PRESSURE ON PIPES

The pipelines should be designed to withstand external vertical pressures including earth pressures (dead loads) and surcharge pressures (live loads) transmitted from the ground surface, where applicable.

For design purposes, when calculating the vertical overburden load on pipes, we recommend using a design total unit weight for properly compacted backfill of 125 pcf. The effective internal friction angle of the backfill may be taken as 35 degrees for the purposes of these calculations.

6.4 SITE PREPARATION AND EARTHWORK

6.4.1 General Grading Requirements

Earthwork should be performed in accordance with applicable local, state, and federal regulations, as well as the recommendations of this report. Earthwork should be performed under the observation and testing of the geotechnical engineer, to confirm that what is constructed is consistent with the assumptions used in our analyses to develop the design recommendations herein. Earthwork is expected to primarily consist of site preparation, temporary trench excavations, subgrade preparation of trenches for placement of new pipe sections, subgrade preparations for possible manholes, and trench bedding and backfilling.

All areas to be cut, to receive fill, or to receive stockpile materials should be cleared, stripped and grubbed of all trees stumps, roots, brush, grass, or other organic matter, abandoned utility lines, or other unsuitable material. Cleared and grubbed material as well as all rubble waste that may be encountered or created during construction should be should be disposed of appropriately at a location away from the site. Any material exposed at final grade or from excavations that is judged to be unsuitable by the geotechnical engineer should be removed.

The exposed excavated trench surface should be cleared of all loose debris. However, if the soil or loosened material is less than 6 inches thick, it may be moisturized (if needed) and compacted in place. The exposed excavated surface should be observed by geotechnical personnel to confirm that satisfactory subgrade soils have been encountered. If loose or soft materials are encountered at the bottom of the excavation, additional removal may be required.

The bottom of manhole excavations should be prepared such that the manhole will be supported by uniformly firm material. As with the trench bottoms, the exposed excavated surface should be observed by geotechnical personnel to confirm that satisfactory subgrade soils have been encountered. It is expected that rock will be encountered at the bottom of any manhole excavation. If loose, soft, or otherwise unsuitable materials are encountered at soil subgrade level, additional removal may be required. Surficial loose material above the rock resulting from the excavation should be moisturized and compacted in place, or removed.

6.4.2 Temporary Excavations and Shoring Conditions

The surface fill may not hold its shape upon excavation, a temporary excavation slope at 1:1 may be necessary through the fill material. Excavation below the fill into the formational material may be done vertically. Surcharge loads from vehicle/equipment parking and traffic or stockpile materials should be set back from the top of any temporary excavation a horizontal distance equal to at least one (1) times the depth of excavation to rock.

The subsurface conditions encountered are generally suitable for open cut-and-cover type construction. Vertical excavation in rock should generally be stable. Regardless, all OSHA safety guidelines should be adhered to for this construction, particularly for personnel entering the excavation. Therefore, no one should enter a trench with a vertical cut greater than 4 feet without proper shoring. In any event, excavation and personnel safety during construction is the sole responsibility of the Contractor.

For braced shoring in rock, a uniform pressure distribution should be used. The maximum pressure would be 25H, with H in feet and the resulting pressure in psf.

Provisions for adequate surface drainage should be provided to drain water away from the excavations, and the excavations should be protected against flooding to avoid water damage to the exposed excavations. In addition, the control measures should be placed such that the resulting drainage does not lead to concentrated water flows that would erode the surface soils elsewhere.

6.4.3 Materials

6.4.3.1 Pipe Bedding and Pipe Zone Materials

Pipe bedding material refers to the material placed immediately below the pipe. Unless otherwise required by project specifications, bedding material that supports underground utilities should consist of sand, gravel, crushed aggregate, or other free-draining granular soils. This material should consist of material imported from an offsite source that is suitable for use as bedding for the design pipe type. In general, crushed rock bedding should be clean, granular basaltic gravel conforming to ASTM C33, size 67. The bedding material should be compacted to at least 90 percent relative compaction. If the size of the project warrants it, crushing of the excavated basalt into bedding-size material may be performed.

The "pipe zone" material, which is the zone extending from the pipe bedding that supports the pipe up to 12 inches above the top of the pipe, can be similar to the pipe bedding material. When acceptable to the pipe designer and manufacturer, a Modified General Fill discussed in Section 6.6.4.3 may also be used instead of pipe bedding material in the upper portions of the pipe zone, from a distance above the bottom of pipe of 0.7 times the outside pipe diameter up to the top of the pipe zone.

6.4.3.2 General Fill

General Fill may be used for trench backfill above the pipe zone level as discussed in Section 6.4.3.1.

General Fill should consist of material excavated from the project site, or imported from an off-site source, that is suitable for use in constructing engineered fill. Fill materials should be free of organics, debris, or other deleterious materials. Materials for use as General Fill should not contain rocks or hard lumps greater than 6 inches in maximum dimension, and should have at least 80 percent passing the 3/8 inch sieve and at least 20 percent passing the number 200 sieve. No nesting of rocks should be permitted, nor should perishable, spongy, hazardous, or other improper material be used.

It is our opinion that the soil we encountered in our borings is generally suitable for use as General Fill for this project. However, the intact basalt would likely be too blocky for use as fill unless crushing operations are performed. Even then, some soil mixing may be required. Backfilling the entire trench with bedding material is not recommended, to prevent the intrusion of surface water into the trench excavation.

In the event that space is too limited such that compaction equipment cannot be used around the pipe or manholes, the use of CLSM for backfill is acceptable.

6.4.3.3 Modified General Fill

This material is an alternative to using pipe bedding material discussed in Section 6.4.3.1 for the "pipe zone" beginning at 0.7 times the outside pipe diameter, measured from the bottom of pipe, to 12 inches above the pipe. The Modified General Fill is to meet all the recommendations for General Fill in Section 6.4.3.2, except that there should be no rock or hard lumps greater than 1½ inches in maximum dimension. This material will need to be placed in thin lifts and compacted as per Section 6.4.3.1. This material is generally more difficult to compact than pipe bedding material, but provides a less pervious backfill preventing subterranean water buildup. Greater care will need to be taken by the Contractor to compact this alternative material adequately without damaging the pipe.

6.4.4 Placement and Compaction

The maximum dry density of soil materials should be determined in accordance with the latest version of ASTM D1557. All references to relative compaction refer to the ratio, expressed in percent, of the in-place dry density of the compacted fill to the maximum dry density obtained from ASTM D1557. The field density of fill should be determined in accordance with the Sand Cone Method (ASTM D1556) or the Nuclear Method (ASTM D2922 and D3017).

The moisture content of engineered fill materials should be at, or up to 3 percent above, optimum water content. Higher moisture contents are acceptable, but carry a greater risk of developing "pumping" conditions and inhibiting further compaction of subsequent layers. Fill material should be placed in lifts generally no greater than 8 inches, loose measurement. Materials greater than ¾ inch are to be placed so that they are completely surrounded by compacted finer soils. Each lift should be compacted to the minimum relative compaction prior to placement of additional fill, and density tests should be performed on each compacted lift prior to placement of subsequent lifts. Areas represented by failing tests should be reworked and retested prior to placement of any subsequent lifts. Fill placement should be done under continuous observation of geotechnical personnel.

Bedding should be placed around pipes in lifts, with each lift being compacted. Where proximity to the pipe may damage the pipe, compaction shall be by tamping, using a wood board, hand shoveling, or other positive means to ensure full placement of material around the pipe. The use of jetting should not be permitted unless the subgrade is free draining (i.e., there is no ponding of water at all). Given the typically rocky nature of the expected trench subgrade, wrapping the bedding in filter fabric is not required.

Scarified materials and materials used for general backfill are to be compacted to at least 90 percent relative compaction. All pipe bedding and pipe zone material should be compacted to at least 90 percent relative compaction. Claims of any soil being "self-compacting" are unsubstantiated and are not acceptable. The field densities of materials are to be determined in accordance with the Sand Cone Method (ASTM D1556) or the

Nuclear Method (ASTM D6938). However, nuclear tests need to be performed to the appropriate lift depth. Surface “scatter” tests are not acceptable. Not having the appropriate nuclear gauge to test to depth is not sufficient excuse to override this recommendation.

We estimate the shrinkage of soil, residual soil, and saprolite compacted to 90 percent relative compaction to range from 4 to 16 percent.

6.5 Potential for Sulfate Attack on Concrete and Corrosion

Chemical analyses were performed on two samples obtained from the exploratory borings. As indicated in Appendix B, the sulfate content was less than 0.01 percent. Based on these tests results and the guidelines prepared by the Portland Cement Associate and the American Concrete Institute, the potential for sulfate attack on concrete is considered negligible.

Corrosion is an electrochemical process that results in metal loss. It is unknown to AECOM if any buried metallic objects are planned. However, included in the chemical analyses were resistivity measurements taken in both the as-received moisture contents and in wetted (“saturated”) condition. The electrical resistivity results indicate that in its natural moisture content, the on-site soils are noncorrosive. Upon saturation, the on-site soils become classified as severely corrosive to buried metallic objects. Whilst the pH values were relatively neutral, the chloride content was sufficient that the on-site soils would be classified as exhibiting slight to moderate potential for chemical corrosion. Further communication with corrosion specialists may be required regarding the selection of construction materials for appropriate control and mitigation measures against corrosion of buried metal objects (pipelines, tanks, etc.).

6.6 Erosion Potential

There is significant erosion occurring immediately downslope from the west end of the flume. We believe this is likely due to surface water from rain events flowing down the road, then crossing downslope where the flume heads underground. This happens to be across from an erosional feature in the basalt on the upslope side; apparently surface water from upslope also turns into a concentrated flow across from the same location.

Because of these observations, we ran two double hydrometer tests on the bulk materials obtained from borings B-1 and B-3. On a scale from 0 to 100, the percent dispersion of the material at B-1 was 10 percent, and anything less than 30 is considered nondispersive (Knodel, 1991). However, the percent dispersion of the soil taken from B-3 was 58 percent, and a result greater than 50 indicates a dispersive soil, meaning that fine particles are prone to become suspended in water and migrate, resulting in soil loss (erosion).

At the west end of the flume there is significant erosion occurring downslope in the apparent debris (material possibly deposited during original tunnel construction) in the steep terrain that forms the northwest side of the north fork of Kaunakakai Gulch. We interpret the results to mean that if the erosion reaches the roadway, the roadway will not be resistant to ongoing erosion and that the roadway may one day be cut into from surface water erosion issues. We suggest consideration be given to addressing surface water runoff at this apparent intersection of concentrated water flow, ongoing downslope erosion, and a dispersive roadway material.

6.7 Additional Considerations

We note that it is currently planned to have the top of the buried, new pipe about 2 feet below road grade. However, we also note that the ruts in the roadway can easily reach a depth of about 2 feet. Given the dispersive nature of some of the near surface soils, such rutting is inevitable. Even if the rut is not perfectly aligned with the center of the pipe, such that tires are driving directly on top of the pipe, periodic grading of the roadway, which will be necessary over time as rutting continues, could easily extend to this depth and thereby adversely affect the pipe. Therefore, it may be prudent to attempt to bury the pipe somewhat deeper than just 2 feet. The downside is that this will mean deeper excavation into the harder basalt.

The vertical cracks noted in the cliff upslope at the west end of the alignment are typically a precursor to a failure. For safety reasons, particularly for construction personnel working directly below, but also for maintenance personnel driving to the site after construction, mitigation of the slope instability should be considered before start of the utility replacement.

The amount of erosion downslope of the west end of the flume is considerable. It is also clear that the material being eroded was placed parallel to the gradient of the side slopes to the north fork of Kaunakakai Gulch (unlike the natural lava flows which are roughly horizontal). In addition, the material is uniformly light gray, which is uncharacteristic of basalt that has been exposed to significant weathering over a long period of time (which usually oxidizes to a reddish hue). These features all point to ground up basalt that was likely dumped over the side of the road. While erosion is not currently threatening the flume, the continued erosion could progress to the roadway. While the natural material comprising the roadway is anticipated to have greater erosion resistance than the material dumped downslope of the flume, at some point it is conceivable that the erosion will undermine the new proposed construction.

Groundwater is not anticipated to be encountered during construction of the new pipe. However, surface water runoff could be high during precipitation events, and should be taken into consideration during construction. Grading (sloping) away from excavation wherever feasible should be performed, and care should be taken to unclog and not bury the underflume drainage that already exists.

7 GENERAL CONDITIONS

This report has been prepared for the sole use of HDR and the Owner for the purpose of evaluating options to repair the Entry Ramp into the Waipahu Incinerator. It is not applicable for other purposes, site locations, or firms. This report presents recommendations pertaining to the subject site based on the assumption that the subsurface conditions do not deviate appreciably from those disclosed by our field and laboratory investigation. In view of the general geology of the area; the deep, soft, underconsolidated sediments over a wide area; and the presence of undocumented fill: the potential for encountering conditions different from those assumed cannot be discounted. In addition, we have investigated only a small portion of the overall area at the project site; we have not performed an area-wide investigation into ongoing settlement concerns throughout the Waipahu Incinerator project site. In the event that the concept or the elevations change, the recommendations presented in this report may not be applicable.

When AECOM is not present, it is the responsibility of the Owner to bring any deviations or unexpected conditions observed during construction to the attention of AECOM. Thus, any requisite supplemental recommendations can be made with a minimum of delay to the Contractor.

AECOM has performed no structural evaluation of the site; we make no claim or assumption on the adequacy or condition of the concrete bridge or its capacity.

The clayey lagoonal deposits were assumed to behave similarly to the tested material at 36 feet. While we consider this reasonable for the scope of work authorized, the potential for some variation cannot be discounted. Therefore, neither settlements nor heaves should be considered exact; some imprecision should be anticipated.

Professional judgments presented in this report are based on evaluations of the technical information gathered, on our understanding of the proposed construction, and on our general experience in the geotechnical field. We do not guarantee the performance of the project in any respect. For instance, AECOM has no way of knowing the successful bidder's capabilities, experiences, his choices of crew and equipment, his choice of bidding and operating strategies, or any limitations which may be imposed on him by the Owner or the designer. Therefore, we can only guarantee that our engineering work and judgments rendered meet the standard of care of our profession at this time and location, for work performed under similar circumstances.

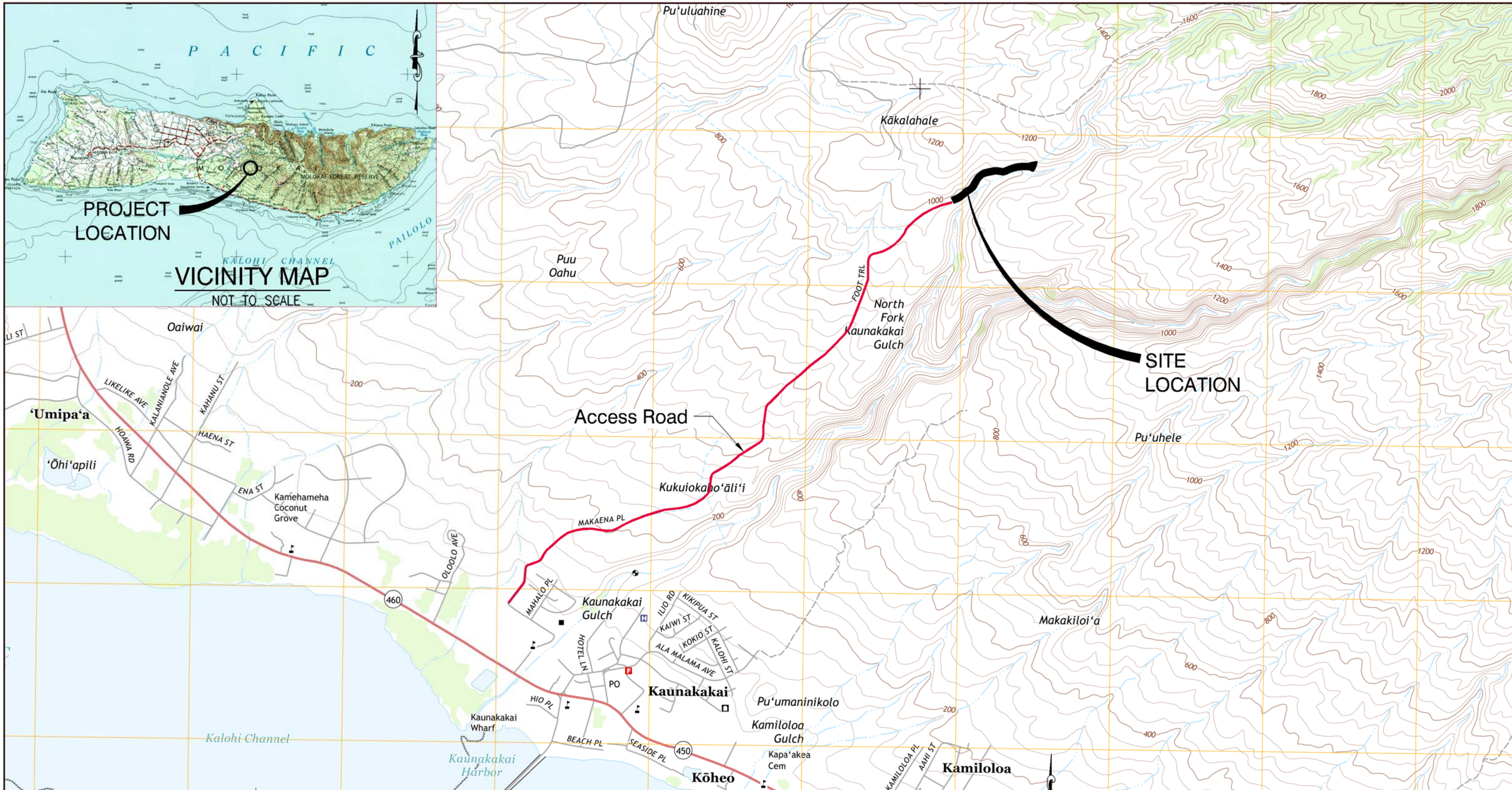
8 REFERENCES

Knodel, Paul C, 1991. *Characteristics and Problems of Dispersive Clay Soils*, Technical Report R-91-09 *by* Department of the Interior, Bureau of Reclamation, October.

Oki, D., Bauer, G. R., 2001. *Drilling, Construction, Water-Level, and Water-Quality Information for the Kualapuu Deep Monitor Well 4-0800-01, Molokai, Hawaii.* U.S. Geological Survey Open-File Report 01-350. 19 p.

Sherrod, D.R., Sinton, J.M., Watkins, S.E., and Brunt, K.M., 2007. *Geologic Map of the State of Hawai'i* Open-File Report 2007–1089, U.S. Geological Survey, Reston, Virginia 2007, < http://pubs.usgs.gov/of/2007/1089/>.

Stearns, H.T., and Macdonald, G. A., 1947. *Geology and Ground-Water Resources of the Island of Molokai, Hawaii.* Hawaii (Terr.) Division of Hydrography Bulletin 11, 113 p; 1 folded map as Plate 1 (scale 1:62,500).



REFERENCE:
Imagery was obtained from the United States Geological Survey at http://nationalmap.gov

APPROXIMATE SCALE
0 2000 4000
SCALE IN FEET

AECOM

Moloka'i Flume
Moloka'i, Hawai'i

Site Vicinity Map

Project No: 60429130	FIGURE 1
Date: July 2015	

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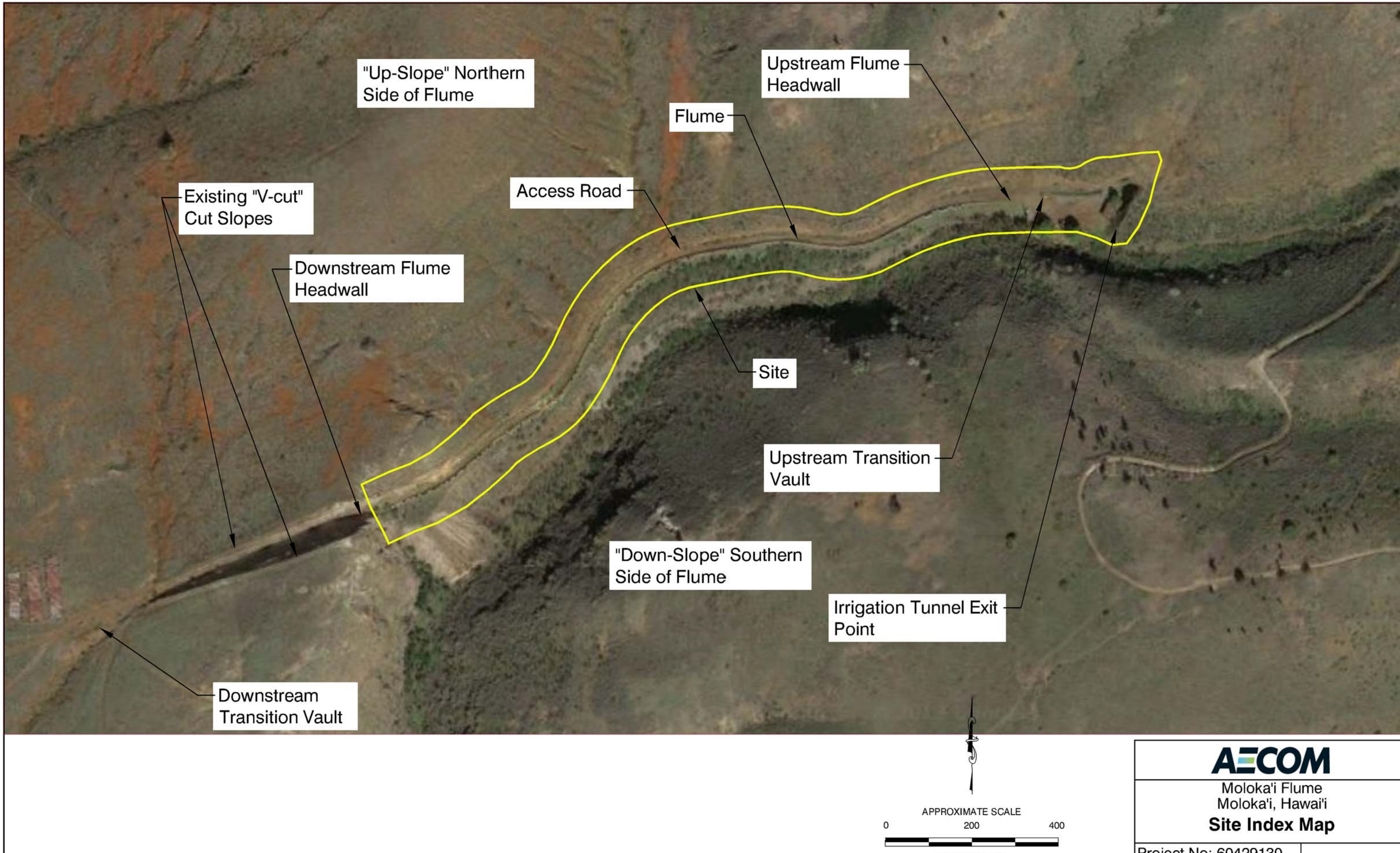

AECOM

Moloka'i Flume
Moloka'i, Hawai'i

Site Index Map

Project No: 60429130	FIGURE 2
Date: July 2015	

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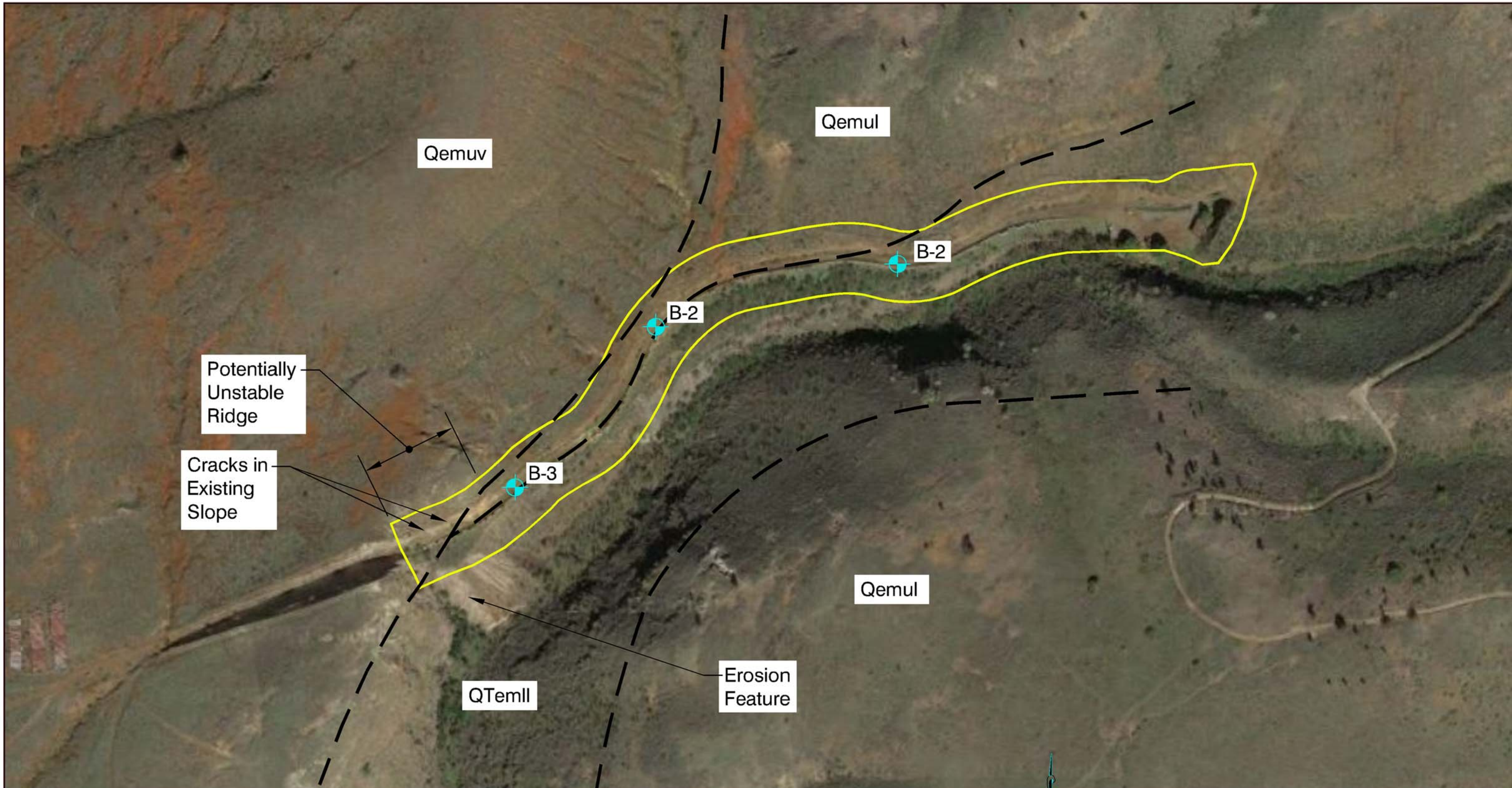


LEGEND:

B-1 Approximate Boring Location and Designation

Geologic Contact, Dashed where Approximated

Qemuv East Moloka'i Volcanics Vent Deposits Upper Member

Qemul East Moloka'i Volcanics Lava Flows Upper Member

QTemll East Moloka'i Volcanics Lava Flows Lower Member

NOTE:

Geologic Contacts based on Sherrod, et. al., 2007; modified by AECOM, based on field reconnaissance and borings.

APPROXIMATE SCALE

0 200 400

SCALE IN FEET

AECOM

Moloka'i Flume
Moloka'i, Hawai'i

Geologic Plan and Boring Location Map

Project No: 60429130

Date: July 2015

FIGURE 3

APPENDIX A
FIELD INVESTIGATION

APPENDIX A

FIELD INVESTIGATION

The field investigation consisted of performing a geologic field reconnaissance and a drilling program. AECOM performed the field investigation on June 1 and 2, 2015.

The field reconnaissance consisted of a site walk by an AECOM geologist to evaluate the geologic conditions along the alignment of the new pipe construction. The results of the field reconnaissance are shown graphically on Figure 3 and were the basis behind much of the text.

The drilling program consisted of advancing 3 borings, designated B-1 through B-3, as indicated on Figure 3.

A Safe Work Plan was developed for this project to address the known hazards of drilling, of working in remote areas, and of other potential safety concerns. Based on as-built maps, communication with HDR, and the State's recollection, no utilities (other than the flume) were present along that section of roadway. Still, Hawaii One Call Center was notified prior to drilling; no utility company acknowledged any utilities in the area. No utilities were struck or damaged during the field investigation.

The borings were advanced by Valley Well Drilling, LLC, using a Diedrick D-25 drill rig equipped with 6-inch diameter hollow stem augers. The borings were advanced to depths of 6.5 to 8 feet below existing grade, whereupon auger refusal was encountered in the strong basalt in all three borings.

An AECOM geologist recorded the soil and core characteristics, observations, sample locations, and other drilling information, and initiated the boring logs in the field. The subsurface materials were characterized based on visual inspection of the samples obtained and of soil cuttings returned to the surface during the drilling operation. These characterizations were done in general accordance with the Unified Soil Classification System (ASTM D2488). The final logs were prepared based on the field logs, subsequent visual observations of the samples, and laboratory test results, in accordance with ASTM D2487. A key to the boring logs is presented in Figure A-1, and the logs of the are presented as Figures A-2 through A-4.

Bulk samples were obtained by collecting soil cuttings from the given near-surface interval and placing the cuttings in plastic buckets. Driven samples were obtained at a spacing of about 2 feet. The driven samples were obtained using a Standard Penetration Test (SPT) sampler or a California sampler. The samples obtained were sealed to preserve their natural moisture content and returned to our laboratory for further review and assignment of laboratory testing.

The California sampler has a nominal outside diameter of 3.0 inches, and a nominal inside diameter of 2.5 inches. The cutting shoe has a nominal inside diameter of 2.41 inches. These intact samples were collected by the sampler barrel being lined with three 0.042-inch-thick brass tubes, each measuring 6 inches in length. After sampling, the brass tubes were sealed with plastic end caps.

The nominal outside diameter of the SPT sampler is 2.0 inches. The cutting shoe and the barrel of the SPT sampler have nominal inside diameters of 1.38 and 1.5 inches, respectively. The disturbed samples from the SPT sampler were placed in plastic bags and sealed to help preserve their natural moisture content.

The driven samples were obtained by driving the sampler into the soil at the bottom of the boring a total nominal length of 18 inches, using a 140-pound hammer falling 30 inches. Generally, the number of blows required to drive the sample is recorded for every 6 inches of penetration. The first 6-inch increment of penetration is considered to be a "seating interval" in potentially highly disturbed soils at the base of the borehole. The total number of blows for the last 12-inch penetration, commonly referred to as the "N"-value, has been used to reflect the penetration resistance. Where the full depth of penetration could not be obtained, partial blow counts are so indicated on the logs.

The relative degree of density of granular soils and the degree of consistency of cohesive soils are generally described on the boring logs according to the conventional correlation presented below:

Granular Soils		Cohesive Soils	
Blow Counts	**Description**	**Blow Counts**	**Description**
< 4	Very Loose	< 2	Very Soft
4 – 10	Loose	2 – 4	Soft
10 – 30	Medium Dense	4 –8	Medium Stiff
30 – 50	Dense	8 – 15	Stiff
> 50	Very Dense	15 – 30	Very Stiff
		> 30	Hard

The density and consistency descriptions may deviate from the correlation for a number of reasons, including reliance on other test results or judgment based on manual manipulation of the sample. It is widely accepted that the above-listed SPT blow count correlation is simplistic, and that the blow count should be adjusted for other factors, including the effective vertical pressure at the sampling depth and other details of the sampling system (such as hammers, rods, samplers, and techniques used). The density and consistency descriptions on the attached logs are based on unadjusted blow counts recorded in the field except for the sampler diameter: for the California samplers AECOM used a nominal 0.7 factor times the raw blow count for density/consistency estimations.

After completion, the boreholes were backfilled with cuttings and adjacent material until flush with the ground surface.

Project: Moloka‘i Flume	Key to Log of Boring
Project Location: Kaunakakai, Moloka‘i, HI	Sheet 1 of 1
Project Number: 60429130	

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
1	2	3	4	5	6	7	8	9	10

COLUMN DESCRIPTIONS

1 **Elevation:** Elevation in feet referenced to the vertical datum noted.

2 **Depth:** Depth in feet below the ground surface.

3 **Sample Type:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

4 **Sample Number:** Sample identification number. "NR" after number indicates no recovery in sampler.

5 **Sampling Resistance:** Number of blows to advance driven sampler 12 inches beyond first 6-inch (seating) interval, or distance noted, using standard hammer and drop.

6 **Graphic Log:** Graphic depiction of subsurface material encountered; typical symbols are explained below.

7 **Material Description:** Description of material encountered; in addition to soil classification and USCS, may include relative density/consistency, moisture, color, particle size, and plasticity; rock description may include strength and weathering.

8 **Water Content:** Water content of soil sample measured in laboratory, expressed as percentage of dry weight of specimen.

9 **Dry Unit Weight:** Dry weight per unit volume of soil sample measured in laboratory, in pounds per cubic foot.

10 **Remarks and Other Tests:** Comments regarding drilling or sampling made by driller or field personnel. Other field and lab test results, using the following abbreviations:

COMP	Laboratory compaction test (OWC, %; MDUW, pcf)
CORR	Corrosion tests
DH	Double hydrometer (% dispersion)
LL	Liquid Limit from Atterberg Limits test (%)
PI	Plasticity Index from Atterberg Limits test (%)
SA	Sieve analysis (% passing #200 sieve)
WA	Wash sieve (% passing #200 sieve)

TYPICAL MATERIAL GRAPHIC SYMBOLS

POORLY GRADED SAND (SP)	SILT (ML)	LEAN CLAY (CL)	POORLY GRADED GRAVEL (GP)
POORLY GRADED SAND WITH SILT (SP-SM)	ELASTIC SILT (MH)	FAT CLAY (CH)	POORLY GRADED GRAVEL WITH SILT (GP-GM)
SILTY SAND (SM)	SILTY GRAVEL (GM)	CLAYEY GRAVEL (GC)	BASALT

TYPICAL SAMPLER GRAPHIC SYMBOLS

Standard California (3 inches OD, lined)

SPT (2 inches OD, unlined)

Bulk sample

OTHER GRAPHIC SYMBOLS

First water encountered at time of drilling (ATD)

Water level measured at specified time after completion of drilling and sampling

Minor change in material properties within a stratum

Inferred or gradational contact between strata

GENERAL NOTES

1. Soil classifications are based on the Unified Soil Classification System (ASTM D2488). Descriptions and stratum lines are interpretive; actual lithologic changes may be gradual. Field descriptions may have been modified to reflect results of lab tests and further review (ASTM D2487).

2. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced. They are not warranted to be representative of subsurface conditions at other locations or times.

AECOM

Project: Molokaʻi Flume	Log of Boring B-1
Project Location: Kaunakakai, Molokaʻi, HI	Sheet 1 of 1
Project Number: 60429130	

Date(s) Drilled	**6/1/15**	Logged By	**J. Kronen**	Checked By	**L. Rapp**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**6-inch-OD bit**	Total Depth of Borehole	**6.5 feet**
Drill Rig Type	**Diedrich D-25**	Drilling Contractor	**Valley Well Drilling**	Approximate Surface Elevation	**959 feet**
Groundwater Level(s)	**Not encountered**	Sampling Method(s)	**Bulk, Standard California, SPT**	Hammer Data	**Rope and cathead; 140 pounds, 30-inch drop**
Borehole Backfill	**Soil cuttings**	Location	**East end**		

Elevation, feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance, blows/foot	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
	0		SK-1			**FILL** Very dense, slightly moist, dark brown, SILTY GRAVEL WITH SAND (GM)			
958			1	50/5"			8	117	SA(14)
	2						12		Tests on SK-1: DH(10) LL=35, PI=16 COMP: OWC=13.5% MDUW=122 pcf
956						**RESIDUAL SOIL** Very dense, moist, reddish brown, CLAYEY SAND WITH GRAVEL (SC); completely weathered basalt			
	4		2	38					CORR
954			3	77					
	6					**BASALTIC SAPROLITE** BASALT, dark gray and very dark brown, moist, highly to slightly weathered, generally very weak matrix with strong clasts; Aʻa in sampler shoe	21	70	
952						**Bottom of boring at 6.5 feet (drilling refusal)**			
	8								
950									
	10								
948									
	12								
946									
	14								
944									
	16								
942									
	18								
940									
	20								

Report: GEO_HI_10_WBULK; File: HON_MOLOKFLUME.GPJ; 7/14/2015 B-1

Project: Moloka'i Flume
Project Location: Kaunakakai, Moloka'i, HI
Project Number: 60429130

Log of Boring B-2

Date(s) Drilled	**6/1/15**	Logged By	**J. Kronen**	Checked By	**L. Rapp**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**6-inch-OD bit**	Total Depth of Borehole	**8.0 feet**
Drill Rig Type	**Diedrich D-25**	Drilling Contractor	**Valley Well Drilling**	Approximate Surface Elevation	**958 feet**
Groundwater Level(s)	**Not encountered**	Sampling Method(s)	**Bulk, Standard California, SPT**	Hammer Data	**Rope and cathead; 140 pounds, 30-inch drop**
Borehole Backfill	**Soil cuttings**	Location	**Mid point**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, blows/foot	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
958	0		SK-1			**FILL** Very dense, moist, medium brown, CLAYEY SAND WITH GRAVEL (SC)			Test on SK-1: CORR
956	2		1	91/ 11.5"			14	80	WA(45)
						BASALT Gray, dry, hard, slightly weathered, strong but fractured, slightly to moderately vesicular, with some feldspar phenocrysts			
954	4		2	50/6"					
						With interbeds of saprolite / highly weathered basalt, trace olivine			
952	6		3	50/1"			23	69	WA(11)
						Becomes black, moist, very weak; no highly weathered interbeds			
950	8		4	50/0.5"		**Bottom of boring at 8.0 feet (drilling refusal)**			
948	10								
946	12								
944	14								
942	16								
940	18								
938	20								

Report: GEO_HI_10_WBULK; File: HON_MOLOKFLUME.GPJ; 7/14/2015 B-2

AECOM

Figure A-3

Project: Moloka'i Flume	**Log of Boring B-3**
Project Location: Kaunakakai, Moloka'i, HI	Sheet 1 of 1
Project Number: 60429130	

Date(s) Drilled	**6/1/15**	Logged By	**J. Kronen**	Checked By	**L. Rapp**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**6-inch-OD bit**	Total Depth of Borehole	**6.8 feet**
Drill Rig Type	**Diedrich D-25**	Drilling Contractor	**Valley Well Drilling**	Approximate Surface Elevation	**957 feet**
Groundwater Level(s)	**Not encountered**	Sampling Method(s)	**Bulk, Standard California, SPT**	Hammer Data	**Rope and cathead; 140 pounds, 30-inch drop**
Borehole Backfill	**Soil cuttings**	Location	**West end**		

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, blows/foot	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight, pcf	REMARKS AND OTHER TESTS
	0		SK-1			**FILL** Very dense, dry, reddish brown, CLAYEY SAND WITH GRAVEL (SC)			
956									
			1	97			11	103	
	2					**BASALTIC SAPROLITE** BASALT, dark grayish brown, moist, slightly weathered, very weak, slightly vesicular, with abundant feldspar phenocrysts	10	108	
							10		Tests on SK-1: DH(58) LL=41, PI=21 COMP: OWC=13.5% MDUW=123 pcf
954									
	4		2	46					
952						Becomes black with reddish brown weathering on clasts			
	6		3	43			15	83	
950						**Bottom of boring at 6.8 feet (drilling refusal)**			
	8								
948									
	10								
946									
	12								
944									
	14								
942									
	16								
940									
	18								
938									
	20								

Report: GEO_HI_10_WBULK; File: HON_MOLOKFLUME.GPJ; 7/14/2015 B-3

APPENDIX B
LABORATORY TESTING

APPENDIX B

LABORATORY TESTING

Laboratory testing procedures were performed in general accordance with the latest applicable procedures and standards of the American Society for Testing Materials (ASTM), unless otherwise noted. All tests were performed in an AECOM laboratory unless otherwise noted. A summary of the test results is provided in Table B-1. The following paragraphs provide additional details of the laboratory tests performed.

Water Content (ASTM D2216) and Dry Density (ASTM D7263)

Water contents and dry unit weights were determined for selected samples obtained from the field investigation. The test results for individual samples are presented on the logs of borings in Appendix A.

Liquid and Plastic Limits (ASTM D4318)

Liquid and plastic limit tests were performed to evaluate the properties of fine materials and to confirm the visual classification of the soil. The results of the plasticity tests on selected samples are provided graphically on Figure B-1 as well as on the boring logs for ease in correlation with the subsurface profile.

Wash Analyses (ASTM D1140)

The percent passing the No. 200 was obtained by performing wash analyses, or WA, to help confirm visual classification of the subsurface materials. The results are shown on the boring logs in Appendix A at the corresponding sample depth.

Grain Size Distribution (ASTM D6913)

Grain size distribution tests, also referred to as "sieve analyses" and abbreviated "SA," were performed to evaluate the general gradation of the soil and to verify the visual classification of the samples. The results of the grain size analyses have been shown graphically on Figure B-2, with the percent passing the No. 200 sieve recorded on the boring log at the corresponding sample depth.

Double Hydrometer (ASTM D4221)

The purpose of the double hydrometer is to obtain a percent dispersion value. The percent dispersion is the ratio of the percent passing the 5 micron size when not using a dispersing agent compared to when a dispersing agent is used. This percentage is an indicator of a soil's natural dispersion, which translates to its potential to erode or migrate in the presence of water. For ease in comparing the results of the two-part test (i.e., with and without a dispersive agent), the results of each sample are presented graphically by themselves on Figures B-3 and B-4.

Compaction (Moisture-Density Relation) Test (ASTM D1557)

Two moisture-density relation tests were performed in the upper 5 feet of material within the roadway in order to represent the material likely to be excavated and reused as backfill. The results of the compaction tests are presented on Figures B-5 and B-6.

Chemical Tests (ASTM G187, D6919, D4327)

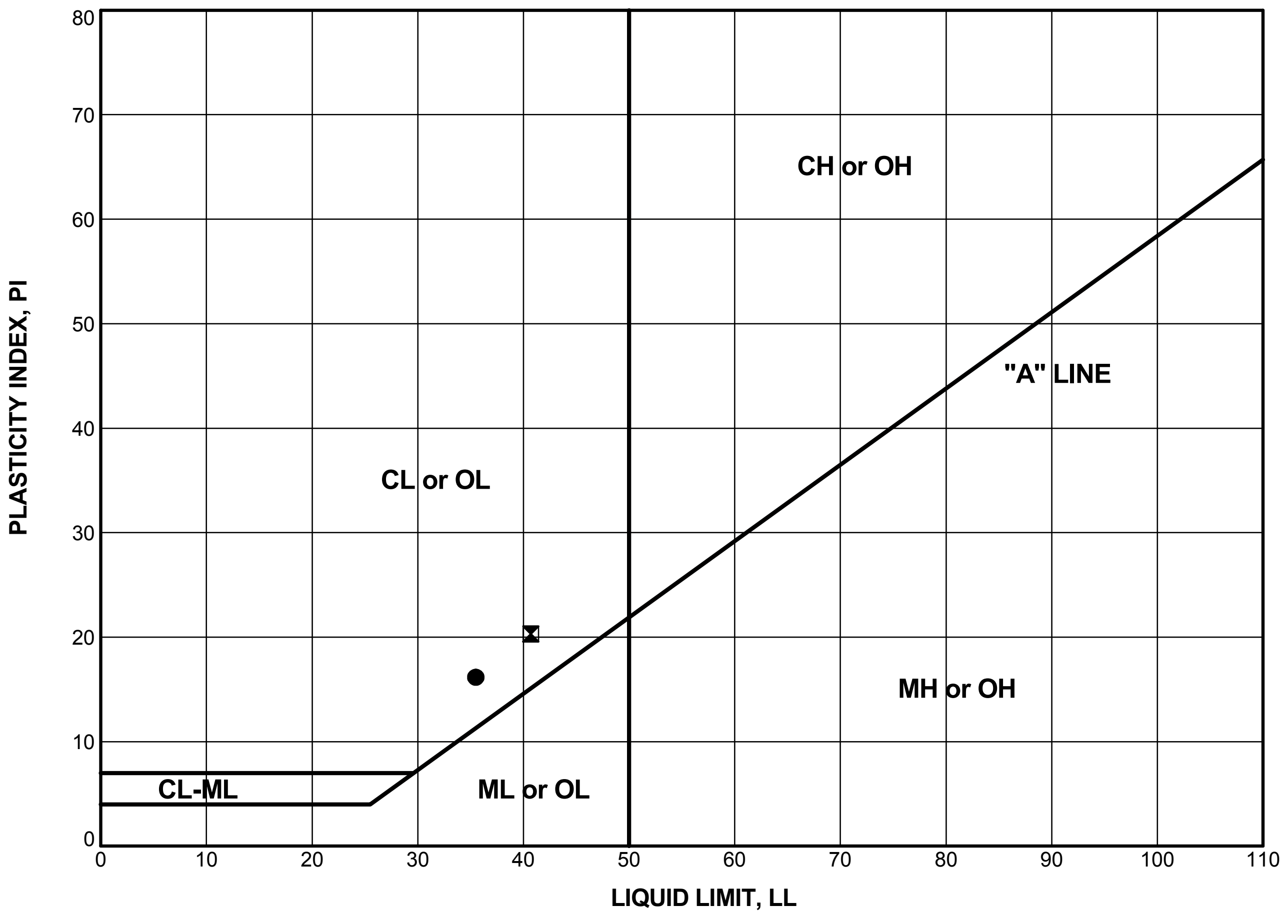
A series of chemical tests were performed by HDR (formerly Schiff Associates, Corrosion Engineers) on two representative samples to help estimate the corrosion potential of the subsurface materials. These tests include key results of resistivity and pH; sulfate content; and chloride content (respectively); and other constituents. The results of the tests are summarized on Figure B-7.

TABLE B-1
SUMMARY OF SOIL LABORATORY DATA

Sample Information				USCS Group Symbol	In Situ Water Content, %	In Situ Dry Unit Weight, pcf	Sieve			Atterberg Limits			Lab Compaction		Other Tests
Boring Number	Sample Number	Depth, feet	Elevation, feet MSL				Gravel, %	Sand, %	< #200, %	LL	PL	PI	Maximum Dry Unit Weight, pcf	Optimum Water Content, %	
B-1	1-3	1.5-2.0	957.5	GM	8	117	49	38	14						
B-1	SK-1	0-5	956.8	SC	12		30	45	25	35	19	16	122	13.5	DH
B-1	2	3.0-4.5	955.4	SC											CORR
B-1	3-3	6.0-6.5	953.0	SC	21	70									
B-2	SK-1	0-5	957.5	SC											CORR
B-2	1-2	1.5-2.0	956.5	SC	14	80			45						
B-2	3-3	5.1-5.6	952.9	GP-GM	23	69			11						
B-3	1-2	1.5-2.0	955.5	SC	11	103									
B-3	1-3	2.0-2.5	955.0	SC	10	108									
B-3	SK-1	0-5	954.5	SC	10		18	50	32	41	20	21	123	13.5	DH
B-3	3-3	6.0-6.5	951.0	SC	15	83									

NOTE: The laboratory tests were performed in general accordance with the following standards:

Water Content - ASTM Test Method D2216
Dry Unit Weight - ASTM Test Method D7263
Particle Size Distribution Analysis by Mechanical Sieving - ASTM Test Method D6913 (-#200 by ASTM D1140)
Atterberg Limits - ASTM Test Method D4318
Laboratory Compaction by Modified Effort - ASTM Test Method D 1557C
Hydrometer and Double Hydrometer (DH) - ASTM Test Methods D422 and D4221
Corrosivity Tests (CORR) - ASTM Test Methods G187 (Resistivity), D6919 (pH), D4327 (Chloride and Sulfate)



Boring Number	Sample Number	Depth (feet)	Test Symbol	Water Content (%)	LL	PL	PI	Classification
B-1	SK-1	0-5	●	12	35	19	16	Clayey Sand with Gravel (SC)
B-3	SK-1	0-5	⧗	10	41	20	21	Clayey Sand with Gravel (SC)

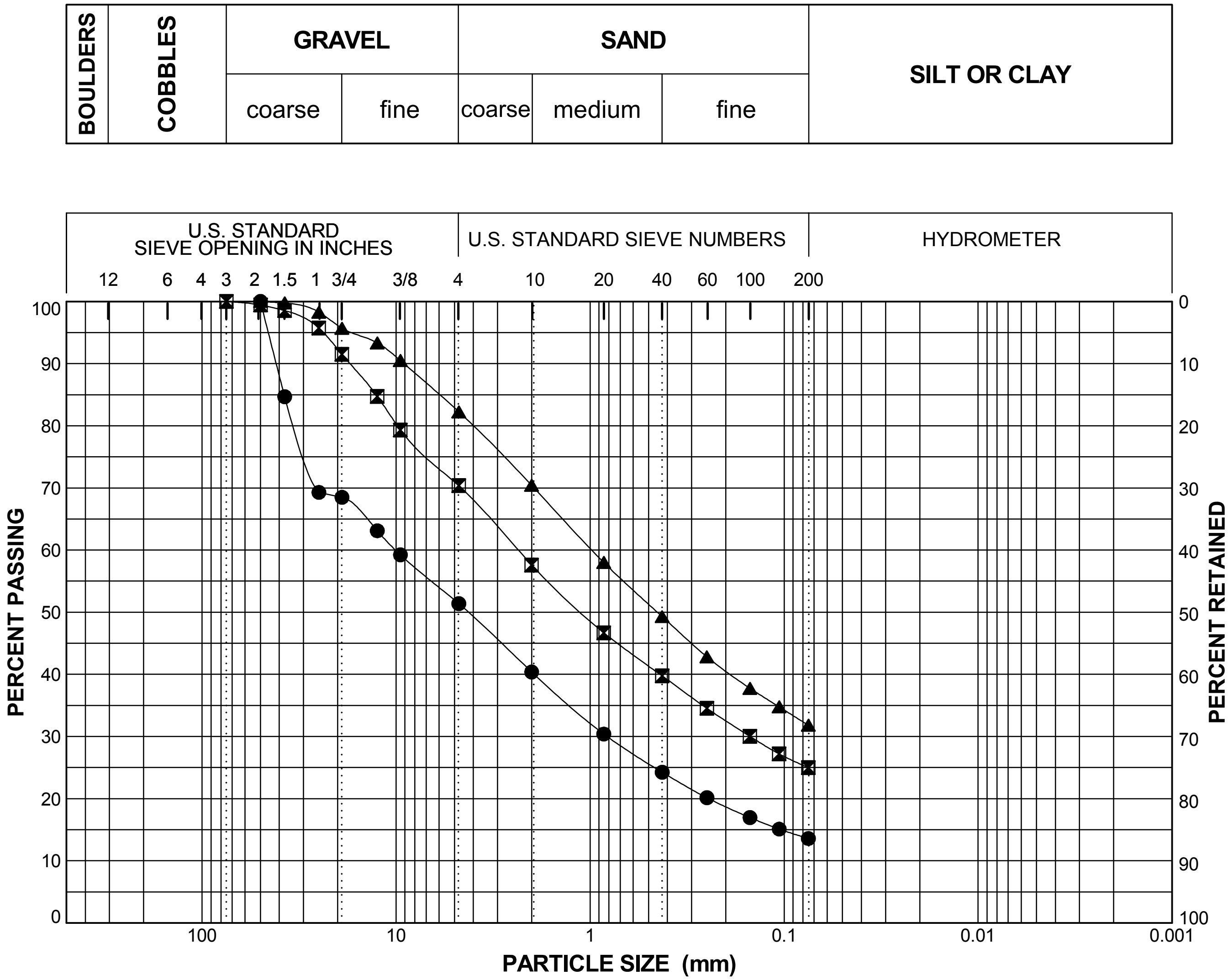
Report: ATTERBERG_PLOT_8 PTS HWC; File: HON_MOLOKFLUME.GPJ; 7/9/2015 B-3

Moloka‘i Flume
Kaunakakai, Moloka‘i, HI
60429130

PLASTICITY CHART

AECOM

Figure B-1



Boring Number	Sample Number	Depth (feet)	Symbol	%G	%S	%F	Classification
B-1	1-3	1.5-2.0	●	49	38	14	Silty Gravel with Sand (GM)
B-1	SK-1	0-5	⧗	30	45	25	Clayey Sand with Gravel (SC)
B-3	SK-1	0-5	▲	18	50	32	Clayey Sand with Gravel (SC)

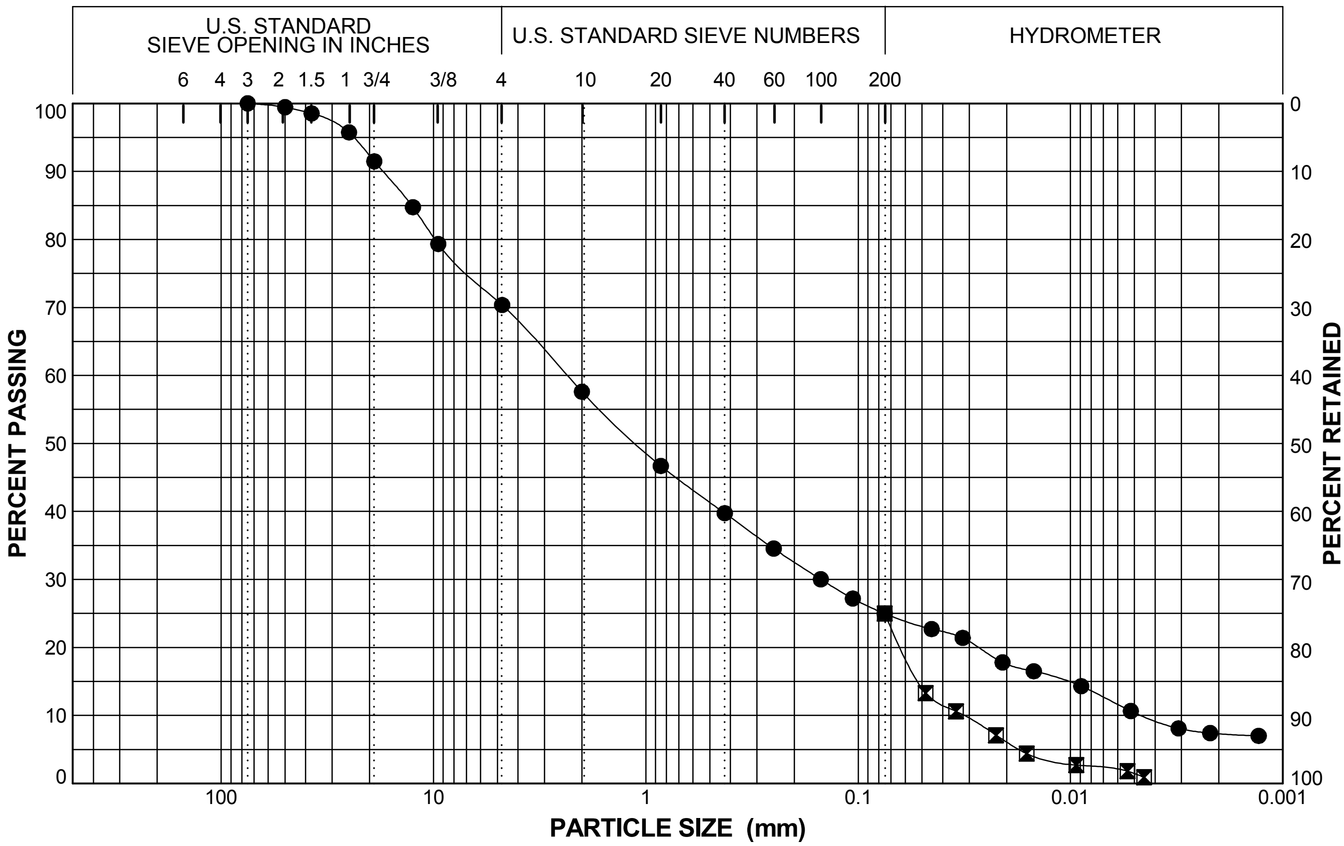
Moloka'i Flume
Kaunakakai, Moloka'i, HI
60429130

PARTICLE SIZE DISTRIBUTION CURVES

AECOM

Figure B-2

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



= sample tested without dispersing agent or agitation

Boring Number	Sample Number	Depth (feet)	Classification
B-1	SK-1	0-5	Clayey Sand with Gravel (SC)

Liquid Limit (LL)	Plasticity Index (PI)	% finer than 5μ	% Dispersion
35	16	10	10

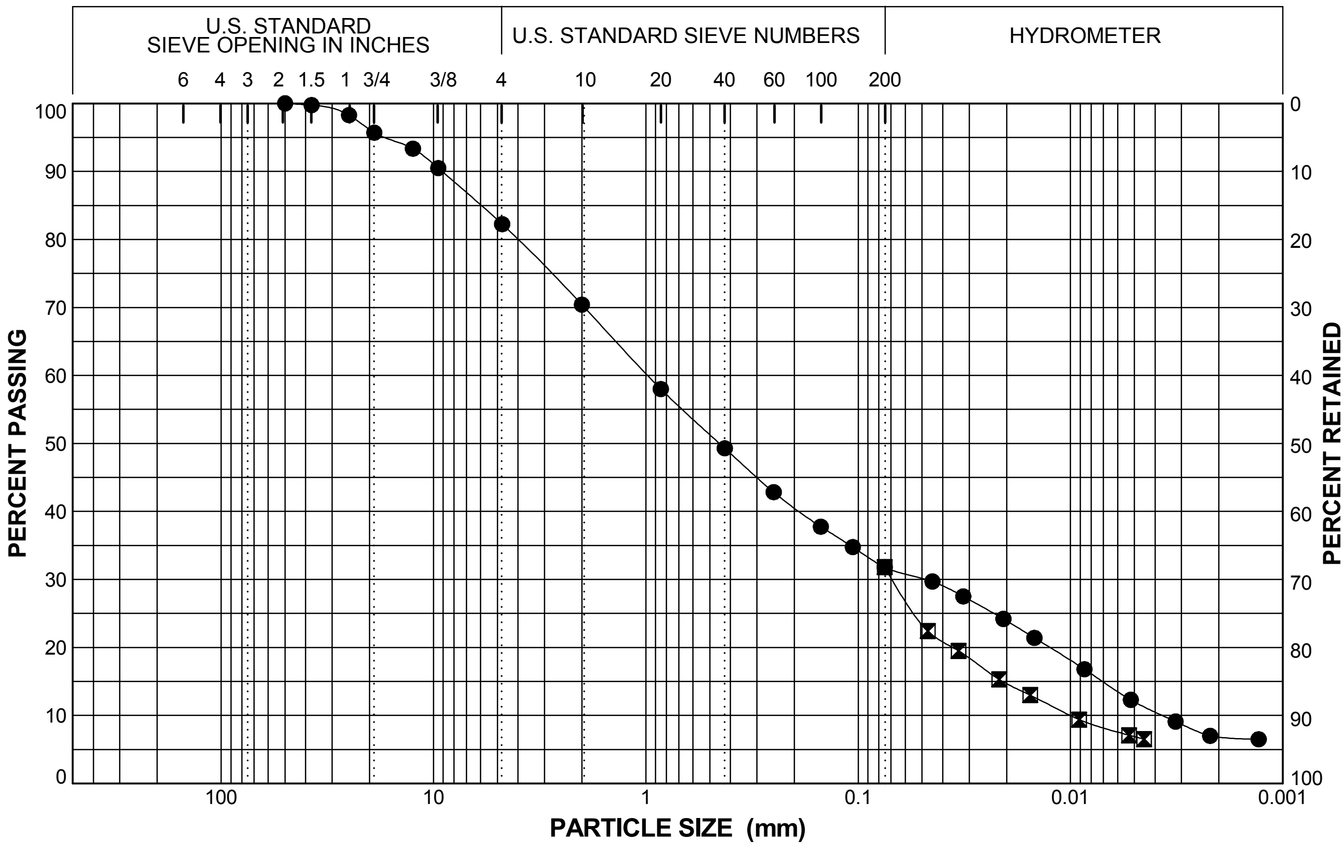
Moloka‘i Flume
Kaunakakai, Moloka‘i, HI
60429130

PARTICLE SIZE DISTRIBUTION CURVES
% Dispersion from ASTM D 4221 Standard

AECOM

Figure B-3

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



⧗ = sample tested without dispersing agent or agitation

Boring Number	Sample Number	Depth (feet)	Classification
B-3	SK-1	0-5	Clayey Sand with Gravel (SC)

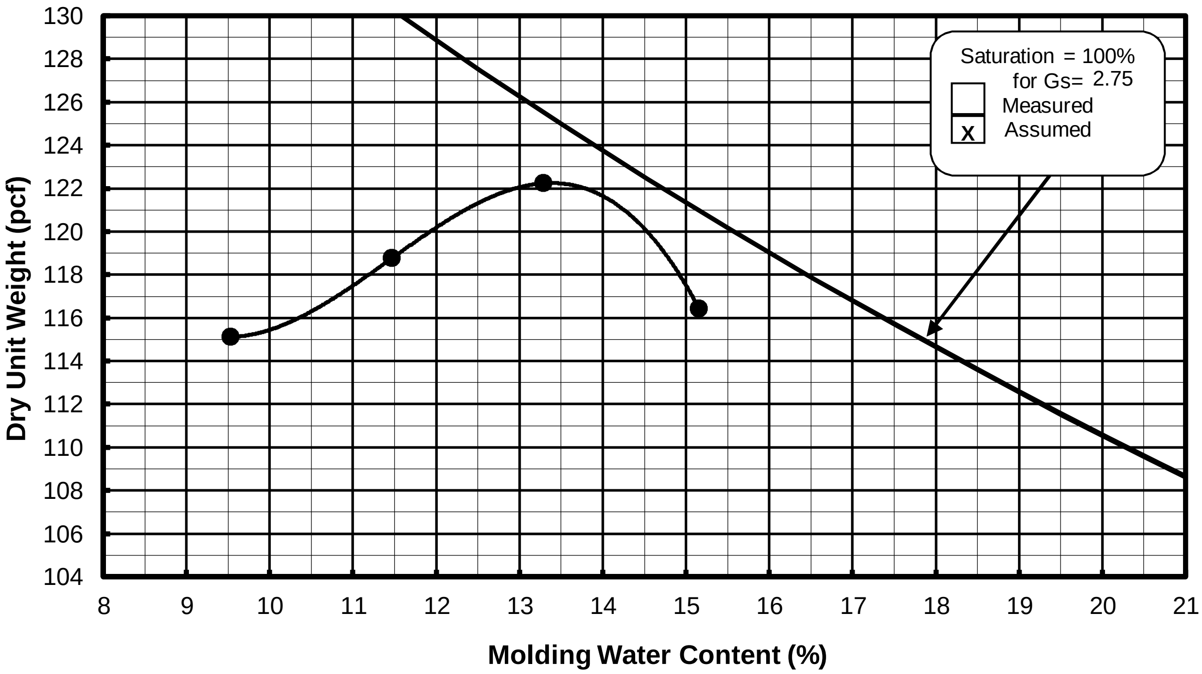
Liquid Limit (LL)	Plasticity Index (PI)	% finer than 5μ	% Dispersion
41	21	12	58

Report: SIEVE_SNA_DOUBLE_HYDR; File: HON_MOLOKFLUME.GPJ; 7/9/2015 DHB-3

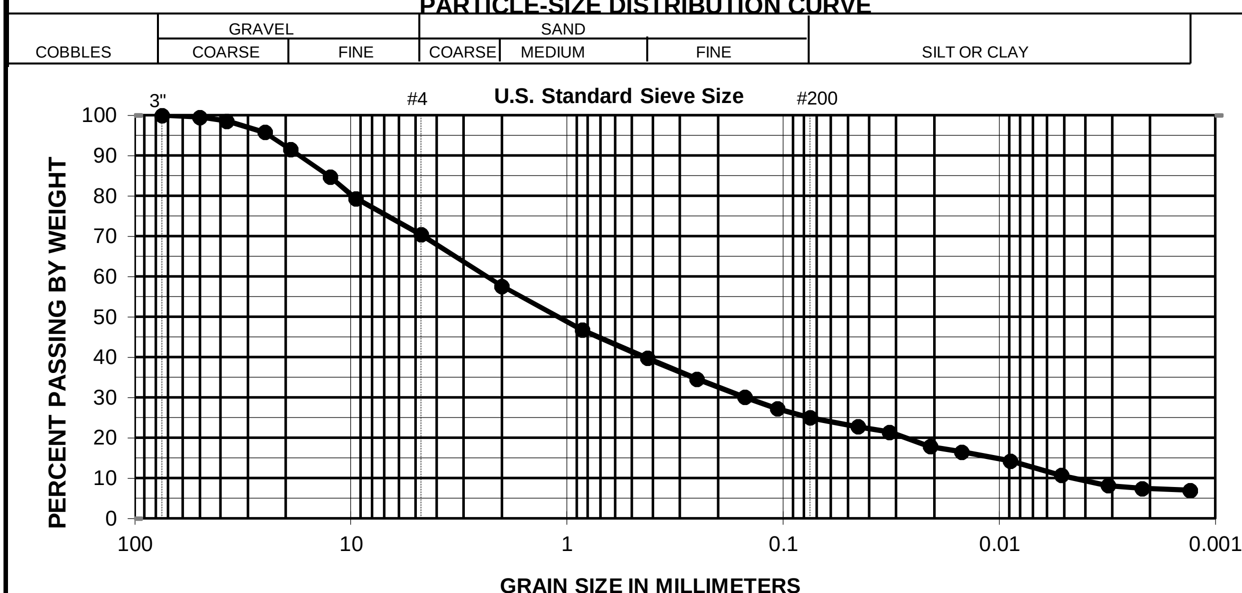
COMPACTION CURVE

Test Method: ● ASTM D 1557 ■ ASTM D 698 ◆ CA-DWR: S-10 ❍ Other Effort

Compaction Procedure: **C** Specimen Preparation Method: **Moist**



PARTICLE-SIZE DISTRIBUTION CURVE



NOTATION: ● Representative of entire sample ◆ Representative of compacted specimen ■ Representative of compacted specimen and entire sample

Boring Number	Sample Number	Depth (ft.)	Optimum WC (%)	Maximum DUW (pcf)	Description and/or Classification
B-1	SK-1	0 ~ 5	13.3	122.2	Strong brown clayey Sand with gravel (SC)

PROJECT NAME: **Moloka'i Flume**
PROJECT NUMBER: **60429130**

COMPACTION AND INDEX PROPERTY DATA

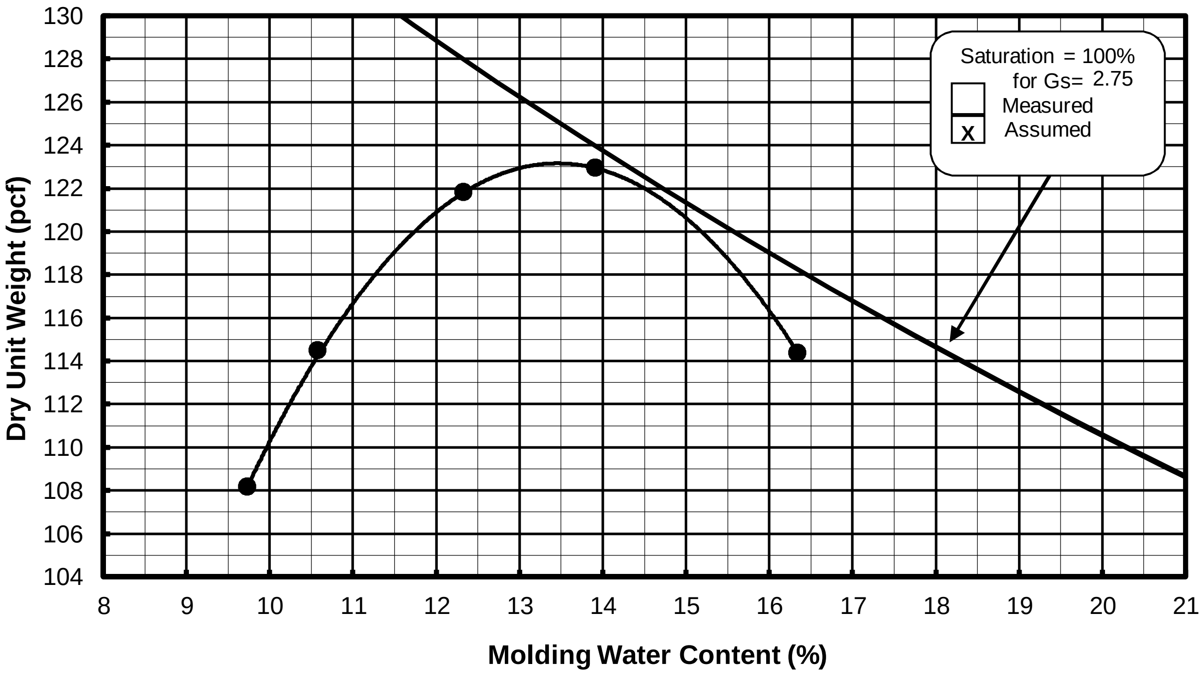
FIG B-5

SUBMITTED BY: Thomas J. O'Meara

COMPACTION CURVE

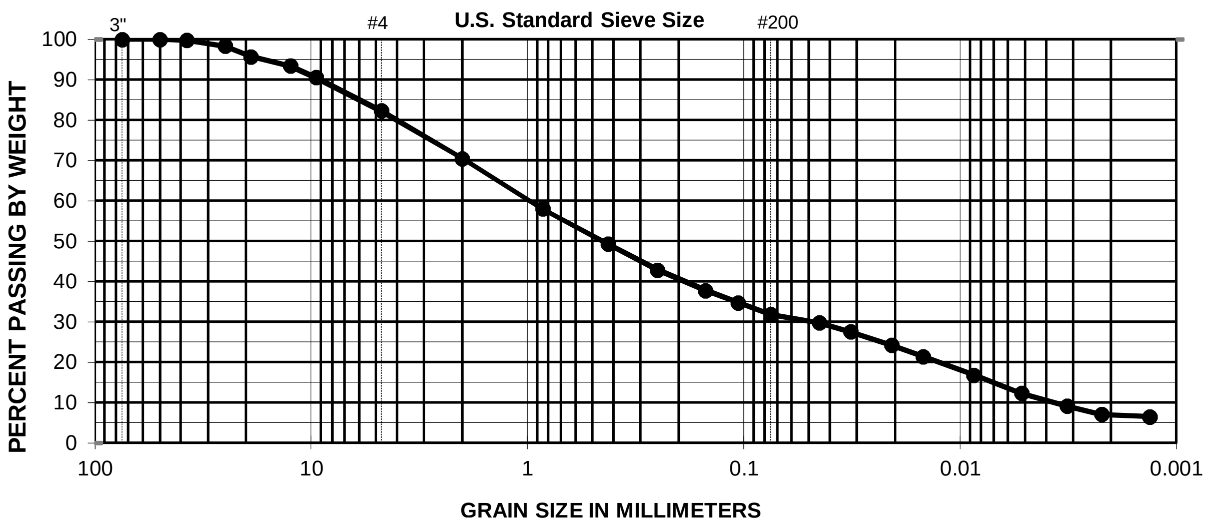
Test Method: ● ASTM D 1557 ■ ASTM D 698 ◆ CA-DWR: S-10 ❍ Other Effort

Compaction Procedure: **C** Specimen Preparation Method: **Moist**



PARTICLE-SIZE DISTRIBUTION CURVE

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	



NOTATION: ● Representative of entire sample ◆ Representative of compacted specimen ■ Representative of compacted specimen and entire sample

Boring Number	Sample Number	Depth (ft.)	Optimum WC (%)	Maximum DUW (pcf)	Description and/or Classification
B-3	SK-1	0 ~ 5	13.5	123.0	Brown clayey Sand with gravel (SC)

PROJECT NAME: Moloka'i Flume **PROJECT NUMBER: 60429130**	**COMPACTION AND INDEX PROPERTY DATA**	**FIG B-6**

SUBMITTED BY: Thomas J. O'Meara

Table 1 - Laboratory Tests on Soil Samples

AECOM, HI
Moloka'i Flume
Your #60429130, HDR Lab #15-0457LAB
9-Jun-15

Sample ID			B-1, Sample 2 @ 3'	B-2, Sample SK-1 @ 0-5'
Resistivity		**Units**		
as-received		ohm-cm	144,000	296,000
saturated		ohm-cm	2,000	2,120
pH			7.4	6.8
Electrical Conductivity		mS/cm	0.09	0.10
Chemical Analyses				
Cations				
calcium	Ca^{2+}	mg/kg	8.9	15
magnesium	Mg^{2+}	mg/kg	11	9.8
sodium	Na^{1+}	mg/kg	94	95
potassium	K^{1+}	mg/kg	3.1	7.8
Anions				
carbonate	CO_3^{2-}	mg/kg	ND	ND
bicarbonate	HCO_3^{1-}	mg/kg	131	85
fluoride	F^{1-}	mg/kg	6.9	5.6
chloride	Cl^{1-}	mg/kg	40	24
sulfate	SO_4^{2-}	mg/kg	9.5	58
phosphate	PO_4^{3-}	mg/kg	ND	3.1
Other Tests				
ammonium	NH_4^{1+}	mg/kg	ND	ND
nitrate	NO_3^{1-}	mg/kg	48	15
sulfide	S^{2-}	qual	na	na
Redox		mV	na	na

Electrical conductivity in millisiemens/cm and chemical analysis were made on a 1:5 soil-to-water extract.
mg/kg = milligrams per kilogram (parts per million) of dry soil.
Redox = oxidation-reduction potential in millivolts
ND = not detected
na = not analyzed

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About AECOM

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